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of the 21st World Congress of Soil Science

VOLUME I

RIO18

21st World Congress of Soil Science

SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO
Viçosa, MG, Brazil - April 2019

P R O C E E D I N G S

of the 21st WORLD CONGRESS OF SOIL SCIENCE

Rio de Janeiro, August 12-17, 2018 BRAZIL

S O I L S C I E N C E

Beyond Food and Fuel

RIO18
21st World Congress of Soil Science
Rio de Janeiro August | 12 - 17

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VOLUME I

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SUMMARY

RIO18
21st World Congress of Soil Science
Rio de Janeiro August | 12 - 17

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GENERAL PROGRAM

PRESENTATION

Dear participants

On behalf of the International Union of Soil Science (IUSS), the Brazilian Soil Science Society (SBCS) and the Latin American Soil Science Society (SLCS), it is our pleasure to present the two volumes of the 21st World Congress of Soil Science Proceedings. The first volume covers the plenary sessions and technical tours and the second volume the abstracts presented in poster sessions. We want to acknowledge the authors of the papers, peer reviewers, committee members, and the production staff whose volunteer work put shape to the 21st WCSS Proceedings.

During the meeting, eight (8) conferences from highly renowned scientists and authorities were held, with subjects related to the event theme - Soil Science: beyond food and fuel. There were also 73 conferences in 16 Interdivisional Symposia, and 5 Technical & Innovation Symposia.

The themes of these lectures were defined over the last three years, with the participation of the scientific divisions of IUSS and SBCS, and were structured during InterCongress 2016 and in others meetings of the Organizing Committee and Scientific Committee. The 21st WCSS also had oral presentations of 648 papers submitted in 75 divisional symposia and 15 IUSS working group symposia, plus 3 poster sessions with 1,608 submissions in total.

The Proceedings of the 21st WCSS with the abstracts of the 2,256 papers, presented orally or as poster are also available to download from the 21st WCSS homepage. The conference / lecture summaries that were provided by the speakers are included as well.

Again, thank you all for the participation and support.

Prof. **Leandro Souza da Silva**
Editor, Scientific Committee Chair

PREFACE

Fellow Soil Scientists,

I congratulate you all for celebrating the 21st WCSS being held in Rio, Brazil from 12-17th August 2018. The theme "Beyond Food and Fuel" is highly pertinent. Multifarious demands of humanity provisioned by soil include: (i) moderating the environment, (ii) strengthening biogeochemical and biogeophysical cycles, (iii) sourcing of raw materials, (iv) creating an archive of human and planetary history, and (v) generating cultural and aesthetical values. Above all, the world peace and security depend on healthy soil capable of provisioning numerous ecosystem services. Indeed, a healthy soil is an essential prerequisites to attaining peace at: (i) local, regional and global scale on the one hand, and (ii) at personal, family, community, national and international level on the other. The goal is to lead a life in perfect harmony with mother nature – the soil.

Personal or individual transformation to create a healthy soil is the pathway to peace, by being at peace with ourselves. Soil degradation and desertification, anthropogenic climate change and the related extreme events, pedological/agronomic droughts and the attendant extreme events, low agronomic yields and perpetual hunger, and marginal living and desperateness are also serious threats to global peace and stability, and require policy interventions at local, regional and global scale. If soils are not restored, crops will fail even if rains do not; hunger will perpetuate even with emphasis on biotechnology and genetically modified crops; civil strife and political instability will plague the developing world even with sermons on human rights and democratic ideals; and humanity will suffer even with great scientific strides.

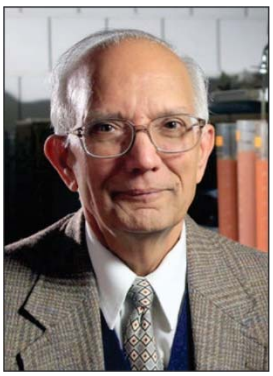
Political stability and global peace are threatened because of soil degradation, food insecurity, and desperateness. Therefore, restoring degraded soils and desertified lands are essential to global peace and security. Soil is the gift of nature for achieving eternal peace and prosperity.

I wish you all a personally pleasant and professionally rewarding experience at the 21st WCSS in Rio.

Prof. **Rattan Lal**
President, International Union of Soil Sciences

CONFERENCES

Beyond Food and Fuel: The Power of Soil to Address Global Issus of the 21st Century



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Abbreviated CV: Rattan Lal is a Distinguished University Professor of Soil Science and Director of the Carbon Management and Sequestration Center, The Ohio State University. He served as Sr. Research Fellow and professor in Australia, Nigeria, Iceland and USA. He has authored/co-authored more than 1,500 journal articles and books. He is included in the Thomson Reuters list of the World's Most Influential Scientific Minds, and among the most cited scientists. He received the Honoris Causa degree from five universities in Europe and Asia, and is fellow of the five professional societies. Dr. Lal mentored almost 300 graduate students visiting scholars from around the world. He was President of the World Association of Soil and Water Conservation, International Soil and Tillage Research Organization, Soil Science Society of America and is the current President of the International Union of Soil Sciences.

Abstract: Principal soil functions beyond food and fuel production include: 1) Environment Moderation such as climate buffering, denaturing and filtering pollutants, and gaseous exchange between soil and the atmosphere,2) Biogeochemical Cycling such as that of several elements (C,N,P,S) and water, and the process of cation exchange,3) Raw Materials and Foundations for civil structures, and source of clay, minerals and antibiotics,4) Repository and Archive of planetary and human history, gene pool and biodiversity, and paleoclimate, and 5) Cultural, Spiritual, Aesthetical and Artistic such as art, landscape, religious, and mystical. Demands on soil for these functions is increasing with increase in human population and the affluential life style. Because of the competing demands on soil for non-agricultural purposes, it is important that soil resources are protected, restored, and managed sustainably and efficiently. Thus, it is pertinent to implement the concept of eco-intensification of producing more from less, increasing agronomic productivity per unit of land area so that the land can be saved for nature. Rather than expanding agriculture, the land area needed for cereal production can be decreased from 700 million hectare (M ha) in 2005 to 500 M ha by 2100 by narrowing the yield gap. Soil quality must be restored by using CNPK with integrated nutrient management rather than NPK fertilizers so that soil organic carbon stock can be enhanced. The cumulative potential of soil organic carbon sequestration in world soil between 2020 and 2100 is estimated at 178 Pg or equivalent to an atmospheric drawdown of ~84 ppm of carbon dioxide. With increase in number of megacities (>10 million people) from 31 in 2016 to 83 in 2100, it is also essential to adopt soil-less systems of food production within the cities by recycling waste water and nutrients and by using aquaculture, aquaponics, hydroponics, aeroponics, aero farms and sky farming. Study of soils of extra-terrestrial bodies and of soil processes under low gravity or no gravity conditions is a priority for space exploration by humanity. The significant role of sustainable soil management for advancing Sustainable Development Goals of the U.N. and also promoting world peace and harmony cannot be over-emphasized. Soil, the finite and a non-renewable resource over the human time scale, must never be taken for granted.

Keywords: Soil functions, ecosystem service, climate change adaptation and mitigation, urbanization, sky farming, space agriculture, soil less agriculture, eco-intensification, SDGs, soil and world peace

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Brazilian Agriculture: Beyond food and fuel

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Abbreviated CV: Celso Moretti is currently the Executive Director of Research and Development at Embrapa, where he is a researcher in plant production and public manager. At Embrapa he was the head of the National Center for Horticultural Research and Head of the Research and Development Department of Embrapa. He holds management training at several institutions, including the Harvard School of Government, Harvard University, USA. He has been a visiting professor at the University of Florida since 2006, an honorary professor at the Universidad Nacional del Santa (Peru) since 2010 and has been an advisor for MS and Ph.D. students at the University of Brasília (UnB) from 2003 to 2017. He has international experience as lecturer and consultant in the area of public management. He was a consultant with the United Nations Development Plan for China, the Inter-American Development Bank and the Colombian Ministry of Agriculture.

Abstract: Feed a growing population, estimated in 10 billion people in 2050. Produce food, fiber and bioenergy in a sustainable way, preserving and protecting the environment. Transform the reality of a country, from being a food-insecure nation to become one of the world's food basket. Brazil did all that, in less than five decades. The secret of this extraordinary paradigm change has name and surname: research, development and innovation. With continental dimensions and located in the tropical belt of the world, a region with poor, acidic soils, and temperature and relative humidity suitable for pests and diseases, Brazil did not have a agricultural production model to copy in the 70´s. Thus, the development of a tropical agricultural model was imperative. During the so-called first agricultural revolution, the country increased the production of commodities in 500% increasing the cropped area in 60%. Three pillars were in the basis of the agricultural revolution: the development of a sustainable platform; the "tropicalization" of plants and animals; and the transformation of poor, acidic soils into fertile land. A second agricultural revolution called sustainable intensification is underway. Integrated crop, livestock and forestry systems comprise around 30 million acres and are allowing the recovery of degraded areas as well as the production of protein and biomass. The next wave on tropical agriculture is focused on the multifunctional nature of agriculture. Brazil sees agriculture as a source not only of food, fiber and bioenergy, but also for nutrition and health, environment and ecosystem services, tradition, gastronomy and tourism, among other relevant options.

Soils of the world: how to reconcile the needs for food, fuel, water quality and biodiversity

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Abstract: The natural capital of soils that underlies ecosystem services is primarily determined by three core properties: texture, mineralogy and soil organic matter, and therefore the synergy or tradeoffs between them. I describe 6 successful strategies of synergy between increasing food production and mitigating climate change or improved use of soil moisture. At the global scale yield increases during the Green Revolution saved large areas from deforestation and delayed the atmospheric buildup of CO2 by 5 years. In China higher grain yields are now obtained with lower N fertilizer inputs. In the Philippines minimizing greenhouse gases via a redox window that can be used in alternative wetting and drying of flooded rice. In Malawi increasing transpiration rates with higher maize yields using hybrids and fertilizers. In the Brazilian Amazon increasing soybean and beef production while decreasing deforestation at the same time. In the Brazilian Cerrado integrating crops with beef cattle and eucalypts, keeping a soil cover throughout the year with no irrigation and high yields.

Soils and biodiversity: providing global scale benefits

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Abbreviated CV: Diana H. Wall is the Founding Director of the School of Global Environmental Sustainability, a Biology Professor, Senior Research Scientist at the Natural Resource Ecology Laboratory and a University Distinguished Professor at Colorado State University. She is an environmental scientist and a soil ecologist and her research has focussed on the Antarctic McMurdo Dry Valleys. Wall investigates ecosystem processes, soil biodiversity and ecosystem services and how these are impacted by global change. Wall is a globally recognized leader and speaker on life in soils and climate change. Wall has received the Mines Medal, the Scientific Committee for Antarctic Research President's Medal, the Soil Ecology Society Professional Achievement Award, the Tyler Prize for Environmental Achievement and in 2018 was elected in the National Academy of Sciences.

Abstract: Belowground ecosystems contain an estimated twenty-five percent of the earth's biodiversity– from bacteria to larger soil animals and plant roots. Despite this vast diversity, these organisms and their habitats remained largely ignored compared to their aboveground counterparts. Scientific evidence shows that soil organisms provide essential services including decay of organic matter, nutrient cycling, cleansing of water, and regulation of pests and pathogens. The Global Soil Biodiversity Initiative was established to accelerate the use of soil biodiversity science because the complexity of biodiversity is often ignored in management and policy agendas. For example, we need knowledge of the distribution of soil organisms, including pathogens of major agricultural crops and humans. A global effort is needed to synthesize biological data that may not obey political boundaries. GSBI researchers worldwide are actively assuring that soil biodiversity science, including its benefits are included in global policy agendas such as the Convention on Biological Diversity, to address how soil biodiversity can be better preserved, restored and used.

Collective design of farming systems that conserve and promote soil functions

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Abstract: The intensification of agricultural production in the most vulnerable regions of the world is imperative to meet food security and the various United Nations Sustainable Development Goals (SDG) (Keesstra et al., 2016). Yet the means to achieve agricultural intensification must be tailored to the social-ecological contexts where productivity increases are needed. It is of little help to keep raising yields in developed regions and countries, heavily subsidised and with high environmental impact, as this production rarely reaches the poor in the poorest regions of the world (Tittonell et al., 2016; Cassidy et al., 2013). Food must be produced where food is most needed, and food security is made up of food availability as much as access, stability and utilization (WHO, 2017). The capacity of human bodies to utilize food depends, among other things, on the possibility to cook food, which is often limited by the availability of fuelwood in poor regions, and on ingesting the right balance of nutrients with the diet (FAO, 2017). This means that

food security, energy security and human nutrition are tightly interlocked. Yet, agricultural development efforts have not been necessarily addressing these three aspects jointly, but rather focused on short term yield increases. A conspicuous example of that is Africa. In spite of the push for new germplasm, irrigation schemes, sometimes mechanisation, very often fertilisers, veterinary and other synthetic inputs, food production per capita in most of sub-Saharan Africa remains at the same level as in the 1960s (cf. FAO Stat and SOFI, 2015). This is not necessarily proof that the above mentioned agricultural technologies are of no use. Individually taken, they have been often shown to improve the production – if not always the productivity – of single crops or animals, normally under controlled experimental conditions or in researcher-managed or project-supported demonstrations in farmer fields. But their true impact on food security and nutrition has been seldom documented beyond such isolated examples, beyond the time horizon of externally funded research or development projects. There are many reasons that could be put forward to analyse such failure. From a soil scientist´s perspective, I propose to analyse these reasons by examining them from three perspectives: sustainability, complexity and uncertainty. These are three dimensions inherent to social-ecological systems that need to be considered for better targeting our efforts in research, developing and policy making to address food insecurity. During the conference, I illustrated with concrete examples from different parts of the world, from smallholder sub-Saharan Africa or Latin-American agriculture to large sale commercial farming in Argentina or The Netherlands, that the collective management of soils and natural resources is key to the achievement of the various SDG through soil restoration and management, by enforcing sustainability, dealing with complexity at different scales and dimensions, and by contributing to reduce uncertainties. But many of the examples examined correspond to isolated cases where a relatively small group of farmers, or a community or a municipality are engaged in a process of collective soil restoration or management, but these seldom extend beyond the limits of that particular territory. Mainstreaming innovations that rely on collective soil management requires policy support a much as institutional innovation, in order to accommodate new instruments and technologies fit to specific contextual conditions (cf., Tittonell and Giller, 2014; Tittonell et al., 2016) and to absorb the transaction costs associated with collective management.

Brazilian Soils: food, fuel and beyond[1]

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Abstract: In broad literature texts, Brazilian soils are usually presented at a generalized scale, where predominate the so-called tropical soils, characterized by strongly weathered and deep soil profiles where nutrients were mostly depleted by intense soil genesis processes under a humid climate with high temperatures. However, the agricultural production statistics places the country among the world's largest exporter of coffee, soybeans, beef, and crop-based ethanol. Technologies such as the nitrogen biological fixation and no-tillage system, developed to take in account the characteristics of Brazilian soils in areas of Cerrado (Central region of Brazil) and south and southern states, allowed for the success of grain crops. It is also relevant in the country family farm agriculture, which accounts for about 70% of the food that comes to the table of Brazilians. The Brazilian forestry sector has made, in a short time, remarkable progress, mainly with eucalypt plantation (area of 5.7 million hectares). More recently, systems such as agroforestry, crop-livestock-forestry integration, agroecology and organic farms production are growing. However, the Brazilian soils also have an important function in terms of the biomes and ecosystems, some that are unique to the country, they support. These are divided in morphoclimatic domains or biomes, among them: the Amazonian rain forest, the largest continuous tropical forest in the world; the Atlantic forest, one of the world's top biodiversity hotspot from the coastal mountains to inland plateaus; the Araucaria forest, in the southern part of Brazil under a more temperate climate; the Cerrado, covering a large region with low-density forest vegetation and grasses; the Caatinga, a unique environment in the northeast part of Brazil, with species adapted to long dry periods; the Pantanal, a swampy land in the central and western parts of the country rich in biodiversity; the Pampas, native grasslands in the extreme south of the country extending to Argentina and Uruguay; and the Mangues, the shoreline vegetation represented by manglars and mangroves. Each of these domains, defined by landscapes, climate, vegetation and soils, also result in exclusive aspects of the local population, revealed in their arts and beliefs. Thus, Brazilian soils and the ecosystems they support are very rich in terms of biodiversity, culture, and agriculture. The sustainable management of these soils is key to the country and to the world food security.

[1] Marcos Gervasio Pereira and Ademir Fontana are co-authors

Integrated soil-crop system management for food security and sustainability

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Abstract: Over the past five decades, Chinese grain production has increased 4-fold, from 110 Mt in 1961 to 557 Mt in 2014, with less than 9% of the world's arable land feeding 22% of the world's population, indicating a substantial contribution to global food security. However, the increased crop production in China was supported merely by increased consumption of resources, such as fertilizers, chemicals, and so on. Excessive fertilization has caused low nutrient use efficiency and high environmental costs in agricultural production. Balancing crop productivity, input efficiency and environmental protection is essential for sustainable intensification of agriculture both in China and even globally. To achieve both food security and environmental sustainability, agricultural development in China must be transformed to address dual challenges, from solely high yield to both high productivity and high resource use efficiency. We have developed an integrated soil-crop management system focusing on achieving both high crop-productivity and high resource-use-efficiency termed as "double high-DH" technology system. which features: (i) maximizing the use of solar radiation as well as temperature periods most favorable for crop growth, and significantly increasing grain yield by closing the yield gap, (ii) synchronizing nutrient supply with crop nutrient uptake patterns through optimization of root-zone nutrient supply spatially and temporally and increasing nutrient use efficiency by using various nutrient resources, (iii) improving soil quality and productivity by adding recycled agricultural products and effectively reducing nutrient losses from soil. Large scale demonstration in China has realized the aim of reducing 30-50% of N fertilizer input while increase productivity by more than 30-50%.

Soils as a key factor in the mitigation and adaptation measures in climate change

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Abstract: The presentation focused on relevant elements from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change – IPCC, particularly those in chapter 11 (Agriculture, Forestry and Other Land Uses - AFOLU) from the contribution of Working Group III that addresses issues related to climate change mitigation. Among the mitigation options from AFOLU the following are included: (1) reduction in the emissions of methane (CH4) and nitrous oxide (N2O) from croplands, grazing lands, and livestock; (2) conservation of existing carbon stocks through, for instance, conservation of forest biomass, peatland and **soil carbon that would otherwise be lost**; (3) reduction of carbon losses from biota and **soils** through management of changes within the same land-use type, for instance, by **reducing soil carbon loss by switching from tillage to no-till cropping**) or by reducing losses of carbon-rich ecosystems, for instance, reduced deforestation, **rewetting of drained peatlands**; and (4) **enhancement of carbon sequestration in soils**, biota, and long-lived products through increases in the area of carbon-rich ecosystems such as forests (afforestation, reforestation), increased carbon storage per unit area, e.g., increased stocking density in forests, carbon sequestration in soils, and wood use in construction activities. Some categories of mitigation in forestry, including reducing deforestation, restoration of organic soils, restoration of degraded soils, forest management and forest restoration were assessed with respect to practices and impacts and with regard to technical mitigation potential, ease of implementation and timescale for implementation. In the case of restoration of organic soils, soil carbon restoration on peatlands and avoided net soil carbon emissions using improved land management were two practices provided with potential impact of increased methane emissions. For restoration of degraded soils, land reclamation (afforestation, soil fertility management, water conservation, soil nutrients enhancement, and improved fallow) were examples of practices included. At carbon prices per tone of CO_2 equivalent (t CO_2-eq)up to 100 US$/t CO_2-eq, the restoration of cultivated organic soils has the highest mitigation potential when compared to cropland management, grazing land management, restoration of degraded land, rice management, livestock and manure management. This potential is also high at carbon prices up to 50 US$/t CO_2-eq and even at prices up to 20 US$/t CO_2-eq, behind only the mitigation potential for cropland management at these two last prices. Finally, the economic mitigation potentials for AFOLU in 2030 (forestry, manure management, livestock, restoration of degraded lands, restoration of cultivated organic soils, grazing land management, rice management and cropland management) by region (OECD-1990; Economies in Transition; Latin America; Middle East and Africa; and Asia) shows that the largest economic mitigation potential at carbon prices up to 20 US$/t CO_2-eq, up to 50 US$/t CO_2-eq, and up to 100 US$/t CO_2-eq concentrate in the OECD region.

INTERDIVISIONAL SYMPOSIA

Division 1: Soil in Space and Time

1.1 - Advances in observation, classification and mapping of soils

Conveners: **Lucia Anjos** (UFRRJ/BR) and **Jacqueline Hannam** (CU/UK)

a) Challenges in observation, classification and mapping of soils

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In the past decade, scientists and the human society understood the important role and functions of soils in local and global environmental processes and problems as well. The pressure of securing enough quantity of food in the desired quality also highlighted the precious value of soils. The hunger for high quality, high resolution, continuously updated and internationally comparable soil data has been experienced in several science disciplines, in environmental and agricultural policy making and related management, in modelling and many other areas. At the same time, there was a big boom in the development in observation techniques and technologies from microscopes to satellites, and in the processing methods and technologies of the giant amount of data. The paper will discuss the major challenges in observation, classification and mapping of soils including the great range of kind and the variation of the availability of resources, the great differences in capacities of interpretation, and the problems with standardization of measurements and evaluation methods, as well as validation of results.

Keywords: Soil observation; classification; mapping
Financial Support: Hungarian National Science Fund, OTKA 113171

b) Advances in observation and mapping of soils

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In this talk an overview is provided how soils are observed, classified and mapped. Soils can be observed in a soil pit, using a soil auger or push probe, along road cuts and in quarries. An overview is presented of the measurement of soil properties and morphometric characteristics, soil depth functions, and soil profile imaging and mapping. The overall purpose is enhanced understanding including more objective ways of identifying and delineating soil horizons and treating the soil as a continuum with depth. There has been considerable progress in the in-situ measurement of soil properties and soil functions linking a range of instruments with soil inference systems on delineation and assessment of soil horizon purity, and the realization. Systematic classification of soils started in the mid-1800s – initially focusing on geologic concepts and parent materials and then with an emphasis on climate and vegetation. Since that time, classification systems have been developed that have focused on, for example, chromatic aspects, soil age and development, textural differentiation, maturatal – based on age or zonal and azonal groupings. There has been wide discussion on whether systems should be genetic or morphometric. Soils are classified as-they-are, and not to classify them according to guesses about their origin. Soil classification leaped in the early 1950s. Both Soil Taxonomy and WRB have been endorsed by the International Union of Soil Sciences (IUSS) as the internationally accepted soil classification systems. There are great hopes and strides that newly developed Universal Soil Classification System may move soil classification in the 21st century following rapid advances in soil mapping. Soil cartography, which originated in Germany, France, Austria, the Netherlands, and Belgium in the 1850s and 1860s, was based on ideas and classification approaches from agrogeology. The demand for soil mapping was greater in Russia and the USA than in Europe because of the need for the development of new and extensive territories for agriculture. There are large differences among countries not only in the status of mapped areas (extent, scale) but also in the status of scanning and digitizing existing information and combining it with other data layers to produce digital soil maps.

Keywords: Soil profiles, soil mapping, pedology

c) Soil classification: from Dokuchaev to a comprehensive sequential quantitative centroidal system

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Humans have been classifying soil entities for millennia. With Dokuchaev's systematic understanding of soil formation, classification was put onto a more objective basis. Today we still have many systems extant. Soil profile descriptions have always been difficult to successfully translate between taxonomic systems. In order to do this, there is the requirement for a comprehensive system of soil classification. We need a way of objectively comparing and coalescing taxa from existing systems to remove redundancy, and recognize gaps and eventually obtain a comprehensive set of quantified taxa. Such a system is under development. As a first step centroids were estimated for taxa within four existing systems at various categorical levels based on 22 soil variables at 20 depths. Nearest-neighbour distances were calculated based on the principal component space of the soil variables to remove redundancy of the existing soil classification and evaluate the equivalence between the different soil classification systems. After removing the redundancy, Great Groups of the New Zealand Classification and Australian Soil Classification and Soil Groups of the World Reference Base for Soil Resources were sequentially added to the Great Groups of the US Soil Taxonomy. This resulted in a comprehensive soil classification system. The comprehensive soil classification allowed for the further addition of taxa from other soil classification systems and was capable of robustly allocating unknown soil profiles via either hard or fuzzy allocation methods. A dynamic systematic nomenclature algorithm has also been developed. Merging and simplifying of such different systems demonstrates the possibility of similar mergers with taxonomies of other nations, creating a fully populated taxonomic space – a truly global or universal soil classification system. Experiments are underway with the Brazilian and French soil classification systems. Further development now requires systematic international cooperation.

1.2 - Soil data and information for smarter land management

Conveners: **Peter Wilson** (CSIRO/AU) and **Noel Schoknecht** (SSA/AU)

a) Soil Information: A global treasure for delivering food production and agricultural sustainability impact

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What is the value of agricultural land and how can soil information be used to estimate it? This presentation will review the need for valuation and highlight opportunities for this process, together with pitfalls that obstruct its implementation. What is the value of soil? In the late 1990's Costanza assigned the annual value of soil-mediated ecosystem services in the tens of trillions of US Dollars. This value can only increase as food systems come under greater pressure to intensify: The FAO estimates that by 2050, food production systems will need to increase activity substantially to achieve the food security demands of a population of over 9 billion [Alexandratos and Bruinsma 2012]. At the same time, the demand for clean water and other ecosystem services, many of which are soil-dependent, are also increasing. The demands for better soil management to support intensification are growing. How well is soil information linked to this global change? Sustainable intensification implies changes in soil management behaviour. The concept that links behaviour and information is valuation. The provision of soil information

has increased substantially over recent years. It is a global treasure. Yet, like treasure, its value is waiting to be fully realized. For example, at global scale, how widely is soil information used in assessments of global food, water or environmental security in order to protect soil quality? At a community scale, soil can be a rural community's greatest collective asset; yet how often is figured in individual decisions about land use? At a local scale, how widely is soil information used in rural land valuation, or in pricing the effect of soil degradation or amelioration? Here we see substantial opportunity to improve the use of soil information through valuation. Using examples from Australia and elsewhere we identify cases where soil information could improve decisions about land management. We relate cases where major soil engineering to improve soil value (e.g. clay amendment of sands) represent a challenge to existing spatial soil information platforms. Following this, we make the case to develop methods to convert soil information into valuation instruments that can more directly influence decisions.

b) Soil Data Exchange Standards, Development and Implementation Perspectives from the Oceania Regional Soil Partnership

Peter Wilson[1]; David Medyckyj-Scott[2]; Alistair Ritchie[2]; Linda Gregory[1]
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[2]Manaaki Whenua - Landcare Research, Riddet Road Massey University, New Zealand.

The Oceania region covers a vast expanse of the Indian and South Pacific Oceans. A good understanding of the regional soils and their required management is essential to ensure soil security, sustainable food production and the maintenance of essential ecosystem services. Data on the soil resource is required at all scales and easily accessible in formats that can be readily integrated and used for a wide range of purposes (Global Soil Partnership (GSP) Pillar 4). Soil data exchange standards and the delivery of harmonized soil data and information using application program interfaces (APIs) based on widely adopted technical specifications are essential components of local, regional and global soil information systems (GSP Pillar 5). At global levels, development of soil data exchange standards have been variously progressed through the GlobalSoilMap specifications, the IUSS Working Group on Soil Information Standards, the International Standards Organization (ISO 28258), the OGC Soil Interoperability Experiment (led by Manaaki Whenua, CSIRO and ISRIC), the Research Data Alliance and GODAN agriculture and soil working groups and now through the GSP Pillar 4 and 5 action plans and the development of the Global Soil Information System GLOSIS. This presentation discusses some of the ways that the Oceania Regional Soil Partnership is developing, testing and implementing soil data standards and exchange services. It presents examples of local, regional and global efforts and approaches and considers the needs for progressing global sharing and interoperability of soil data. Based on our experiences we draw the following conclusions. That we need to learn from other domains and adopt and leverage from their advances rather than re-inventing approaches – such as better utilizing the OGC's Observations & Measurements, Time Series and other geoscience domain models. We need to extend these only when it is impossible to describe our soil specific domain. That further progress requires clarity and mandates for who is performing what role and better coordination and more resources to utilise themavailable but limited specialist expertise, knowledge and leadership. Data standards, vocabularies and other components need to be managed and controlled through domain expertise (IUSS Working Group on Soil information Standards) and promulgated and shared through interaction with user communities (e.g. Research Data Alliance and the GODAN interest groups).

Keywords: Soil; data; standards, interoperability

c) The Global Soil Information System (GLOSIS) – progress and application.

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The Global Soil Information System (GloSIS) results from a Plan of Action for Pillar 4 set out by the Global Soil Partnership (GSP), and aims to develop a spatial data infrastructure (SDI) that brings together soil information collected by national institutions. This is to be achieved in a decentralized manner, with source institutions retaining their data and controlling access to their data infrastructure. GloSIS is thus envisioned as a federation of soil information systems (SIS), with soil data providers represented as nodes that are able to communicate in a commonly recognisable way. This federated approach will empower countries (and other data providers) to develop their soil information systems as reference centres for national soil information. To implement GloSIS several 'building blocks' are devised: the Domain Model, Data Exchange, GloSIS Node, Support Node and Discovery Hub. The Domain Model defines how data are structured and related. Data exchange is a realisation of the GloSIS domain model allowing parties to send/receive data. For GloSIS, the OGC Web Feature Service standard will be initially used for data exchange. GloSIS and Support Nodes are the implementation methods and technologies for setting up a GloSIS-compliant soil information system. The discovery hub is a web-based gateway to the GloSIS nodes, enabling access the federation and offering data discovery functionality by providing users with ways to search by geo-spatial location, meta-data or data fields. The GSP will support the participation of countries and other data providers in GloSIS through a 'CountrySIS' programme. Guidelines for this programme, as well as an implementation manual, will be developed for this purpose. The federative architecture of GloSIS will allow data providers to join as a node in the federation according to three participation levels: Ad-hoc implementation: data providers that already possesses a soil SDI implement the GloSIS data exchange protocol in its data services. Reference implementation: data providers build their SIS based on the GloSIS reference implementation which is an off-the-shelf, deployable bundle based on open-source software that performs the functions of a GloSIS node. The reference implementation is thus foreseen as a ready-to-run block. Support implementation: data providers unable to set up and maintain a SIS can store and publish their data through the GloSIS support node that is hosted by the GSP.

Keywords: Soil information system; data; database; web service.

1.3 - Pedodiversity and biodiversity

Convener: **Budiman Minasny** (The University of Sydney/AU) and **Ellen Kandeler** (UH/GE)

a) How Soils Reflect Biodiversity on Earth Through Geologic Time

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Biodiversity (i.e., biological diversity) refers to the number of different species in an ecosystem. Like soils, biodiversity is primarily the result of a region's precipitation and temperature, as well as disturbance that controls the length of time over which evolution occurs. Because biota is one of the five soil forming factors, soil profiles take on characteristics of the ecosystems (hence biodiversity) in which they reside. Consequently, grasslands, tropical rainforests, temperate deciduous forests, boreal spruce forests, and deserts reflect (or "remember") the biome in which they developed. Even subaqueous soils reflect aquatic ecosystems. Although complexity arises along borders that have shifted back and forth, this biome-soil association is a useful tool for understanding how paleosols provide clues to biodiversity inngeologic time, including global scale event, such as the advent of photosynthesis and the enrichment of oxygen in the Earth's atmosphere, and the

colonization of Paleozoic landscapes by vascular plants.
Keywords: Ecosystems; Paleosols; biomes; soil classification

b) Soil Microbial Diversity as Controlled by Pedodiversity in New South Wales, Australia

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The potential link between soil biodiversity and pedodiversity have not been explored at global scales. Anthropogenic threats and decays on soil biodiversity and their impacts on soil functioning - as recently warned - might differ by soil habitats. A global assessment beforehand is needed on what to define actions and cautions concordant with the different soil natures around the world. Soil attributes (e.g. soil pH, soil C) has been primary drivers of soil microbial diversity in both biogeographic studies and in-depth surveys. However, by only knowing that key factors regulate the soil biota is not a comprehensive knowledge yet and, furthermore, there are every so often ambiguous results that a deeper analysis at a soil diversity level (e.g. by soil horizons, classes, types) is frequently suggested. As never before, this is possible thanks to the access into both soil microbial DNA data from NGS technology and a profound soil physicochemical characterisation by pedometrics approaches. On this basis, the hypothesis tested was that soil microbial diversity is controlled by pedodiversity (e.g. by soil type) and, therefore, a co-spatial correlation between them would be established across a region. Observed data from forty-nine sampling sites were taken following two orthogonal transects (~1000 km each) across New South Wales (Australia). Paired soils were sampled at both natural and disturbed ecosystems. Soil biodiversity was estimated from archaea, bacterias and fungi communities (16SrDNA and ITS genes). The cospatial relations between soil microbial diversity and soil properties were assessed by bootstrapped regression trees models whose output enabled predictions of soil microbial distribution at 1km across NSW. Diversity and dissimilarity of the soil microbes (α-diversity and β-diversity) were comparable to soil type´s distribution (ASC system) even beyond other remarkable environmental factors (e.g altitude). Indeed, there was an increase in microbial diversity towards western NSW, however, the diversity of fungi and archaea were significantly lower and higher in Vertosols, respectively. Bacteria showed also similarities with soil distribution but did not reveal a determined preference – e.g. soil preferences for different abundant bacteria groups would be obscuring a clear result. Then, a co-spatial exploration is suggested at a higher microbial taxonomic (e.g. family) and pedodiversity (e.g. soil spectra) levels.
Keywords: Soil biodiversity; pedodiversity; bio-pedodiversity; soil microbial diversity; soil biogeography.
Financial Support: The University of Sydney, Australia; Conicyt-Becas Chile, Government of Chile.

c) Mapping, Understanding and Predicting Soil Microbial Diversity Across France

Chemidlin Prévost-Bouré Nicolas[1], Terrat Sébastien[1], Karimi Battle[1], Dequiedt Samuel[1], Horrigue Walid[1], Arrouays Dominique[2], Wincker Patrick[3], Cruaud Corinne[3], Bispo Antonio[2], Maron Pierre-Alain[1], Ranjard Lionel[1]
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Microorganisms are extremely abundant and diverse in soils. Their huge diversity is central in soil functioning regarding the diversity of functions it supports (mineralization, detoxification, stability of soil…) and is more and more studied, especially in a context of increasing pressure on soil resources. Conversely to macroorganisms whose distribution on a wide scale has been studied for over a century, spatial scaling and determinism distribution of soil microorganisms on nationwide scale still needs to be documented, notably to decipher the environmental filters shaping these communities. Over ten years, the soil microbial communities were investigated at the scale of France to characterize their distribution, understand the ecological processes and the underlying environmental filters shaping their distribution, and predict their abundance and their biodiversity. This long-term study was based on the French Soil Quality Monitoring Network (2200 sites, RMQS), which is representative of soil and land-use diversity in France. On each RMQS site, soil microbial communities were investigated for their biomass, richness (bacteria and fungi), community composition and relative abundance of each taxa, notably by means of high-throughput sequencing techniques. Mapping these characteristics provided the first extensive referentials on soil microbial communities, demonstrating their heterogeneous and non-random distribution at the scale of France into biogeographical patterns (radius from 40 to 260 km). Examining the turnover of soil microbial community composition demonstrated it was similar for micro- and macroorganisms, conversely to standard postulates. This turnover was supported by two non-exclusive environmental selection and limited dispersal. Whatever the soil microbial characteristic (biomass, richness, community composition, taxa relative abundance), it was mainly determined by soil characteristics and land-use but the filters and their hierarchy changed with the characteristic considered. Based on these referentials; models were developed to predict soil microbial diversity over the whole France; and, for the first time, 16 microbial habitats were delineated according to their specific bacterial community and environmental context (soil parameters, land use, climate), and characterized for their bacterial interaction network. Gathered into the French Atlas of Soil bacteria, these findings support innovative tools to diagnose soil microbial quality.
Keywords: Wide-scale; soil; microbial community; biomass; diversity; structure; referential; habitats; interaction network.

1.4 - Functional land management: managing soils from ped to planet

Conveners: **Rogier Schulte** (Wageningen University/NE and **Erika Micheli** (Szent Istvan University/HU)

a) Interactive Augmented Reality Workshop for Matching Supply and Demand for Soil Functions

Rogier P.O. Schulte[1], Lilian O'Sullivan[1,2], Erika Micheli[3], Adam Csorba[3], Victoria Ballester[4]

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Is the world big enough? We are witnessing a rapid increase in the global demands on how we use the land of our planet. The FAO estimates that we require a 60% increase in food production by 2050 to achieve food security. The Paris Climate Agreement assigns high expectations on soils to sequester carbon to limit global warming to well below 2ºC. The Sustainable Development Goals aim for the sustainable management of water for all, for a halt to the decline of biodiversity and for the sustainable management of waste from our cities. The questions that are now emerging at the top of the policy agenda are: is it possible to meet all these demands simultaneously in a context of a declining resource base? And, if so, how should we manage our land accordingly? Soil science has produced a wealth of knowledge at a range of spatial scales, from laboratory studies to global assessments, on the relationships between soil properties, soil management and soil processes. The urgent need to address the global pressure on land resources now requires us to harness this knowledge and put it to use to manage soils from ped to planet. Functional Land Management is a policy framework that allows soils to meet the demands for soil-based ecosystem services at multiple scales, for example from the provision of

clean water at local scale to the provision of food at regional scale and the mitigation of climate change at global scale. But who decides on how the world's land is managed? Governments chart agricultural and environmental policies for the long terms management of land, while at the same time, millions of farmers decide on a daily basis how they manage their fields. How can we connect these decision makers to ensure coherence? How can we ensure that international policies translate into soils that work better to meet humankind's expectations while sustaining their capacity to deliver ecosystem services into the future? And vice-versa: how can we encourage farmers' decision making to align to the grand challenges? In this Interdivisional Session of the IUSS Congress, we will use the concept of Functional Land Management to explore how to connect decision making on soil management across spatial scales, through a combination of key-note lectures (one for each spatial scale), contributed presentations and an interactive workshop in which participants are challenged to manage a virtual agricultural catchment. Imagine a scenario where you do not have to wait to see the trade-offs and synergies of land management in real time, or a scenario where all actors with a role in sustainable land management can work to find solutions together. In one of the first of its kind, participate in an augmented reality workshop that showcases the potential of emerging technologies with a view to increasing our scope to make rapid assessments of sustainability in relation to spatial landscape optimisation exercises. Workshop outcomes will include an assessment of local, regional and global policy instruments, recommendations for further policy formation.

Keywords: Functional Land Management; ecosystem services; scale; soil functions; virtual reality; demands; scenarios.

Financial Support: This work was conducted as part of the LANDMARK (LAND Management: Assessment, 713 Research, Knowledge Base) project. LANDMARK has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635201.

b) Ecosystem services sustainable management at the agricultural frontier in Brazil

Ballester, Maria Victoria Ramos[1]; Rizzo, Rodnei[1]; Garcia, Andrea[1]; Faria, Vivian Maria Vilela[1]; Tourne, Daiana Monteiro[1]; Schulte, R.[2]; Creamer, R.[2] and Osullivan, L.[2]

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This study address sustainable land management to preserve ecosystem services at the agricultural frontier, Upper Xingu Basin, MT, Brazil, we applied a conceptual tool designed to support policy making to manage five selected soil functions and demands. In this study, we implemented an Interdisciplinary GIS Based Multi-model Approach to understand how land use change due to agricultural expansion and intensification are affecting soils functions at the arch of deforestation. Encompassing two large Brazilian Biomes, the tropical rain forest and Cerrado (savannah), the study area of ~170.000km2 has undergone extensive changes in land use and land cover since the late 1970. In only 40 years has already lost 30% of its natural vegetation, which was replaced mainly by pastures for cattle raisin. Since the early 2000, a new cycle started and currently the Xingu Upper basin is under and increased agriculture intensification process (e.g. double cropping) to produce corn and soybean for the international market. Land tenure is dominated by medium to large farms (100 to >1000 ha), and 33 % of the area belongs to an Indigenous Land known as Xingu Park. Average farmers are family farmers and/or family business farmers, still original settlers from 30/40 years ago with strong German background and highly technified. Average soybean yield is about 3.6 ton of grains ha-1. According to stakeholders, the main limiting factor for agriculture is infrastructure and absence of government. The lack of support affects markets and international trading with high costs for stocking and distribution of soybean production. Most of the land for agricultural production is rain fed; irrigation is still not common due to lack of electricity. Traditionally, soybean producers adopt Direct Seeding Mulch-Based Cropping System (soybean -corn) drive by market prices. As proxys for foil indicator for supply, we used a 2015 land use map derived from remote sensing data. Demand was expressed as annual productivity (kg/ha/y) from census data spatialized by land use type. Evapotranspiration as the proxy for water availability and water yield for demands. For Biodiversity indicator we used Indigenous Land and Conservation Units as suppliers and Legal Reserve and Permanent Protection Areas as demand (legal instruments). Nutrient Cycling supply was mapped base on Base saturation of 0-30 cm of almost 400 soil profiles and demand by average fertilizer application (NPK) spatialized by land use. Carbon storage and GHG Seq. Carbon sequestration were derived from field measurements spatialized by land use and demands by field carbon sequestration measurements and policy (Zero illegal deforestation target). Our result show that this approach can be applied to a range on landscapes and is a useful tool for decision-making and policy implementation and support.

Keywords: Land use; planning; ecosystem services; policies; water.

Financial Support: This work was conducted as part of the LANDMARK (LAND Management: Assessment, 713 Research, Knowledge Base) project. LANDMARK has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635201.

Division 2: Soil properties and processes

2.1 - Microbial and nonmicrobial products for multi-use (agriculture, urban, industries, etc)

Conveners: **Fátima Souza Moreira** (UFLA/BR) and **Jerri Zilli** (EMBRAPA/BR)

a) Exploiting the biotechnological potential of microorganisms genomes.

Eric Triplett[1]

[1]UF/USA

b) Contribution of biological nitrogen fixation andPGPR for profitable environment-friendly agricultural Production.

Graham O'Hara[1]

[1]MU/AU

c) Legislation of microbial and nonmicrobial products for agricultural use.

Hideraldo Coelho[1]

[1]MAPA/BR

2.2 - Interactions between physical, biological and chemical processes in soil

Convener: **Stephan Peth** (UK/GE)

a) Extrapolation of chemical, physical and biological properties and functions from micro- to the macro-scale

Rainer Horn[1]

[1]CAU/GE

b) The power of the soil on microbiome function and interaction

Eiko Kuramae[1]

[1]NIOO/NE

c) Spatial distribution of soil microorganisms within their habitat

Ellen Kandeler[1]

[1]UH/GE

2.3 - What is hidden in soil water data or databases?

Convener: **Birl Lowery** (UW/USA)

a) Application of PTF for diagnostics, monitoring and predictions in Brazil.

Javier Tomasella[1]
[1]CEMADEN/BR

b) HYBRAS Hydrophysical database for Brazilian soils: experiences, challenges and perspectives.
Marta Vasconcelos Ottoni[1]
[1]CPRM/BR

c) A global database of soil infiltration data: status and perspectives
Harry Vereecken[1]
[1]Agrosphere/DE

2.4 - Advanced techniques in soil mineralogy and biological process in mineral formation

Convener: **Valdomiro Souza-Junior** (UFRPE/BR)

a) Recent advances on XRD-based techniques applied to soil minerals studies
Bruno Lanson[1]
[1]Earth Sciences Institute/FR

b) Improvements on soil mineral studies based Synchrotron radiation techniques
Donald L. Sparks[1]
[1]University of Delaware/USA

c) Mineral-life interaction in soil environment
Francisco Javier Cuadros[1]
[1]The Natural History Museum/UK

Division 3: Soil Use and Management

3.1 - Soil fertility management and the African Green Revolution

Conveners: **Bernard Vanlauwe** (IITA/KE) and **Rebbie Harawa** (AGRA/KE)

a) Scaling Integrated Soil Fertility Management Practices in Africa: The experience and lessons from the Alliance for Green Revolution in Africa (AGRA)
Rebbie Harawa[1], Bashir Jama[2], Abednego Kiwia[1] and David Kimani[1]
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Improving soil health is essential to reversing the low productivity that has plagued Africa's smallholder agriculture over the past 40 years. During this period, the yield of maize, a staple food crop in Africa stagnated at about 1.0 t/ha. To address the situation, there is consensus among the research and development community that the best approach is that of integrated soil fertility management (ISFM) which integrates organic and inorganic sources of nutrients. ISFM is a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic efficiency of the applied nutrients and improving crop productivity (Vanlauwe et al., 2011; Vanlauwe et al, 2015). Towards the widescale uptake of ISFM technologies, AGRA supported mass awareness through 140,000 on-farm demonstrations, large and small, in 13 countries since 2008. Besides maize, the demos covered other staple food crops in Africa: sorghum, millet, cassava, rice, teff and several grain legumes (beans, soybeans, cowpeas, pigeonpea, chickpea, and groundnuts). The demonstrations were designed with the close participation of the communities: farmers, extension staff, input suppliers (seeds and fertilizers), and agrodealers, among others. To enhance adoption of the ISFM practices, access to input and output markets were facilitated through a value chain approach dubbed Going Beyond Demos. By 2017, over 5 million farmers were trained on ISFM practices and nearly half were using them. Generally, the use of ISFM technologies was found to increase the yields of grain legumes by over 100% and that of cereals by over 200%, as compared to control where ISFM technologies were not used. This is against baseline yields of 1.0 to 2.0 t/ha for cereals and under 0.5 t/ha for grain legumes. In the less rainfall areas where sorghum and millet are the predominant crops, the most promising technology is fertilizer microdosing in which about a third of recommended fertilizer rates are applied in planting holes as opposed to being broadcast. For maize, fertilizer use is generally attractive when grain yields exceed 2.0 t/ha in many regions. The Going Beyond Demos approach – which arose from the realization that creating awareness of appropriate soil fertility management and good agronomic practices alone was not enough to lead to wide scale adoption by smallholder farmers in Africa – is a key institutional innovation for improving soil fertility in Africa. Taking to scale ISFM impacts and sustaining them requires improving access to affordable credit to purchase fertilizers that are expensive in Africa, access to markets, and extension and advisory services to smallholder farmers. To a large extent, adoption is market driven as commodity sales provide cash incentives to invest in the new technologies.

b) Different approaches to increase productivity and fertilizer use efficiency
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Sub-Saharan Africa records the biggest yield gap world over. This happens due to a complex combination of factors, ranging from use of poor germplasm, low soil nutrient status, poor agronomic practices, pests and diseases to poor investments in agriculture. Concerted efforts have been made in developing and testing a number of approaches to overcome these challenges in order to increase crop productivity. However, their widespread application has remained limited. There is evidence that technologies such as plant breeding have now become valuable tools in crop improvement for rapid precision breeding for specific purposes. Several climate resilient agricultural approaches such as conservation agriculture and crop rotations help maintain a healthy agroecosystem. The use of right fertilizers for specific crop and site (not national recommendation approach) are needed to increase crop productivity. These approaches need to be combined with effective integrated pest and disease management systems and increasing water use efficiency in rainfed agriculture. Increasing Africa's agricultural productivity will require multidisciplinary investment including in research and extension, infrastructure, value chains' development; and backed by appropriate policies.

c) The science of agronomy at scale.
Keith Shepherd[1]
[1]ICRAF/KE

3.2 - Sustainable soil management

Conveners: **Pedro Luiz de Freitas** (EMBRAPA/BR) and **Julian Dumanski** (WB/CA)

a) Soil carbon management and global environmental services and soil health.
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Food security is critical for the expanding global population, negatively impacted by finite resources and climate extremes. The goals are to improve long-term productivity, profits and food security, particularly under the increasing threats of climate change in the form of drought and flooding. Conservation Agriculture Systems (CAS), based on three key principles: 1) continuous crop residue cover on the soil surface; 2) continuous minimum soil disturbance; and 3) diverse crop rotations and cover crop mixes with location specific complementary practices, have slowly evolved as a sustainable production system that can lead to food

security with additional ecosystem services and environmental benefits. At the core of Conservation Agriculture is the transformation toward soil health and systems management innovation with emphasis on regenerative carbon (C) management. Conservation Agriculture is a major player in our survival through C cycling and soil C storage. The important role of new diverse crop rotations and cover crop mixes providing opportunities for C input that will make food production systems more resilient and increase water use efficiency. Conservation agriculture systems enable innovative concepts transitioning toward "continuous living cover", "perennializing agriculture", and "relay cropping" systems that provide both opportunities and challenges. Maintaining the vitality of the number, diversity and activity of the living organisms that depend on C as their food source, is a key factor. Plant diversity must be understood and nurtured to enhance soil biodiversity and resilient ecosystem services. A strong partnership is needed among all social, economic, and political sectors to promote innovation, adoption and success with emphasis on principles, a science foundation and the environmental value of CAS to our global food security.

b) Contributions of zero tillage for sustainable soil management – Brazilian experiences in adopting ZT/CA and integrated systems.

John Landers[1]
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From 1972, Zero Tillage adoption in Brazil has had profound effects on Brazilian agriculture's performance; agricultural exports were 41% of the 2017 total. Brazil's ZT area is now estimated at 35 million hectares, occupying 55% of crop area; all sectors of agribusiness and agricultural research/extension have engaged with farmers and civil society to promote this technology, which reduced erosion to 11% and runoff to 20% of plough-based systems. ZT is totally compatible with other advances in technology, such as: biological controls, controlled traffic, precision agriculture and inclusion of cover crops in the rotation. Farmer-based initiatives were essential to early adoption, mainly via municipal-level Friends of the Land Clubs. Initially, the reasons for adoption were erosion control and lower direct costs, including halving diesel consumption plus reduced machinery investment costs in the medium term. Planter and drill designs improved continually to export quality, while shorter cycle cultivars allowed second crop maize to be planted after soybeans on approximately half of the tropical soybean area, while cover crop options have greatly diversified and improved in quality. In time, secondary benefits appeared: higher biological activity improves nutrient economy as does higher soil organic matter (also raising soil moisture-holding capacity), better internal drainage increases the planting window, reduced water use in irrigation, while integration of crops and livestock improves returns to both. Social benefits extend beyond the advances in technology and the farm gate, such as: engendering greater farmer respect for the environment and off-farm impacts: land use intensification revitalising degraded pastures (mitigating the demand to clear new land), reduction of silting in reservoirs and waterways, mitigation of flood peaks, enhanced aquifer recharge, improved water supplies for urban populations, lower global warming via better GHG balance and albedo reflection from straw, lower food prices, increased participation of agricultural exports in the GDP and virtual extinction of basic food imports, besides eliminating the dust clouds during conventional soil preparation. Policy actions were needed: to accept ZT as eligible for subsidised credit, bank insurance with rural credit was reduced by one percentage point (reduced erosion risk) and, since 2010, the Low Carbon Emission Agriculture Program has contributed with 3,0mi. ha of ZT adoption and 0,5 mi ha of integrated crop-livestock systems. Although repeated crop successions, and not pluri-annual rotations are the rule, Brazilian farmers and researchers now lead the world in sustainable tropical and sub-tropical agriculture.

c) Relation of CA to healthy farms and healthy landscapes.

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Conservation Agriculture (CA) is based on three principles: a) Minimum soil disturbance b) Permanent soil cover with crops and/or crop residues c) Diversity of species through crop rotation, crop association and other arrangements. When these principles are adopted simultaneously, the system can provide soil health conceived as the appropriate chemical, physical and biological soil conditions that permit soil productivity with food quality, human health and environmental quality. This is easy to achieve at the plot level because there is available technology developed since the sixties and seventies of last century, that was responsible for a huge control of erosion and for the recovering of soil organic matter content among any other benefits. CA in a wide sense is not only the land use of No-Tillage System of Annual Crops but also Integrated Livestock Production without Overgrazing, Perennial Crops and Vegetable Production with Permanent Soil Cover, Agroforestry and Forestry, and also Permanent Protection of Sensible Areas and Water Sources. Because of these technological possibilities, CA is capable to promote healthy farms depending only on the will of individual farmers. But CA has the power of transforming bigger spaces promoting healthy landscapes. In order to scale-up CA in continuous geographic areas, collective actions are required at least at the watershed level to reach landscape scale. It involves a minimum level of Soil Governance, Project Support, Public Policies, Social Organization and Training Facilities in order to ease general adoption mainly from the less provided people. There are several good initiatives for the spreading of CA that deserve to be known and disseminated, even because only 150 million hectares, around 10% of the world total cultivated area, are made under Conservation Agriculture and must be expanded. In certain circumstances, CA is responsible for the improvement of original land aptitude and potential under natural vegetation, enhancing Carbon Sequestration and mitigating Climatic Changes.

3.3 - Sustainable P fertilizer use in tropical soils

Conveners: **Paul Withers** (Bangor University/UK) and **Vinicius de Melo Benites** (Embrapa Soils/BR)

a) Poor P use efficiency and novel fertilizers - when can the latter mitigate the former?

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Fixation of phosphorus (P) in soils is often regarded as a huge problem for agriculture globally, due to the term "fixation" often being poorly defined and also often confused with P adsorption onto, or precipitation in, soils. At the same time many countries suffer from eutrophication of water bodies due to movement of "legacy" P from soils to surface water supplies. Co-existence of problems due to fixation and legacy P in the same soil or region seems paradoxical and new fertilizer products often promise to solve both issues, paradoxically again sometimes simultaneously. The agronomic efficiency of P fertilizers is primarily controlled by P reactions with the soil surfaces and interactions of fertilizer form/placement and soil moisture conditions that affect root interception of, or access to, the fertilizer. With a few notable exceptions, losses of P from soil do not markedly affect the agronomic efficiency of P fertilizer use, but certainly have the potential to cause adverse environmental effects. In many soils fixation of P has much less effect on fertilizer efficiency than is commonly believed, and products that claim to improve fertilizer efficiency have much less effect than is commonly claimed. Recent reviews of the performance of "enhanced" P fertilizers have concluded that they have no, or little, agronomic effect. Situations where we really need to be concerned about P fixation are in soils with no, or a poor, history of P fertilizer use, on soils with strong P retention due to high contents of aluminium and iron oxides, on soils rich in calcium carbonate, and where crops require large and/or rapid P uptake to grow successfully. The role of fertilizer formulation and plant breeding in these situations will be discussed in relation to improving P fertilizer use efficiency in tropical soils.

b) Comparing Phosphorus Legacies in Temperate and Tropical Soils

Agriculture

Tom Bruulsema[1], Luis Prochnow[1], and Heidi Peterson[1]
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Intensive application of phosphorus fertilizers began at different times and accelerated at different rates both among and within nations and cropping systems. Most nations that successfully increased crop productivity over time also went through a period during which phosphorus inputs to cropland considerably exceeded outputs. The aim of this presentation is to compare countries and cropping systems, both temperate and tropical, for length and degree of such surpluses, in relation to the productivity gains achieved. For example, a cumulative surplus of 30 Tg of phosphorus has recently been reported for Brazil. The ratio of inputs to outputs has shown little change, but owing to increasing cropland productivity, the size of the annual surplus continues to increase. In contrast, in North America and in Europe, cropland productivity continues to increase in spite of declining or stable inputs. How do previous cumulative surpluses in those regions compare with those more recently observed in Brazil? Prospects for future improvements in phosphorus use efficiency may depend on the legacy of past applications, as well as improvement in nutrient application practices and cropping system management for improvement of soil health.

c) Transitions to sustainable management of phosphorus in Brazilian agriculture

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Brazil's large land base is important for global food security but its high dependence on inorganic phosphorus (P) fertilizer for crop production is not a sustainable use of this finite resource. Nowadays Brazilian Agriculture is responsible for 12% (2.2 Tg P yr-1) of current Global demand for P but it is predicted to rise to 4.6 Tg P yr-1 in 2050, representing 22% of global demand. During the buildup of soil fertility in Brazilian P-fixing, the use of higher fertilizer rates is justified but in agricultural soil under long-term fertilization, the P inputs should be similar to P exports, however, it is not the current management used. A new strategic analysis of current and future P demand/supply concluded that the nation is secondary P resources which are produced annually (eg livestock manures, sugarcane processing residues) could potentially provide up to 20% of crop P demand by 2050 with further investment in P recovery technologies. However, the much larger legacy stores of secondary P in the soil (30 Tg in 2016 worth over $ 40 billion and rising to 103 Tg by 2050) could provide a more important buffer against future P scarcity and enable a transition to a more sustainable P use. In the longer term, farming systems in Brazil should be redesigned to operate profitably but more sustainably under lower soil P fertility thresholds, adopting management strategies to reach a better input/output balance.

3.4 - Agricultural management for soil health to support a growing population

Conveners: **Tom Bruulsema** (IPNI/USA) and **Luis Ignácio Prochnow** (IPNI/BR)

a) Effective and efficient nitrogen management to support the pillars of sustainability

Roberto Norton[1]
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The effective and efficient use of plant nutrients has many dimensions, including supporting environmental, economic and social goals. The complexity of outcomes is often attempted to be resolved into various nutrient performance indicators. These could include nutrient balance, nutrient productivity, soil nutrient levels and losses to the environment. The most common indicator is partial nutrient balance (PNBN) which attempts to reconcile N removals and additions to assess trends in nutrient "efficiency". This can be estimated at a country or regional level, with often imperfect assumptions about both inputs and outputs. Some reports attempt to disaggregate values by crop or region, but most annual systems are poly-cropped, while a regional assessment can conflate quite diverse production systems. Examples of indicators assessed at different scales - national, regional, industry, crop, farm or paddock will be presented. However, in all examples, PNBN fails to recognise the many important dimensions of nutrient efficiency and effectiveness. The importance of any indicator should be considered over several crop cycles at a farm level and should be used to develop meaningful benchmarks communicated to growers to assist them in improving nutrient management and enhancing soil health. PNBN has been proposed as a benchmark either in policy settings or as management guides for growers but it is not an environmental indicator as it only assesses a single fate of the supplied N. It does not link to any change in soil nutrient storage and so is basically dissociated from soil fertility. It is not linked to economic goals and is dimensionless so does not consider the magnitude of any imbalance. There are significant and important limitations in using a single indicator as a measure of sustainability. Multiple indicators that include soil health, economic performance and future productivity are required to assess progress towards economic, environmental and social goals.

b) Phosphorus availability in soils - biological, chemical and physical approaches for a sustainable agriculture

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Phosphorus (P) plant availability is determined by the concentration of phosphate ions in the soil solution and the soil replenishing ability after root uptake. The replenishing of phosphate ions depends on soil characteristics such as mineralogy, soil chemical reactions, plant biological interactions and soil physical conditions. Soils rich in alumina or iron oxihydroxides or clay minerals like kaolinite, predominant in tropical regions, react chemically with P to form insoluble compounds, inaccessible to plant roots. Crop demands may be adequately supplied when readily available P pools are maintained at a critical level in the soil solution and with constant P inputs by fertilizer to compensate plant uptake, leaching and/or runoff. Improving our mechanistic understanding of soil P dynamics—involving soil-rhizosphere-plant interactions and how they influence P availability—is important for improving a future sustainable P management. In Europe, a 5R strategy has been proposed to improve the stewardship of P and to act as a blueprint for national and global P sustainability: Realign P inputs more precisely to maximize efficiency, Reduce P losses to the streams and oceans, Recycle more P in bioresources, Recover and reuse P from wastes and Redefine P requirements in the food chain (Withers et al. 2015). This 5R strategy should also be more deeply understood in other regions of the world for getting a more agroenviromentally friendly use of his precious nutrient. Moreover, more efficient, reliable and sustainable ways should be sought for 'feeding the crop, not the soil', improving crop recovery of fresh P applications and better using the legacy P remaining in the soil from previous cropping. There appears to be scope for innovations across a broad range of technologies including machinery for placement, chemistry to inhibit soil sorption, foliar P stabilization and absorption and both micro- and macro-germplasm to improve uptake and reduce P demands. Such innovations are encouraged in a 4R approach to nutrient stewardship at the farm level, seeking to apply the right source, at the right rate, at the right time, and in the right place.

c) Potassium: A Newcomer to Soil Health and Sustainability Discussions?

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Plant acquisition of soil potassium relies on many processes in the rhizosphere. Understanding these processes better is essential for creating improved practices. At stake is human health. Citizens of many countries have potassium deficient diets that increase both health risks and health care costs. Solving the human potassium nutrition problem requires sustainably managing potassium in soils to produce potassium-rich foods people will routinely eat. Research has shown that soil mineralogy strongly influences potassium behavior in soils and affects the accuracy with which we can assess both the quantity of plant-available potassium and how long soil supplies will last. Routine soil testing methods can miss important pools of plant-available potassium. They also inadequately assess potassium transitions from one pool to another, such as the movement of potassium into interlayer positions of vermiculite. Microbial and fungal communities in the rhizosphere also contribute to plant-available potassium, yet their impacts are just beginning to be understood. Unraveling these complex interactions of factors in the rhizosphere is important to improving assessments of soil fertility and maintaining that fertility at sustainable levels.

Division 4: The Role of Soils in Sustaining Society and the Environment

4.1 - Soil organic matter to secure food and water and the 4 per 1000 initiative

Conveners: **Beata Madari** (EMBRAPA/BR)

a) The '4 per 1000 initiative'.

Claire Chenu[1], Farshad Amiraslani[2], Magali Garcia Cardenas[3], Martin Kaonga[4], Lydie-Stella Koutika[5], Jagdish Ladha[6], Beata Madari[7], Cornelia Rumpel[8], Yasuhito Shirato[9], Pete Smith[10], Brahim Soudi[11], Jean- François Soussana[12], David Whitehead[13], Lini Wollenberg[14]
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Soil organic matter is at the nexus of global challenges: food security, climate change adaptation and mitigation, soil security. The 4 per 1000 initiative, launched at the Climate COP21 within the Lima-Paris Action Agenda proposes to increase soil organic carbon (SOC) stocks to simultaneously address all these challenges. It directly addresses three sustainable development goals: SDG2 'no hunger', SDG13 'Climate action', and SDG15 'Life on land' and indirectly concerns several others. The initiative targets agricultural soils in priority, which are often the most degraded soils and because of the high expected benefits in terms of soil fertility and hence of productivity. A range of agricultural practices are available that allow to increase SOC stocks while ensuring a resilient, productive and environmentally friendly agriculture, so that a large-scale deployment can be aimed at. Here, we review and discuss the main limits and criticisms addressed to the 4 per 1000 initiative. These are biophysical barriers (permanence and reversibility of the soil organic C storage (needs for water, nutrients), trade-offs (other GHG emissions, other uses of the biomass), and socio-economic barriers (adoption of practices, economic benefits, adequate incentives). The feasibility of the proposed aspirational target (an annual increase of standing SOC stocks by 0.4%) is also debated. This lively debate helps to shape the initiative and shows that the implementation of the initiative has to be spatially differentiated, accounting for socio-economic and pedoclimatic regional differences. Avoiding GHG emissions from organic rich soils, such as peatlands, remains a priority. The 4 per 1000 initiative has successfully placed soils in the political arena and is a unique opportunity, in combination with other global efforts such as the Global Soil Partnership, to set a platform between scientists, policy makers and practitioners for interactions and common action. The plan of action of the 4 per 1000 initiative includes advocating the importance of soils and soil organic matter and engaging a diversity of local, national and international stakeholders, establishing priorities for an international research and scientific cooperation program, providing reference criteria and indicators for SOC management projects evaluation, setting up a collaborative platform open to partners and members of the initiative and developing a digital resource centre on soil organic carbon management.

Keywords: Soil organic matter; carbon sequestration; science – policy interface.
Financial Support: 4 p 1000 Initiative, French National Research Agency (ANR)

b) '4 per mille' a global perspective.

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In response to the Paris Agreement, the 4 per 1000 program was set out as an ambitious aspiration, for the first time setting a global goal to promote good soil management that can help mitigate climate change. The target is to increase global soil organic matter stocks by 0.4 percent annually. It is now supported by almost 150 signatories from various countries, regions, international agencies, private sectors and NGOs. We mapped out the required sequestration rate globally and discussed potentials in several regions of the world. Global reported soil C sequestration rates showed that under best management practices, 4 per 1000 or even higher sequestration rates can be achieved. High C sequestration rates can be realized for soils with low initial SOC stocks in the first 5 years. Regions with high inherent SOC content can be difficult to further increase SOC levels. Conversely, regions with low inherent SOC can also be challenging, as high temperature enhances decomposition, and the removal or burning of crop residues are still frequently practiced. The potential of soil to sequester C to offset greenhouse emissions has been widely debated. However, 4 per 1000 is a practicable solution that soil scientists can offer. There are direct benefits through improving soil conditions. The 4 per 1000 initiative should be view as concept than a specific number. The challenge for cropping farmers is to find a new generation of practices that will further improve soil condition and deliver increased soil carbon. Disruptive technologies can help agricultural practices to soak up more carbon in the soil, create soil security to achieve food security and mitigate climate change. The initiative is also an opportunity to implement a sound and credible soil carbon auditing protocol for monitoring, reporting, and verifying SOC sequestration which can be fit into national GHG inventory procedures. As a strategy for climate change mitigation, SOC sequestration should be implemented immediately. It buys time over the next ten years whilst other effective sequestration and low carbon technologies will become viable. Advances in 4 per 1000 initiative requires collaboration and communication between scientists, farmers, policy makers, and marketeers. Soil C 4 per 1000 can make soils a sustainable resource, not a renewable
resource.

c) Agroecological Transitions to Promote Biodiversity Conservation and Provision of Ecosystem Services

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Healthy soils are crucial for maintaining agricultural productivity, conserve biodiversity and deliver other ecosystem services, such as water regulation, carbon storage and nutrient cycling. However, soil management based on the strengthening of ecological processes is complex, context specific and has to fit the realities of farmer's production situations. Management guidelines should therefore be informed by integrated knowledge about the socio-ecological systems and functional ecology, brought together in interdisciplinary and participatory set ups. The international FOREFRONT Program, which was launched in 2016, brings together scientists from different disciplines and countries to link the landscapetransforming strategies of the various actors with the landscape consequences in terms of ecosystem services. In this Program, our current study aims to understand the linkages between farmers perceptions, ecosystem services and biodiversity in agroecosystems in Zona da Mata, Minas Gerais, Brazil. Combining participatory and analytical methods, the research was developed in co-creation with farmers and other local stakeholders, creating a synergic and action-oriented approach. We constructed a farm typology to understand the implications of farm diversity for promoting agroecological transitions and agrobiodiversity conservation; used a semi-quantitative methodology to unravel the contrasting and complex perceptions of farmers on ecosystem services and their management and; selected representative farms under different management strategies to thoroughly assess the connections between farm management, soil quality, diversity of soil microorganisms and diversity of plants in pastures and coffee fields. Agroecological farmers in our study showed a more complex perception on ecosystem services, which results into more diversified and autonomous agroecosystems as well as greater adoption of alternative management strategies. These results point out the potential of agroecology to enhance ecosystem services provision and biodiversity conservation, while taking into account local actors preferences and needs. The multi-level analysis of agroecosystems, including social and ecological components is crucial to grasp the complexity of realistic management scenarios and to design effective strategies to reconcile natural resources conservation and agricultural production.

Keywords: Socio-ecological systems; participatory research; functional ecology; farm typology; soil quality
Financial Support: This work is funded by: the Interdisciplinary Research and Education Fund (INREF) of Wageningen University & Research; Stichting Het Kronendak; and the Brazilian agencies: Fundação de Amparo à Pesquisa do Estado de Minas Gerais (Fapemig) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

4.2 - Soil Education and public awareness

Conveners: **Eric Brevik** (US) and **Fabiane Vezzani** (UFPR/BR)

a) TRIL: Let's frame the soil education scene?

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The need for education in soil science is most limited to one type of institution, limited to a certain type of industry, or bound by national borders. There is need to educate those who do not know about soil and its central role many of societies grand global challenges, as well as, the on-going education of those who work with or have expertise in soil. The Teaching-Research-Industry-Learning (TRIL) nexus proposed an education framework that enabled learners to take more responsibility for their learning, the teachers taking a more facilitatory role. Being student centered and focusing on 'learning-by-doing' the model also encourages the incorporation of real-world problems and where possible involving those who experience these problems, or work to address them, in the learning environment as well. In some cases, the solutions created are used by the problem's client, secondly the experience not only increases the learner's knowledge of soil science but developing also developing a social awareness or license. This model has now been modified to accommodate the diversification of soil science education across many disciplines and that there are different needs in the depth of soil science understanding. There is still and will always be a need for the soil science expert and this is recognised in TRIL as those who need to – 'know soil'. There is also a need in early education and for the broader community to be aware of soil and its importance. This requires the adoption of education approaches that weave soil into a narrative, part of the art, included in the school garden, and shows the relevance of soil. Here soil may not be the focus of the learning but part of it and this approach is termed – 'an awareness' of soil. The bridge between these two dimensions is those who need to know how soil is integrated into their work. This group maybe described as the agronomist, environmental policy maker, market analyst. They place a value on soil and therefore need enough soil knowledge to – 'know of' soil. This framework is agnostic and can be used to scaffold many learning environments and this will be demonstrated in this talk using some exemplars. The adoption of a student-centered approach is essential as this is focused on know the needs of the student and ensures we as educators know what they need to know about soil. Making it real.

b) Soil education in Latin America.

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This paper will draw a brief panorama of how Soil Education has been developing in Brazil and Latin America. In Brazil, soil education as a formal field appeared within soil departments at Agrarian Sciences faculties and universities and more recently in Geography faculties. However, it exists as a content in environmental education, done at formal and non-formal education, that includes basic education schools, museums and science centres (not much), social movements and non-governmental organizations. Within the soil science community, it started with the creation of the Brazilian Soil Science Society (SBCS) in 1947, as a technical commission called Soil representation and study methods and Soil Science teaching. In 1987, it became Soil science teaching, and in 2007, it was renamed to Soil Education and Soil Public Awareness, widening its approach. Since them, the number of sites doing Soil Education increased to more than 30, and it was possible to keep biannual meetings that bring together a diversity of students, school teachers, extension agents, researchers and university docents. The Latin American Soil Science Society (SLCS) is constituted by 19 National Soil Science Societies and its Education and Teaching Soil Science Program is of paramount importance and concern for the SLCS. "Thus Are de Soils of my Nation" is nowadays the Latin American educative project that is being developed by most of his national societies. Like a part of the original statements that conform this project, constructed under the perspective of diverse methods of study and pedagogical theories, the real fact that is assumed, is that by playing and dreaming children learn and construct new knowledge and establish permanent neuronal networks interconnecting diverse areas and cerebral functions. For this reason and in this context, our most important objective is to make children understand in an interdisciplinary way, that soil is the indispensable natural resource to preserve life on Earth while they work, play, argue their observations on the school orchard and learn. In order to achieve our aims, we work under three principal lines: The educational work carried out into the

schools as a scientific activity. The "Symposium of Educative Innovations on Teaching and Learning Soil Science". The training of teachers in "Didactics of the Soil Science Teaching.
Keywords: Soil; sustainability; education.

c) Which Public? Audiences of soil communication from an arts and humanities perspective.
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Raising soil awareness typically refers to the dissemination of soil information to various target groups by science and policy experts. While outreach efforts initiated by scientific institutions are crucial for the education of particular stakeholder groups, the success of raising soil awareness in the general public requires more than a transfer of scientific knowledge. Sensory, emotional, embodied, aesthetic, indigenous, and other forms of knowledge are also needed to communicate the urgency of soil protection goals and to create lasting bonds between members of society and the environments they inhabit. Artists offer alternative forms of knowledge and knowledge transfer methods, providing much insight to the discourse on raising soil awareness. Specifically, artists “are in the business” of communicating with the general public, or in the words of art theorist Claire Bishop (2012), “one of the central requirements of art is that it is made to be seen and reflected upon by a spectator”. How, where, and in what contexts do artists communicate with their audiences, and what can be learned for raising soil awareness? In this paper, I will address these questions by examining data from a mixed-methods study of 107 soil artworks I conducted from 2012 to 2015. Using arguments from audience studies and relational aesthetics, I argue that some of the most interesting and successful soil artworks are those “which take being together as a central theme, the ‘encounter’ between beholder and picture, and the collective elaboration of meaning” (Bourriaud, 1998). In addition to the ability of art to illustrate the beauty, complexity, and functionality of soil, art can also engage viewers in what art critic Nicolas Bourriaud describes as “relational” experience, including instances of participatory learning, collective social reflection, civic engagement and political activism.
Keywords: Raising soil awareness; soil art; audience studies; relationality; mixed-methods research.
Financial support: DAAD 2018 travel grant; Research Funding provided by DFG Graduate Study Group 780/3 Perspectives on Urban Ecology III; Andrea von Braun Foundation

4.3 - Paradigm change in soil science: utopia or reality?

Conveners: **Guilherme Sobrinho** (Lapsiafro/UFRRJ/BR) and **Alexandra Toland** (DE)

a) From soil properties to soil functions and beyond: paradigm change in soil science?
Thomas J. Sauer[1]
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This presentation will address the evolution of soil science as a scientific discipline within the context of Thomas Kuhn’s “The Structure of Scientific Revolutions”. Soil science began as an extension of interests shared with geology, geography, chemistry, and agriculture. Early practitioners focused on the spatial distribution and properties of soils primarily to assess their suitability for the cultivation of crops. As subdisciplines developed (soil chemistry, soil physics, and soil biology), soil maps and interpretations became more detailed. The pedologists’ interpretations were now informed by the accumulated knowledge of soil processes and how they affected and were effected by soil properties. More recently, fewer and fewer resources are devoted to field soil mapping and research on pedology with a greater proportion of funding now invested in the study of soil functions including how they relate to ecosystem services. Does the current scenario represent a natural evolution of soil science as a discipline or does it represent a paradigm shift? In either case, what are the consequences and opportunities for the future of soil science?
Keywords: soil science, paradigm, ecosystem services

b) Producing a dynamic soil information system for society. Are we ready?
Charles W. Rice[1]
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Soils are critical natural resources that support a wide range of human activities. Although their importance is recognized, the current systems in place for widely monitoring soils and their conditions, including physical, chemical, and, least of all, biological characteristics, along with measures of soil loss through erosion, do not provide an accurate picture of changes in the soil resource over time. Moreover, information on land use or other activities that might be creating changes in soils are not routinely collected and linked to soil data. This gap was noted by the U.N.'s Food and Agriculture Organization (FAO) in the 2015 report, State of the World's Soils. To achieve a better understanding of policies and practices affecting soils, there is a need for a robust, longitudinal, multi-location dataset that captures chemical, physical, and biological soil attributes, coupled to information on environmental conditions and land use activities. Conceiving and implementing such a broad dataset demands thoughtful consideration of the available and preferred methods for collecting uniform data, appropriate indicators and metrics for different soil attributes, and practical consideration of the needs of users of the data. Information for end users include documenting soil erosion, soil carbon, ecosystem services, food productivity and many others, Because such a database would be a significant endeavor and national resource, a serious discussion is needed to design such a dynamic soil information system.
Keywords: Soil Monitoring; soil policies; soil health
Financial Support: Kansas State University

c) Cultural patterns of soil understanding.
Nikola Patzel[1]
[1]IUSS Division 4 Working Group on Cultural Patterns of Soil Understanding chair. Germany, 88662 Überlingen, Seestraße 5. Email: patzel@bodenkommunikation.info

Natural scientific approaches towards soil, as used in common soil science, are not the only effective and valuable ones. We live in a mentally heterogeneous world with fairly different patterns of nature relation and different ideas on how to deal with soil. Even within soil science and agronomy, there exist quite different approaches towards soil. This situation of different approaches needs a careful attention and consideration: to see their different effects on soil and people, and also for soil communication and sustainability issues. The search on cultural patterns of soil understanding is a search for inter-disciplinary and (sub-)cultural differences, as well as for common human traits of soil perception and conceptualization. The aim of this effort is to become and strengthen potential bridge builders: people who can act as networkers and knowledge brokers between different realities of life, perceptions of soil, and types of knowledge. In this presentation, an overview on a variety of cultural understandings of soil will be given, linked with hypotheses about its implications for soil science, soil education and communication. Eventually, soil scientists may need to know and to reflect their own paradigm in relation to other ones, and maybe even to ponder on whether paradigmatic changes may be needed, and – if yes – which ones. Key words: soil perception, concepts of soil, soil relation, mental patterns, frames, symbols, multi-disciplinarity, cultural differences, soil communication

4.4 - Soils, Society and Culture: people´s connections to soil.

Conveners: **Nikola Patzel** (IUSS/DE) and **Cristine Muggler** (UFV/BR)

a) Soil: make the invisible visible.

Christian Feller[1]
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This communication will focus on different soil perceptions by society. Human perception of soil is a paradox, since there is the obvious surface – and the nontransparent inside. And very different concepts exist of "windows to soil perception": - Soil seen as a natural compartment, providing numerous ecosystem services to human societies. It is the "Dokuchaev soil" (D-Soil), the soil of soil scientists; - Soil seen as its economical and legal value, that is, a resource providing marketable goods and financial yields. It is the "soil capital" (F-Soil) described by economists, lawyers and politicians, but few of them consider soil as a natural capital for the welfare of the whole society; - Soil as a cultural issue (C-Soil), implying myths and religions, history, art, etc. It is often the soil of the general public, in some cultures it is also the soil of farmers. It is often observed that the word "soil" is polysemous, that is, it has a wide spectrum of meanings and is part of a larger "semantic field". For communication between soil scientists and the general public it often has to be replaced by other words as earth, dirt, etc., or even considered in a broader dimension as land or terroir, sometimes even "the land of the ancestors" or similar. These observations lead to the fact that the "soil" – the D-Soil – of the soil scientists is hidden from people whose view is the F-Soil, and a large part of humanity is concerned with the C-soil. In the same way, FSoil and C-Soil are often hidden to soil scientists. May we all learn to look through more than one window.

b) Soil Ethics – Soil Care, Beliefs and Values.

Sabine Grunwald[1]
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This talk will critically discuss soil-environmental ethics considering historic, contemporary, and emerging perspectives. Historic human-nature relationships, resembled to this day in indigenous cultures, have focused on respect and fear of nature, magical and mystical thinking, rituals to maintain control and power over natural forces, and/or a deep connection with the Earth as a living body. In Modernity and Postmodernity, scientific knowledge of soils' conditions, functions, processes, services, genesis, and changes due to management and disturbances, such as global climate change, have increased profoundly. Soils have been mapped, quantified, objectified, commodified, and managed as a valuable resource to serve a variety of mainly human-centered needs (e.g., food and fiber production). Despite technological and scientific progress in land use management there is substantial soil degradation, soil quality and carbon loss as well as increased threats to sustain soil-ecosystems at global scale. Contemporary soil/land ethics is grounded in regulation, governance, policy, and stewardship to protect the finite resource soil juxtaposed with profits and social equity. Currently more than 50% of the world population lives in urban areas increasingly detached from soil and nature. For many people soils have become abstract seen on a map, a number in the news, or an image floating through the Internet. This development is somewhat associated with shifts in perception, mindlessness toward self and the environment, disembodiment, loss in relatedness and connection with soil and nature. Expansive soil environmental ethics is grounded in integral ecology, deep care and compassion for soil, the land, life, and planet Earth entailing (1) cognitive empathy referring to factual understanding of soils, environment, and soil health and security, (2) emotional empathy to viscerally sense and feel embodied nature/soils - being the other, being the Earth, and (3) empathic concern referring to other-oriented emotions evoking actions directed toward the welfare of life and the environment. Only the full integration of all three empathies enacts deep care and valuation of soil and the land to bring forth socio-cultural shifts that translate into policy and governance to secure soils unconditionally. An ethics that transcends self-centeredness and dissolves separation between I and other/nature gives way to an integrated, balanced, and harmonious way of being in community with soil, nature, and the Earth.

c) Sacred Ploughing, Divine Soil: The Agrarian Sovereign in Eastern India

Milinda Banerjee[1]
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Soil (in Bengali, mati) has recently become an immensely important political signifier in the Indian state of West Bengal. Since 2013, annual 'Mati Utsav' (Soil Festival) events are being held, centred on a 'Mati Tirtha' (Soil Pilgrimage-Place) in Burdwan, near the state capital Kolkata. Why has soil assumed such sacred importance? This paper addresses this issue through a focus on eastern India. Soil or earth has long been sacralised in India, given its importance to agricultural fertility. Across centuries, changing notions and practices of kingship, marriage, reproduction, and property have often used the soil/earth/field as central metaphors. I begin by analysing the late precolonial Shivayan tradition, centring on the god Shiva, and study the ways in which soil-care received renewed attention in contexts of early modern peasantization, state formation, demographic growth, and religious cult-proliferation in frontier areas of Bengal. I also interrogate other strands of early modern Bengali cultural production on soil. I then shift attention to the colonial era to examine how 'lower caste' peasants in Bengal, such as the Rajavamshis, combined premodern-origin notions of ploughing as a divine and kingly activity with modern vocabularies of peasant autonomy, democracy, as well as soil improvement, in order to form hybrid discourses about agrarian reform and peasant sovereignty. I show how new technologies centring on soil-care and agriculture were thus successfully vernacularized by Bengali peasant communities. Elite-Bengali intellectuals, such as the Nobel Laureate poet Rabindranath Tagore, too gave new sacred and intellectual-political meanings to soil and ploughing. In both elite and peasant cases, I show the transregional links, and especially the impact of global capitalism as well as of 'Western' discourses and practices of soil science and technology. Finally, I shift my attention to the postcolonial era, and show how such hybrid discourses retain traction into the twenty-first century. The present resurgence of political interest in 'soil' needs to be contextualized in relation to the attempted dispossession of peasants by predatory land-grabbing industrial capitalism, as well as in relation to political protests by peasants as well as middle-class politicians that have used symbolism centring on the divine nature of soil, on sowing as a sacred and political (as well as gendered) act, on the association of political femininity with soil, and on the protection of small peasant property. My broader argument is that scholars of soil perception need to be sensitive to these regional traditions, and the intrinsic links between cultural perceptions of soil and the socio-political demands of subaltern populations, if they are to successfully build solidarities with peasant communities, from areas of soil-care to battles about peasant sovereignty.

Keywords: India; West Bengal; theology; peasant; capitalism; ploughing; soil

TECHNICAL & INNOVATION SYMPOSIA

TECHNICAL & INNOVATION SYMPOSIA

IHSS Symposium: "Fresh and Humified Organic Matter: a key factor in the soil processes and sustainability

Conveners: **Etelvino H. Novotny** (EMBRAPA/BR) and **Deborah P. Dick** (UFRGS/BR)

a) Affirmation of the Existence of Humic Substances and Humin and their Importance in the Interfacial Reactions of Soil Organic Matter.

Roger S Swift[1] and Michael H B Hayes[2]
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[2]CES, University of Limerick,Ireland.

The validity of the term and the very existence Humic Substances has been questioned and a 'Soil Continuum Model' (SCM) proposed to describe the decomposition of soil organic matter (SOM)a. We fundamentally disagree with these concepts. The SCM focuses on the ability of decomposer organisms to access organic debris and SOM, and on the protection against decomposition afforded by soil minerals. In effect the SCM regards SOM as a continuum spanning the full range from intact plant material to highly oxidized carbon in 'carboxylic acids'. The authors also state that there are no components of SOM that are inherently resistant or acquire resistance to decomposition. We demonstrate that nothing could be further from the truth. It is inappropriate to refer to SOM components and their transformations as a 'continuum' because it is a heterogeneous mixture of a wide range of discrete materials with different compositions with different pathways and rates of decomposition. We will present a number of reasons why the SCM is a flawed concept and cannot be used to describe the known behaviour and composition of SOM. Compelling evidence regarding the existence of components of SOM (including humic substances), obtained using a variety of extraction and fractionation procedures, which exhibit widely different chemical properties and decomposition behaviour. Evidence from Spectroscopy and modelling will be presented to illustrate these major compositional difference and the impossibility of considering them to be part of a 'continuum' concept which fails to identify the different components of SOM and recognise their importance in many interfacial reactions in soil.

Keywords: Soil Organic Matter, Humic Substances, Humin, Composition, Decomposition

b) Humification an obsolete expression or still a relevant process for soil organic matter maturation? – What tells us solid-state NMR spectroscopy?

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Since the first isolation of humic acids via alkaline extraction by Achard in 1786, the perception of humic substances (HS) as an important component of soil organic matter (SOM) has undergone considerable changes. During the last years, the concept of HS and the expression of humification has been questioned in particular with respect to their suitability to explain the formation of biochemically recalcitrant SOM. Most of the recent criticisms are based on limiting the concept of humification to SOM, soluble in alkaline solution. This, on the other hand, is in discrepancy with the definition published by the International Humic Substance Society (IHSS), in which humification comprises all biochemical and chemical reactions occurring during the decay and transformation of plant and microbial remains leading to complex and heterogeneous mixtures of polydispersed materials. However, the nature of the latter and the involved reactions are still matter of present research and discussions. One analytical tool, which already shortly after its introduction into soil science in the 1980's led to results questioning previous paradigm, represents solid-state 13C – and latter 15N - NMR spectroscopy. The new findings had major implications on our present understanding of the origin of SOM and the mechanisms by which it is formed. Up to now, the application of established and advanced NMR spectroscopy results in unexpected findings, which are still challenging our scientific view of soil biochemistry. Therefore, the intention of the present contribution is to summarize how established solid-state NMR techniques contributed to our knowledge of SOM stabilization or humification and to demonstrate the potential of advanced one and two dimensional techniques for a better understanding of biochemical processes in soils, sediments and water.

Keywords: soil biochemistry, solid-state NMR spectroscopy, C and N cycling
Financial Support: International Humic Substance Society (IHSS)

c) Sustainable Intensification (crop-livestock-forest integrated systems) and Impact on Soil Organic Matter Dynamics and Reactivity

Ladislau Martin-Neto[1], Amanda M. Tadini[1,2], Alberto C. C. Bernardi[3] and Débora M.B.P. Milori[1].
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Conservative soil management is a priority in Brazilian agricultural research and technology transfer for farmers. Besides extensive adoption of no-tillage practices in croplands areas, more recently croplivestock-forest (CLF) integrated production systems are gaining adoption by farmers in all Brazilian regions. In 2016 in a national survey, realized by Consultancy Kleffmann, hired by a public-private organization (Network of Support to Integrated Systems Adoption, with participation of Embrapa) identified 11.5 million of hectares under integrated systems adoption, a surprisingly positive result. The CLF integrated production system is an eligible practice within Brazilian Low Carbon Agriculture Plan, launched by Brazilian Government in 2011, as part of stimulus to Brazilian farmers increase adoption of sustainable practices. SOM stabilization by organo-mineral association, soil aggregation and physical protection of SOM, and biochemical recalcitrance of SOM are concomitant processes that govern SOM dynamic and reactivity in soils. These reactions involve physical, chemical and biological processes with organic compounds inputs from crops, pastures, trees, and yet from animal dejects, creating a challenging environment to be carefully analyzed. In this presentation combination of physical and chemical soil fractionating procedures with several analytical tools, as elemental analysis (CHN), laserinduced fluorescence (LIF), laser-induced breakdown spectroscopy (LIBS), 13C NMR and other are being applied in long term field experiments generating information about SOM dynamics and reactivity. First results demonstrated increase on SOM content and decrease of humification degree, after five years of experiments, in sites under crop-livestock forest integrated system compared with conventionally managed pastureland, in a transition region from Atlantic Forest to Savannah vegetation in São Paulo State.

Keywords: soil carbon sequestration, spectroscopic analysis, conservative tillage
Financial support: Embrapa (01.14.09.001.03.00) and Fapesp (2017/22950-1)

d) Physiological effects of humic acids: Disturbing the plant growth?

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The use of humic substances as plant growth promoter in agriculture has grown steadily from the lastdecade around 10% at year, or more, whatever indicator is used (sales, treated hectares, number of users) as well as the efforts to understand how these biostimulants work. We summarized here the results of 10 years of field experimentation carried

out by NUDIBA in tropical agriculture using humic substances as plant growth promoter alone or in combination with beneficial bacteria. Agronomic aspects such as doses, forms and time of application were systematically approached for some crops with emphasis on non leguminous plants as corn and sugarcane and tropical fruits. At the same time, the mechanisms of action of these growth promoters were investigated. Our results follow those found by Prof Nardi's and Garcia-Mina's research groups, including increase of nutrient efficiency use and changes in primary and secondary metabolism. More recently, we found some unusual results indicating that humic substances may disrupt normal plant functioning. The understanding of these intriguing modifications may be used to formulate new growth promoters especially targeted for abiotic stress mitigation.

Keywords: Field response, Humic acids, Diazotrophic endophytic bacteria, Ecological intensification of crops
Financial Support: CAPES, CNPq, FAPERJ, FINEP

SSSA Symposium: Soil Health: The Nexus of Human Health and Well Being
Convener: **Richard Dick** (SSSA/OSU/USA)

a) Soil Health: Can it be Defined and Measured?
Richard Dick[1]
[1]SSSA/OSU/USA

b) Soil Health and the Microbial Community: Resilience and Delivering Services in a Shifting Climate
Veronica Acosta-Martinez[1]
[1]USDA/USA)

c) Integrating Soil Health and Ecological Resiliency Concepts to Advance Sustainable Intensification of Agriculture.
David Huggins[1]
[1]USDA/USA

d) Influence of Soil on Human Health
Ian Pepper[1]
[1]UA/USA

e) Soil Health, Food Security, and Human Nutrition
Eric Brevik[1]
[1]DSU/USA

Global Soil Partnership, promoting sustainable soil management
Convener: **Ronald Vargas** (GSP/FAO) and **Eduardo Mansur** (FAO)

a) Introduction to the GSP and sustainable soil management?
Eduardo Mansur[1]
[1]FAO/IT

b) Unlocking the potential of soil organic carbon
Ronald Vargas[1]
[1]FAO/IT

c) Soil pollution: an agenda for action
Natalia Rodriguez[1]
[1]FAO/IT

d) Global Soil Information System (GloSIS)
Yusuf Yigini[1]
[1]FAO/IT

e) Awareness raising on soils
Isabelle Verbeke[1]
[1]FAO/IT

21WCSS Applied Symposium
Convener: **Flávio Camargo** (UFRGS/BR)

a) ABC Plan contributing to Soil Conservation in Brazil
Eleneide Doff Sota[1]
[1]MAPA/BR

b) Developing sustainable crop nutrition solutions
Anke Kwast[1]
[1]Yara International/GR

c) ICLF Network: a public-private partnership to develop Low Carbon Agriculture and food security in the Tropics.
Renato de Aragão Ribeiro Rodrigues[1]
[1]EMBRAPA/BR

d) Soil hydro-physical behavior and the water production in a first order watershed: The water security context
Hudson Carlos Lissoni Leonardo[1]
[1]Itaipu/BR

Soil information, a prerequisite for sustainable soil management
Convener: **Ronald Vargas** (GSP/FAO) and **Eduardo Mansur** (FAO)

a) Introduction to Global Soil Information System (GloSIS)
Yusuf Yiguini[1]
[1] FAO/IT

b) Global Soil Laboratory Network (GLOSOLAN)
Natalia Rodriguez[1]
[1]FAO/IT

c) GSP Capacity Development Programme
Yusuf Yiguini[1]
[1]FAO/IT

d) Latin American Soil Information System (Sistema de Información de Suelos de Latinoamérica - SISLAC)
Guillermo Olmedo[1]
[1]FAO/IT

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PLENARY SESSIONS
Divisional Symposia

C1.1 - Soil morphology and micromorphology

C1.1.1 - Using soil morphology and micromorphology indicators of soil health

(5034 - 1767) Effects of land use in physical properties in andean volcanic ashes soils.

Juan Carlos Loaiza Usuga[1]; Yolanda Rubiano-Sanabria[2]; Melissa Lis-Gutiérrez[2]; Joan Sebastián Gutiérrez Díaz[2]

Universidad Nacional de Colombia, Campus Medellín[1]; Universidad Nacional de Colombia, Campus Bogotá[2]

This study was carried out in the Guerrero Paramo, which is a highland located in the Cundinamarca province of Colombian, our study zone is located, specifically into a micro catchment of the Guandoque River at Tausa village. Potatoes crops are the most predominant soil uses, followed by pasture and natural forest. Soil parental material is made up of mixt sedimentary rocks from Upper Cretacic and Lower Tertiary, and mainly composed of compact sandstones, along with siliceous limolites, lodolites, arcillolites insertions and local volcanic ash layers. As well as, consolidated and semi consolidated quaternary sediments from Guadalupe group, Guaduas formation, and Conejo formation. The enquiry used the catena concept to research nine profiles in seven geomorphological positionsn. The several soils found correspond to medium-textured, eigth Andisols of the suborder Aquand or Udand and one Inceptisol of the suborder Udept; Typic Endoaquand (Fluviolacustrine Plain, Accumulation Glacis and Moraines), Pachic Melanudands (Abrupt homiclinal crest, Accumulation Glacis, Hill and Valley), Lithic humudepts (Slope). The findings show the soil use effect on soil porous system, depending on its morphology and micromorphologic features. This enquiry seeks for interpreting the change of soil use dynamics according to the behavior of porous system and morphologic characteristics. The discussion focuses on the relationship between physical and morphologic features and the organic matter content on topsoil layers and deeper layers with pedogenetic features inherited. Preliminary results allow setting an approach for soil quality indicators, its physical expression, and morphogenetic relation based on the existent soil uses.

Keywords: Moorland, Páramo, Soil uses, Pedogenesis, Micromorphology, Andean soils

Financial support: COLCIENCIAS and Universidad Nacional de Colombia

(4094 - 1260) Micromorphology of soils under sugar cane in the Cauca Valley, Colombia

R. Madriñan[1]; Rosa M Poch[2]; J.M. Plata[2]

Universidad Nacional de Colombia (UN)[1]; Universitat de Lleida (UdL)[2]

In the National University of Colombia at Palmira, a soil museum was created in 2004, in order to show a collection of soil monoliths from the Cauca Valley. It consists at present of 21 monoliths and it is planned to build 40 additional ones. The idea is to have a didactic support in teaching at all levels, to encourage students to know the benchmark soils they can found in the region. With the extraction of each monolith, a series of physical-chemical-mineralogical analysis for each horizon were carried out, accompanied, at all times, by the construction of thin sections for micromorphological studies. Based on this information, a study has been developed of 8 of the monoliths that are found in areas dedicated to the cultivation of cane for more than 50 years. We know that sugar cane is widely cultivated in Valle del Cauca; with associated practices including the burning of litter and the use of heavy machinery, which affect the properties and functionalities of the soil. We want to corroborate, with all these data, the effects of the aforementioned practices on the soil at a physical and chemical level, as well as their relationship with the structure and other properties that can be extracted from the micromorphological studies. A first approach has reported a reduction in the contents of different persistent humic substances in the soil and an increase in bulk density. Finally, a series of alternatives for use and management are presented depending on the type of soil and results obtained.

Keywords: microstructure, litter burning, soil monoliths

Financial support: Universidad Nacional de Colombia (UN) with the support of the Instituto Geográfico Agustín Coazzi (IGAC) and Universitat de Lleida (UdL)

(8189 - 1058) Using micromorphology to assess the physical contamination of topsoil amended with a mixed waste organic output

Stephen Cattle[1]

The University of Sydney[1]

In NSW, Australia, the production and land application of mixed waste organic outputs (MWOO), which are similar to municipal solid waste composts, is steadily increasing. This reflects the commitment by government bodies to reduce the amount of waste going to landfill and to reuse waste beneficially. However, an inevitable consequence of land applying recycled organic waste is that some amount of metal, organic and physical contamination is applied to the soil. Although maximum allowable concentrations of such contaminants are prescribed, in the case of physical contaminants such as glass and plastics, there is little experimental data to indicate whether these maximum allowable concentrations mitigate potential negative impacts. Here, we used micromorphological techniques to describe the distribution and features of physical contaminants found in agricultural topsoil one year after a MWOO had been applied at four different rates, prior to the planting of a wheat crop. Thin section analysis of the soil to a depth of 0.25 m revealed that glass and plastic fragments had not migrated beyond the depth of tillage and MWOO incorporation, but that these physical contaminants were present in a variety of sizes and morphologies. In the higher MWOO application rate soils, physical contaminant particles occupied a variety of positions in the soil depending on size and shape; large, gravel-sized particles tended to act as bridges between microaggregates and organic matter, sand-sized particles tended to act as 'nucleating agents' for soil mineral material or to be located in large pores, and fibres tended to reside in pores, often acting as partial blockages. Sand-sized glass fragments were somewhat difficult to distinguish from quartz grains in thin section, although inspection of sand-sized grains under reflected light microscopy showed glass fragments to be more angular and jagged than quartz grains in the unamended control soil. Particle size analyses of the treated soils showed that the gravel and coarse sand fractions were increased at the higher rates of application. These results suggest that at the higher rates of MWOO application, soil hydraulic conductivity may be compromised if enough physical contaminants are present to block the majority of large pores. Measurement of hydraulic conductivity in previously amended and now re-consolidated soils would be prudent.

Keywords: recycled organics, microplastics, glass

Financial support: This project has been assisted by the New South Wales Government through its Environmental Trust, and the NSW Environment Protection Authority.

C1.1.2 - Structural indicators of soil quality using X-ray computed tomography

(1679 - 1191) Application of an indicator package for soil structural analysis based on x-ray computed tomography

Tseng Chien Ling[1]; Ednaldo José Ferreira[2]; Marlene Cristina Alves[3]; Adolfo N. D. Posadas[4]; Miguel Cooper[1]; Daniel Giménez[5]; André Luiz de Ferraz Lourenço[1]; Carlos M. P. Vaz[2]; Silvio Crestana[2]

USP[1]; EMBRAPA[2]; UENESP[3]; Agrosight Ltd[4]; Rutgers University[5]

Soil is an open and complex system, and quantification of this

complexity has always been a challenge for the scientific community. In view of that, the goal of this work was to develop a group of indicators of soil structure derived from high-resolution x-ray computed tomography to quantify structural properties of a Brazilian Oxisol sample, and for correlating its morphometric, geometric and energetic characteristics. These structural properties are: porosity, degree of anisotropy, Euler-Poincaré number, form factor, fractal dimension, lacunarity, tortuosity, degree of multifractality and asymmetry and system entropy. In addition, we pursued the correlation among structural properties by dendrogram, indicating characteristic groups according to their similarity. It is expected that this work will contribute with a synthesized indicator package for evaluating soil structure.

Keywords: Brazilian Oxisol, soil morphometry, soil geometry, soil energy, X-ray microtomography.
Financial support: CNPq

(1163 - 2717) Assessing long-term effects of zero-till on the porosity of Brazilian soils using X-ray Computed Tomography

Marcelo Valadares Galdos[1]; Luiz Fernando Pires[2]; Hannah Cooper[3]; Ciro Rosolem[4]; Sacha Jon Mooney[3]
University of Leeds[1]; Universidade Estadual de Ponta Grossa[2]; University of Nottingham[3]; Universidade Estadual de Sao Paulo[4]

Zero-tillage (ZT) has been increasingly adopted as a conservationist management system, with environmental and agronomic benefits. However, there is little information on soil pore parameters such as soil pore shape, size and orientation, which affect soil physical, chemical and biological processes. X-ray Computed Tomography enables a high level of detail assessing soil structural properties in three-dimensions and in a non-destructive manner. We used X-ray Computed Tomography to assess and calculate the shape and size of each pore and the network connectivity in undisturbed soil samples collected from a long-term experiment (~30 years) managed as ZT and an adjacent CT site in Botucatu, Southeastern Brazil. The soil is a clay Typic Rhodudalf, and the cropping history included wheat, soybean, black oat, maize, pearl millet, dry beans and brachiaria grass. For the 3D structure analysis, soil pores were classified according to their size and shape distribution. For the shape classification, geometrical parameters known as major, intermediate and minor axes of the ellipsoids that represent each pore were determined using three-dimensional measuring techniques using the Particle Analyser tool in the ImageJ 1.42 software. The network tortuosity (τ) of the pores and connectivity were calculated using the computer program Osteoimage. In both treatments, a single large pore (>1000 mm^3) contributed to a large proportion of total porosity, 91% in CT and 97% in ZT. Average total porosity was higher in ZT (19.7%) compared to CT (14.3%). Average total number of pores was almost twice in CT than ZT. Regarding pore shape, the largest contribution in both treatments was from non-classified pores, followed by triaxial and acircular. CT presented a higher number of micropores that ZT, which is associated with aggregate breakdown induced by ploughing. The connectivity analysis indicates that the soil under ZT (EPC=297) is more connected that the soil under CT (EPC=931). The soil under CT presented larger values of tortuosity (τ_x=1.48, τ_y=1.46, τ_z=1.48). than ZT (τ_x=1.35, τ_y=1.33, τ_z=1.35). The results obtained in this study indicate that long-term adoption of ZT leads to higher pore connectivity and higher total porosity, which has implications in nutrient cycling, root growth, soil gas fluxes and water dynamics.

Keywords: Pore connectivity; network tortuosity; pore shape.
Financial support: FAPESP (2015/50305-8) and BBRSC/Newton Fund (BB/N013201/1).

(1771 - 197) Computed Tomography-Measured Pore Parameters Influenced by Cover Crops and Biofuel Management

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Understanding the effect of cropping practices on soil pore characteristics is important for determining soil productivity and ecosystem services. Objectives of the study were to compare differences in computed tomography (CT) measured soil pore parameters (number of pores, number of macropores, number of coarse mesopores, macroporosity, coarse mesoporosity, total porosity, area of the largest pore, circularity and fractal dimension) among cover crops (CC), no-cover crops (NCC), and biofuel crops [Miscanthus (M): *Miscanthus x gigantus* and switchgrass (SG): *Panicum vergatum*] and examine relationships between CT-measured pore parameters and soil hydraulic and thermal properties. Cover crops were Cereal rye (*Secale cereal* L.), Hairy vetch (*Vicia villosa*) and Austrian winter pea (*Pisum sativum subsp. arvense*). Three replicates each of undisturbed soil cores were collected at two soil depths (0-10 and 10-20 cm) from each treatment. Ten scan images from each core were acquired using an X-ray CT scanner with 0.19 by 0.19 mm pixel resolution with 0.5 mm slice thickness and analyzed with *Image-J*. Soil under CC, NCC, M, and SG on average had 59, 41, 65, and 56 pores on a 2500 mm^2 area across all the depths. Soil under miscanthus had significantly greater CT-measured porosity (0.054 m^3 m^{-3}), macroporosity (0.049 m^3 m^{-3}) and area for the largest pore (89.70 mm^2) than other treatments. The cover crop treatment had approximetly 50%, 28%, and 75% greater number of macropores than NCC, M, and SG treatments. Bulk density (D_b) of soil was 13% lower in M than the NCC. Saturated hydraulic conductivity (K_{sat}) values were positively correlated with most CT-measured pore parameters. In contrast, D_b was negatively correlated with most CT-measured pore parameters (circularity and fractal dimension were positively correlated). While the circularity values were correlated positively with D_b and thermal conductivity (λ), the fractal dimension was correlated positively with volumetric heat capacity (C_v). The study illustrates that M and CC treatments can improve soil pore parameters.

Keywords: image analysis, soil pores, cover crops, Miscanthus, Switchgrass
Financial support: University of Missouri Center for Agroforestry

(5851 - 1831) Linking 3D pore structure to organic carbon contents of Andisols under organic and integrated kiwifruit orchards

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Soil organic carbon (OC) is underpinning many ecosystem services that soils provide. The link between soil biotic activity, soil organic matter decomposition and stabilization, and soil aggregate dynamics has been recognized and intensively studied since the beginning of the 1900s. Soil porous structure and organic matter are not independent entities. Pores are created by abiotic and biotic factors (root growth, burrowing, etc.) and different forms of organic matter stabilize pores of different size. In turn, pore characteristics influence organic matter dynamics. Moreover it has been shown that soil OC and fertilizer management can influence the soil structure both in terms of pore morphology and network organisation. Here, we hypothesized that changes in pore structure resulting from the feedback mechanisms between OC management and soil biota can be captured with 3D X-ray computed tomography (CT), and that such changes can explain differences in the filtering function of soils. Our field site was located in the Bay of Plenty, New Zealand. Andisols that have been under

organic and integrated kiwifruit production since 30 years, were compared. The macropore networks and morphological parameters of intact soil cores of 10 cm diameter and length were determined using X-ray CT at the 3SR laboratory (TomRX Solutions) combined with image processing techniques. Water and copper displacement studies were conducted with the same intact soil cores. At the end of the displacement experiments, the soil cores were cut into slices of 2-cm depth, and pH, total copper and OC contents were analysed. We discuss the correlations between OC contents, soil macropore characteristics and the mobility of inert and reactive solutes.
Keywords: Copper; X-ray Computed Tomography; Pore network
Financial support: European Union's Horizon 2020 Research and Innovation Project PROTINUS, 645717

(2408 - 2440) Quantification of 3D-structures in soil microaggregates

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All biogeochemical processes are regulated or modulated by soil structure, which can be studied at different scales. On a very small scale soil microaggregates (SMAs) with a size smaller than 250 µm are considered to play an important role in soil functioning. Understanding their structure and composition is therefore crucial for the appreciation of many soil processes and functions, such as the storage and cycling of water, nutrients and organic matter. The formation of SMAs and the mechanisms leading to the spatial organization of their building units (primary minerals, phyllosilicates, organic matter, oxides and hydroxides of Al and Fe) is still poorly understood and little is known on the microscale internal architecture of SMAs. The best method for a non-invasive structure analysis is computed microtomography (µCT), as this technique can provide detailed 3D (or even 4D) information on soil microstructure at a high-resolution. In this talk we will introduce possibilities to study and quantify the 3D-architecture of SMAs and how it is influenced by clay content. Morphological parameters that can be related to soil functions associated with SMAs are shown and the possible feedback mechanisms on SMA formation and stabilization are discussed.
Keywords: X-ray microtomography Soil microaggregates quantitative image analysis
Financial support: We kindly acknowledge financial support by the Deutsche Forschungsgemeinschaft within the framework of the research unit "MAD Soil - Microaggregates: Formation and turnover of the structural building blocks of soils" (DFG RU 2179).

(3434 - 3096) Quantifying the Effect of Crop Rotation on Topsoil Structure Dynamics using X-ray Computed Tomography

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Within temperate agriculture systems, soil structure maybe subject to both management-related (tillage, root growth) and natural (faunal activity, wetting/drying, freezing/thawing) processes. Understanding the nature and magnitude of annual changes in topsoil structure is ultimately important for establishing sustainable management practices. This study was undertaken on long-term (>30 years) management plots, maintained at the University of Guelph's Elora Research Station, in Ontario, Canada. Five rotations, all on zero-tillage, were included: corn-corn-soybean-soybean, corn-corn-soybean-wheat, corn-corn-soybean-wheat (under-seeded to red clover), corn-corn-alfalfa-alfalfa and continuous alfalfa (as reference). Intact cores of topsoil were collected early-September (pre-harvest), early-December (pre-winter) and late-April (post-winter), from first-year and second-year corn crops in each of the rotations. High-resolution (40 micron voxel size) 3D radiodensity imagery was obtained by x-ray computed tomography. The greyscale imagery was segmented into resolvable voids and solids, as well as matrix phases. Morphometric analysis of the intra-aggregate voids considered their size, shape and orientation. Image masking permitted quantification of the spatial variabilty of matrix radiodensity, using orthogonal semivariance analysis. Indices of anisotropy and short-range variability were derived from the semivariograms. Attention will be given to comparing the relative influence of growing season and winter processes on structural parameters and their variability.
Keywords: topsoil structure, crop rotations, zero till, x-ray computed tomography, 3D semivariance
Financial support: Ontario Ministry of Agriculture, Food and Rural Affairs; Grain Farmers of Ontario; Natural Sciences and Engineering Research Council of Canada

C1.1.3 - How to use micromorphology to understand palaeosols and polygenetic soils?

(3206 - 2592) A practical approach to studying iron-rich duricrusts using SEM image analysis

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Iron-rich duricrusts are commonly located on old flat surfaces. They promote landscape stability by the protective action of indurated ferricrete, providing important records of multiple soil and geomorphic processes, and paleoclimatic events. In the Southern Serra do Espinhaço (SSE) in Brazil, iron-rich duricrust profiles occur on flat to slightly convex hills of quartzite at elevations of mostly 1200-1400 m asl. Some of these profiles are remnants of old paleosurfaces. Here we describe an image analysis technique to measure morphological attributes of quartz grains in thin sections of iron-rich duricrust profiles over quartzites in the SSE; we present a possible way to investigate the genesis of these materials. Size and shape variations of quartz grains were measured for three iron-rich duricrust profiles (GS_2, PF_1 and PF_3). Thin sections of 5 x 7.5 cm from surface and iron-rich duricrust horizons were studied. Distinct morphological regions (iron concretion and matrix) of iron-rich duricrust horizon were separately analyzed to identify variations in regolith morphology. A scanning electron microscope (TESCAN VEGA3) was used to produce micrographs in backscattered electrons (BSE) for regions of sufficient area using image analysis software (ImageJ 1.50i). Quartz grains within the iron concretions of PF_3 showed morphological properties indicating polygenic processes had occurred during the genesis of concretions. In contrast, PF_1, which showed no evidence of parent material diversity, contained quartz that is indicative of a polycyclic character. We observed fragments of iron concretions with pores previously occupied by quartz grains indicating extensive quartz dissolution during weathering and duricrust evolution. BSE images present a clear contrast between quartz grains and iron-rich duricrust matrix allowing resolution of these materials for specific investigation. Thresholding is effective because populations of grey-level values are usually bimodal in BSE due to very different electron scattering powers of quartz and iron-rich materials. This procedure enables the quantitative analysis of soil materials allowing comparisons of soils and the testing of hypothesis for soil genesis.
Keywords: laterite; ferricrete; iron nodule; quartzite; Serra do Espinhaço
Financial support: São Paulo Research Foundation – FAPESP (2015/17518-8) and National Council for Scientific and Technological Development – CNPq (408138/2016-5)

(8151 - 540) Micromorphology of red palaeosols in Mediterranean loess sequences in the Ebro valley

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During routine soil mapping at detailed scale, extensive sandy loam soils at the southern end of the Ebro Valley were identified in 1987. These soils did not fit with existing descriptions of Quaternary formations in the area. Although loess-like materials were previously identified in Catalonia, the first comprehensive study of five selected loess outcrops suggested that their source areas were located to the West, in windward areas of the Ebro Basin that had only very sparse plant cover during arid, cold periods. Gypsum and carbonate accumulation in modern deposits, together with decarbonation and rubefication in the oldest palaeosols, are the predominant soil-forming processes. Most of the deposits formed 17-34 ka (OSL) ago, i.e., during cold and dry phases of the Late Pleistocene, especially during the LGM (MIS2). The oldest deposits are older than 115 ky (OSL), which means that their pedogenesis occurred probably during the Eemian. Two of these oldest sequences are studied in detail, including micromorphology and detailed particle size distribution. The first one (Mas de l'Alerany) is a truncated profile located in a primary loess outrcrop, with a thickness of 10 m. The second one (Chiprana) is developed on a loess-like infilling of a paleochannel depressions network, and has a thickness of 3.25 m. The Mas de l'Alerany profile shows a very prominent rubefaction (hues 2.5YR), and abundant calcium carbonate rhizocretions. Micromorphologically, the rubefication in Mas de l'Alerany profile corresponds to a partly decarbonated micromass, with patches of crystallitic micritic and stipple-speckled b-fabric. Micrite nodules are abundant, together with fine microlaminated clay coatings. The lower part of the sequence is not rubefacted but presents some microlaminated clay coatings and infillings illuviated from the overlying horizons. The Chiprana profile is younger in age and is also partly rubefacted in its middle section (hues 5YR). It contains very abundant biocalcifications (queras) as biosparite infillings in channels surrounded by decarbonation hypocoatings which are rubefacted. These results may question the use of rubefication as an indicator of age in Mediterranean contexts.
Keywords: rubefaction, biocalcification, soil formation
Financial support: UdL, CENIEH

(4083 - 1616) Pedogenesis and paleoenvironmental reconstruction in a sequence of Spodosols in forest-savanna transition area in Roraima

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The genesis of the Spodosols in the Amazonian hydromorphic plain is associated with two main hypotheses: first one involves the transformation of a preexisting clayey layer, whose lateral dynamics with the dissolution of the clay minerals would leave the quartz skeleton as a residue, and second, its genesis is associated with deposits of alluvial sediments and addition of dissolved organic matter. Outside of the hydromorphic plains, in forest-savanna transition zones, there is also occurrence of Spodosols, as occurs in Roraima, state at the extreme north of the Brazilian Amazon. The questions that lead this study were: is the genesis of these soils associated with the transition from a clayey to sandy cover or is it from past alluvial sandy deposits, just as it occurs in the hydromorphic plains? Another curiosity is the occurrence of sandy paleodune in the region, which raised the following question: the source material of these soils would be paleodunes deposited in drier periods? The area is situated in the center-east of Roraima, with average annual precipitation of 1200 mm. Three Spodosol sequences were studied and the following analyzes were performed: ^{14}C dating, isotopic analysis (dC13), optically stimulated luminescence (OSL) and micromorphology. The organic matter (OM) presented an age of 1538 ± 1381 BP and the isotopic ratio of -26.66 ± 0.24 ‰., evidencing the predominance of plants photosynthetic cycle C3. The age of these deposits was 57.300 ± 6.940 for the Bhm base and 21.100 ± 1.870 at the top. Micromorphology showed the presence of both monomorphic and polymorphic OM. It was possible to see the processes of degradation of OM at the top of Bh and advance of horizon E, in addition to processes of pedoturbation, evidenced by the aligned distribution of grains and polymorphic OM in the fills. The grains have subangular rounding, showing that there was transportation, but of little selected material. It is concluded that the genesis of these soils is associated with different short climate cycles, first with the transport of sandy material from alluvial deposits and then establishment of vegetation and input of OM, initiating podzolization. In the current period there is a degradation of these horizons due to the lowering of the water table.
Keywords: genesis Spodosols Amazon micromorphology
Financial support: UNIVERSIDADE DE SÃO PAULO

(5541 - 950) Synlithogenic pedogenesis in calcareous archaeological landforms of Israel

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Archaeological mounds (tells) are abundant in the Judean foothills of Israel, having 40 tells across an area of 1200 km^2. We tested the influence that ancient humans had on pedogenetic processes within the tells, especially the accumulation of carbonates. We compared soils from within three representative tells with soils from their proximal surroundings (reference profiles). The methods applied included a field survey, particle size distribution, pH, %$CaCO_3$, total organic carbon, and soil micromorphology. Soils of the tells have brownish colors, lack horizonation, high effervescence, massive weak structure, silty clay loam texture, and contain fragments of mud bricks, pottery (many of which are >5 cm), charcoal, and chalk. Occasionally, fragments of shells, bones, and roots also occur. Particle size distribution shows a dominance of silt (60-70%). Chemical data show moderate alkalinity, high $CaCO_3$ content, and minor amounts of organic carbon. Field observations and lab analyses both indicate high similarity amongst the tells and the reference profiles. However, the reference profiles show incipient horizonation, darker colors, more developed structure, and fewer fragments of >5 cm. Micromorphology of both the tells and the reference profiles show cohesively welded peds in a vughy microstructure, groundmass with an open porphyric c/f-related distribution, and discontinuous carbonate recrystallization. Groundmass of the tells includes fragments of mud bricks, potsherds, chalk, and bones, quartz silt grains, charred particles, and plant residues. Groundmass of the reference soils is similar in fine material but not as much in its coarse material. Contrary to the tells, the reference profiles show lower porosity and only minor remnants related to earth construction materials. Infrequently observed in both the tells and the reference soils are calcified biogenic components, and micritic coatings and infillings. Based on these observations, ancient human actions and the dry climate have led to very little mobilization and accumulation of carbonates. Characteristically of synlithogenic soils, the tells are composed of cultural materials, mostly of geogenic origin that disintegrate and deposit simultaneously with incipient pedogenesis.

The anthropogenic materials are as calcareous as the natural soils, but due to human action, carbonates in the tells are distributed differently.
Keywords: Anthropogenic soils, Synlithogenic pedogenesis, Tell, Archaeological mound, Soil micromorphology, Calcium carbonate features
Financial support: United States-Israel Binational Science Foundation grant 2014-341

C1.2 - Soil geography

C1.2.1 - The geography of soils in a changing world

(8446 - 620) A global-scale assessment of soil geography and soil-landscape functioning for biomass production and carbon sequestration

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Knowledge about soil geography and soil-landscape functioning is essential for global studies, particularly to model the impact of climate change on natural resources, including biomass production, land degradation and soil carbon sequestration. Few studies addressed soil geography and abiotic soil-landscape properties as a driver of changing natural resources due to climate change. In this work, we provide insights on the main large-scale drivers of vegetation activity. This was achieved by modelling the mean annual cycle (MAC) of the Normalized Difference Vegetation Index (NDVI) as a function of climatic conditions and landscape characteristics, using both a local and global deterministic modelling approach. Results show that the main MAC drivers of NDVI vary seasonally and depending on regional ecosystem properties, according to the global model ($0.62<R^2>0.76$, $0.14<RSE>0.16$). Temperature, soil texture and pH are the most important drivers for vegetation activity, independently of the month. Moreover, at the start of the growing season, temperature is the most important driver for vegetation activity. As the growing season proceeds, favourable soil properties related to root depth limitations and the water retention capacity (clay, sand, soil depth and pH) become more important than temperature. However, site-specific soil-landscape functioning makes interpretation of the global drivers difficult. For example, SOC had a slightly negative impact on NDVI which could be explained by the low carbon content in agricultural croplands and the fast turnover rates in the tropics. Yet, the local models ($0.07<R^2>0.91$, $0.03<RSE>0.19$) showed that the importance of SOC is highly variable, depending on climate and land use. The ability of global models to provide insights on general trends and the ability of local models to differentiate specific regions in the world provides valuable information for natural resource assessments. Therefore, such global-scale assessments should rely on multi-scale analysis, including local-scale models with soil and landscape variability as drivers. This will be key for advancing soil and food security and develop more effective large-scale climate change mitigation strategies.
Keywords: Soil-landscape functioning, Ecosystem services, Global-scale assessments, Climate change
Financial support:

(5865 - 490) Explaining high carbon stocks in strongly weathered tropical soils

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Umbric ferralsols are highly weathered soils found in the tropical zone, and they contain nearly twice as much carbon (C) stock as other soils of the same order. We explore four scenarios for C accumulation in those ferralsols. Each scenario is evaluated by testing two competing hypotheses that carbon stocks in umbric ferralsols are either a function of C concentration or A-horizon thickness. A meta-analysis of 203 published datasets on ferralsol profiles from 30 countries across 3 continents is used to calculate C stocks in the A horizons based on values of C concentration, bulk density, rock fragment, and horizon thickness. Regression models are developed with carbon stock as the dependent variable and A-horizon thickness as well as C concentration as predictor variables. Our results show that umbric ferralsols have considerably thicker A-horizons (112±58cm average, n=50) than other common co-occurring (non-umbric) ferralsols (34±21cm average, n=153), $p<0.0001$. In contrast, C concentration did not vary between ferrasol types ($p=0.12$); thus, protection by the mineral matrix may not explain alone the differences in C stock. After considering multiple local and regional factors influencing C balance, including inputs and loss, we demonstrate that A-horizon development (i.e., thickness) exerts dominant control on ferralsol C stocks worldwide. The C input from deep fine roots and the rework of the topsoil by bioturbation and/or colluviation are likely to be the main causes for the greater thickness of the A-horizon in umbric ferralsols relative to adjacent ferralsols of similar age and parent material. Climatic variations along the Holocene led to changes in vegetation and therefore C inputs, in special at ecotone zones between savannas and rainforest.
Keywords: Carbon inputs; Thick A-horizon; Ferralsols; Oxisols; Mass movement
Financial support: CNPq - NATIONAL COUNCIL FOR SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT

(3866 - 1883) Field scale soil variability mapping to support precision agriculture

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The most limiting element of precision agriculture is the lack of soil information explaining the spatial variability of crop performance. Besides of the advanced knowledge in soil genesis and morphology, this work requires the understanding of surface genesis, geology, geomorphology and hydrology. This complex mapping and surveying knowledge is not common. That is why only indirect measurements, like electric conductivity mapping or NDVI are used for soil and crop characterization, but none of them explain the reason of heterogeneity. These data sources have to be correlated with soil and terrain features to make better use of them. This study presents an alternative approach to handle spatial soil variability by defining and explaining pilot fields representing different soil associations and defining the most important soil differences responsible for the different productivity and crop performance. Areas around the field with similar soil forming factors and similar soil associations can be delineated and the knowledge learnt from the large scale mapping can be applied for much larger areas. Four heterogeneous agricultural parcels have been selected for the study with different soil types and soil forming conditions. Approximately 100 soil profiles have been opened with the depths of 150 cm. All of these profiles have been described in the field and all soil morphological features, diagnostic features, horizons and materials have been recorded and interpreted in its spatial context. Profiles have been sampled by genetic horizons and chemical and particle size analysis have been performed. Lab data and field morphological characterization were interpreted together to understand and identify the soil forming processes and characteristics responsible for the spatial heterogeneity that needs to be understood for successful precision farming. GIS techniques integrating remotely sensed data together with RTK derived digital terrain model derivatives has been employed for better spatial characterization of the fields. The results clearly confirmed, that soil data is crucial for any precision farming support. Despite of the cost and time consuming nature of soil mapping, the interpretation of any seasonal crop performance data – like NDVI or yield map – can be interpreted with

higher reliability. Linking the pilots to larger zones can decrease the mapping cost and make soil properties better appreciated in the agricultural production system.
Keywords: Large scale mapping, DSM, Soil mapping, precision agriculture, soil spatial heterogeneity
Financial support: The research was carried out within the GINOP-2.3.2-15-2016- 00031 "Innovative solutions for sustainable groundwater resource management" project of the Faculty of Earth Science and Engineering of the University of Miskolc in the framework of the Széchenyi

(1288 - 2795) Historical and present dust deposition and its impacts on typical soils of east Eurasia

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Dust has been shown its impacts on soil development by many studies across the world. Many soils are developed directly on deposited dust such as loess, others may be affected by dust with different intensity and properties. How dust has changed soils and to what extent the changes are occurring remain an important topic for the understanding of soil development and soil functions in various ecosystems and regions. Typical areas in China including the tropical Hainan Island in the south, northeastern Qinghai-Tibet Plateau (QTP) in the northwest and Nanjing, a metropolis urban area in the east were studied, representing dust from natural and anthropogenic sources and different climate, vegetation and original soils. The current deposition rate in these sites differed fundamentally, due to dramatic changes in geographical and geological settings and monsoon environments, where QTP is mainly controlled by winter monsoon and westerlies while Hainan mainly by summer monsoon and Nanjing alternatively by both of them with seasonal changes. Our study shows that loess deposition in QTP controls the soils and soil development. Following the elevation gradient and accompanied environmental changes, secondary soil development processes vary fundamentally and determine soil properties and functions. Ongoing loess deposition is providing important soil base to this weathering-limited alpine environment. Current dry deposition in the Hainan Island is very low, however our study shows historical continental dust deposition had an effect on soil properties. This process is evidenced by Sr and Nd isotope shift of soils sequentially developed on basalt of different ages. Dust may similarly have provided mineral nutrients to this tropical ecosystem. As alternatively controlled by winter and summer monsoons, the urban area in the east China receives both naturally transported loess and anthropogenically produced industrial dust, as well as oceanic input. It is phenomenal that pollutants carried by dust of local and remote sources are accumulated in surface soil, showing the potential impacts of modern dust on soil quality. Considering the geographical extent and the rate of deposition, dust deposition has changing but important impacts on typical ecosystems in the east part of Eurasia continent. Actually often it may outdo weathering rate therefore more attention should be paid to this process, in order to understand the long-term services and sustainability of ecosystems.
Keywords: dust, soil development, soil functions, ecosystems, east Eurasia
Financial support: Supported by National Natural Science Foundation of China (grant no. 41571130051, 40625001, 41130530)

(4954 - 2543) Legacy soil maps from Brazil: organizing and providing layers in an interactive WebGIS

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Digital soil maps at appropriate scales are essential information for land use planning. Nevertheless, Brazilian soil information is scattered in several institutions and stored in several formats. In adition to that, this information have faced an interruption of its systematic soil survey program, providing difficult access to decision makers. In order to organize and safeguard the spatial data produced at the Brazilian Agricultural Research Corporation (Embrapa), a spatial data infrastructure was developed (IDE-Embrapa) where thematic collections related to soil have been gathered and published in a web environment. The objective of this work is to present the initiative of organizing the spatial data of Embrapa related to soil information through the development of the IDE-Embrapa. In order to achieve this goal, the spatial data that were stored in a previous geoinformation infrastructure developed by Embrapa Soils were shifted to the IDE-Embrapa infrastructure. The implementation of the IDE-Embrapa was performed using open source software, based on the Open Geospatial Consortium standards. The IDE-Embrapa infrastructure uses GeoNode platform, which integrates a geospatial database (PostGis) with a map server (GeoServer) and a metadata catalog (PyCSW), and is controlled by a Content Management System in the Web environment. Currently, 100 information layers and 60 documents were catalogued in the IDE-Embrapa Soils (geoinfo.cnps.embrapa.br). These data and metadata are already available for download. Maps represented by various territorial boundaries and scales were registered. The main maps of Embrapa Soils are already catalogued and are available to the user with their own color pattern (styling) for each type of thematic map, allowed by incorporation of a file with the styled layer descriptor (SLD) format to each map. Soil maps, for example, are presented with the colors established according to the Brazilian Soil Classification System, which facilitates users to visualize the spatial distribution of soils in a given region. Currently, the IDE-Embrapa infrastructure is making available the Brazilian soil information available to any external user. This work is under construction and we hope soon to have all maps prepared by Embrapa Soils catalogued and available, in order to safeguard data and metadata, for ready use of these by society.
Keywords: Geoinformation, Geoservices, Geodata
Financial support: Embrapa

(6037 - 2182) LORICA: a soil-landscape model to study dynamics of spatial changes in soils

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Over decadal and larger timescales, the geography of soils presents us with a moving target: soil properties and soil distribution change meaningfully because of geomorphic activity, human impacts and climate change. Although we are getting better at indicating how any one of these drivers affects individual soils, we have difficulties understanding how changes in multiple drivers will affect soil properties, and how this differs over landscape positions and time. Soil-landscape models (SLEMs) uniquely offer the opportunity to simulate these complex dynamics. Therefore, such models function as soil geography's virtual laboratories, where experiments can be performed and hypotheses can be tested. We briefly provide an overview of existing SLEMs before highlighting their capabilities and shortcomings using our own SLEM, LORICA. Our case study will focus

on the 35 square km Konza Prairie in Kansas in the United States, one of the last remaining tallgrass prairies. We illustrate the wide variety of field-observable outputs of SLEM LORICA by examining timeseries of geomorphic and pedologic activity, dynamic maps and landscape cross-sections of erosion, deposition and various soil properties, and the change over time in soil profiles at various locations in the landscape. Comparisons with data from 150 soil profiles in the landscape illustrate that with an informally calibrated parameter set, the model is able to simulate some of the main soil-landscape patterns - but differences between simulations and observations also support the formation of new hypotheses.

Keywords: soil-landscape evolution modelling, LORICA, Konza Prairie, tallgrass prairie, complexity

Financial support:

(5835 - 1188) Soil fertility and soil quality parameters on the different inhabited Galápagos Islands: natural variations and impacts of agricultural land use

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The Galápagos Islands have been formed by hotspot volcanism in the Pacific Ocean; the Nazca Plate is moving across the Galápagos hotspot at a speed of approx. 50 mm/a, which results in a chain of volcanic islands of increasing age with distance from the hotspot. The youngest land surfaces are <10 years old, while the oldest dated surface deposits exhibit ages >2 Ma. Additionally, the higher-standing islands show marked moisture gradients ranging from arid lowland areas to humid highland areas. Four of the Galápagos Islands are inhabited, and agriculture has been practiced for over a century in some areas. In this study, we examine the distribution of soil fertility / soil quality parameters in relation to the islands' distance from the hotspot (age proxy) and elevation (climate proxy), and compare intensively used agricultural areas to adjacent undisturbed National Park areas. The studied soils range from slightly weathered vitric and andic soils to highly weathered oxidic soils. We found decreasing soil pH, organic matter contents and available base cations (esp. Ca) with increasing time of soil formation across the islands. Conversely, soil aggregate stability and the availability of less mobile nutrients like Mn strongly increased with island age. Soil pH and available base cations decreased with increasing moisture on all the studied islands; however, available Mn increased with moisture on the youngest studied island (likely due to increased release from the young parent materials), while it decreased with increasing moisture on the oldest studied island (likely due to increased leaching). Our results from case studies on two of the islands show that intensive horticulture practiced for 1 to 2 decades has strongly altered the soils from their natural state. While the soils' physical condition (bulk density and aggregate stability) has been less affected, the levels of soil organic matter as well as major and minor nutrients have markedly decreased in the horticultural fields. On the other hand, exchangeable Na has built up due to irrigation with brackish water. Soil nitrate concentrations have strongly increased, while dissolved organic C and microbial biomass C have strongly decreased in response to intensive horticultural management. In summary, we encountered naturally contrasting soil conditions on the different inhabited Galápagos Islands and found evidence that intensive agricultural activities have impaired soil quality in this unique ecosystem.

Keywords: Galápagos, volcanic soils, weathering, nutrients, human land use

Financial support: Secretariat of Higher Education, Science, Technology and Innovation (SENESCYT), Ecuador: Prometeo Project

(3478 - 2210) Soil forming processes in recently dessicated lake sediments in the basin of Mexico.

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The lowest portions of the naturally closed basin of Mexico used to be covered by lakes 500 years ago, three of them were saline. Frequent floods during the rainy season have struggled the inhabitants of the basin of Mexico, and large efforts by building dams in pre-hispanic times, and by constructing artificial outflows between 1630 and 1976 have been undertaken to avoid them. All these actions have enhanced lake dessication. Based on historic maps we selected sites that have been exposed to soil development within the lacustrian plains in the northern part of the basin for different lengths of time. We show data of 6 soil profiles on an altitudinal gradient from 2235 to 2241 m asl in the former lacustrian plains. Soil profiles were described in detail in the field and sampled for physical-chemical analyses as well as for micromorphological descriptions. Additionally thin sections of the horizons of each soil profile were described in detail. Particular attention was paid to soil aggregation features, soil pores (biogenic and resulting from dessication-wetting cycles), precipitation of secondary carbonates, reductomorphic features, presence of slickensides and clay illuviation cutans. The lacustrian origin of the soils was evident by shell fragments and stratification features, but also inputs of volcanic materials could be identified and deposition materials accumulated at the upper horizons of the profiles of lowest altitude. The major observed soil formation processes include movement of soluble salts from the profile at highest altitude to the one at lowest altitude, but also within each soil profile. The pH increases together with the electric conductivity as major soluble salts are sodium chlorides and sodium carbonates. Precipitates of secondary carbonates were found, and biopores of several types, as well as reductomorphic features as manganese and iron nodules. The profile located at highest altitude, i.e. the one that has been subject to soil development for longer periods of time, shows in the upper soil horizons well developed granular aggregates and in the subsoil horizons dominantly blocky subangular to angular aggregates, large organic matter contents, many biopores and even clay illuviation cutans. We conclude that despite the young age of the studied soils (400 to 50 years), several features of pedogenic processes can be observed and a soil development gradient can be established according to the lake dessication history.

Keywords: chronosequence, soluble salts, exchange sodium, organic matter, aggregation

Financial support:

(2564 - 2403) Soil Geography of Polar Regions in Context of Global Soil Pattern

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Basic concept on the geography of Arctic and Antarctic soils was developed >40 years ago (Tedrow, 1977). During this period, the abundant information on both soils themselves and soil-forming factors was obtained. This information relevant to soil geography was analyzed and compared. It has been found out that the cold deserts of Antarctica are very specific and differ from other Arctic and Antarctic soil covers by extremely arid climatic conditions and the absence of liquid water. They differ from other polar landscapes also by the set of soil processes (nitrate salinization, rubefaction). All the other pedoregions of two high latitude macroregions have both common and specific features. Antarctic ones differ from their northern analogues by warmer winter and much colder summer, by

less fine earth and calcite and scarce, if any, vascular plants. The paradox is that in spite of such difference in soil-forming factors the sets of soils in Arctic and Antarctic, except cold deserts, are almost the same. Anyway, subpolar and polar soil landscapes of Arctic and Antarctic are not similar ones - they have essentially difference, especially in much larger discontinuity of soil cover in the latter. The common feature of High Arctic and Antarctic soil geography that they have no manifested soil zones but only "islands of pedosphere" in glaciers in Antarctic and in the ocean and glaciers in High Arctic. These fragments of soil cover don't depend on the latitude and macroclimate but mostly are controlled by local factors – topography, parent materials, wind direction, seas bird rookeries. Contrary to the rest parts of the globe this type of soil geography can be named as "insular (or patchy) type of soil distribution" (ITSD). Arctic as a whole has two soil zones "Low Arctic tundra and Mid Arctic tundra" and the northernmost High Arctic ITSD that should be named "tundra-barren". The Antarctic continent with adjacent islands has ITSD with different pedoregions "Subantarctic tundra - Low Antarctic tundra-barren - Mid Antarctic cryptogamic barren – High Antarctic and nunatak Cold desert".

Keywords: Antarctic, Arctic, cold deserts, tundra, barren, islands of pedosphere, soil zones, insular type of soil distribution

Financial support: Russian Science Foundation, Project No. 14-27-00133 (data processing) and Russian Foundation for Basic Research, Project No. 17-05-41157 RGO_a (general concept).

(9593 - 2046) Towards a Brazilian ground conductivity map for radiocommunication planning

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The utility of accurate soil attribute mapping lies far beyond agricultural and other environmental issues. Information on a single or a specific set of soil properties may play an important role on several other human life matters. Trends in digital soil mapping and proximal soil sensors may support current trends for application-oriented soil attribute maps, as for soil electrical conductivity influencing wave propagation coverage of electromagnetic waves applied in telecommunication systems. Radiocommunication planning for lower frequency bands (> 30 MHz) uses soil properties to calculate the prediction of ground wave attenuation. However, methods to estimate ground conductivity may consider limited information on related key soil properties due to difficulties performing field measurements in large areas, what impairs effective predictions of surface wave propagation. This study in progress involves a multidisciplinary ad hoc group on radio propagation, aiming to propose a Brazilian contribution to improve the World Atlas of Ground Conductivities as currently entitled by the International Telecommunication Union. This new approach to obtain improved ground conductivity information considers rule based generalization of geological and soil maps, plus single spoil attribute in-situ measurements. The available Brazilian soil map (1:5.000.000) was generalized into three major conductivity classes, merging morphological and biophysical environments of similar soil electrical conductivity related attributes (i.e.: sodicity, salinity, texture, cation exchange capacity, pH, and base saturation). Major environmental areas known for soil salinity issues were grouped into similar high conductivity ranges. Well-developed soils were assigned as low conductivity areas, where *Latossolos* (similar to well-drained Oxisols) and *Argissolos* (similar to Acrisols or Lixisols) are the prevailing classes representing 63% of the national territory. To validate a rule-based generalization of soil polygon classes, medium wave propagation measurement campaigns are being carried out conjointly with field electromagnetic sensors at soil profile locations from the Rio de Janeiro State soil survey. The preliminary ground conductivity map has yield 74% of the Brazilian territory as low, 20% as intermediate, and 6% as high electrical conductivity. This result has shown reasonable accuracy when compared with field measurements on soil electrical conductivity and wave propagation.

Keywords: Soil Electrical Conductivity; Wave Propagation; Proximal Soil Sensors

Financial support: Empresa Brasileira de Pesquisa Agropecuária (Embrapa); Agencia Nacional de Telecomunicações (ANATEL) - Radiodifusion Ad Hoc Group Project

C1.2.2 - Remote sensing applied to soil Science

(1419 - 2220) Assessing remote sensing data with spatial statistics in precision agriculture field experiments

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Unmanned aerial vehicles (UAVs) allow remote sensing of soils and plants in precision agriculture experiments at high temporal and spatial resolution. Basic UAVs come with RGB cameras which can be used for field scouting, digital elevation modeling, and biomass estimation. More elaborate UAVs can carry different payloads and allow the usage of complex camera systems like multi-spectral, hyper-spectral, or thermal cameras. The advantages of UAVs over satellite images include that UAV flights are always possible, cloud cover does not ruin an image, the image is not taken through the complete atmosphere, and drone images are taken at a higher resolution of about 10 by 10 cm instead of 30 by 30 m which are standard in satellite imagery. Today, it is possible to acquire remote sensing data on a daily basis and to assess agronomic treatments in field experiments. The high spatial resolution of drone imagery allows to use statistical methods which require a high number of measurements such as spectral analysis in the frequency domain. Spectral analysis is a great method not only to assess treatment effects but also to reveal other processes affecting the dependent variable. Co-spectral analysis can be used to identify how two independent variables, for instance, yield and NDVI, are related to each other on a spatial scale. We will present two years of remote sensing data captured with UAVs in soybeans, corn, and cotton. Experimental design of field trials optimized for spatial analysis in the frequency domain will be explained and results from the two year experiment will be shown. Our data set include vegetation indices, soil texture, soil water content, soil matric potential, soil electrical conductivity, stomata conductance, chlorophyl fluorescence, leaf area index, and yield.

Keywords: unmanned aerial vehicles, remote sensing, spatial statistics, precision agriculture, irrigation

Financial support: Alabama Farmers Federation

(8357 - 390) Data mining of the Landsat time series to build predictors for digital soil mapping

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The soil mapping is essential for land planning and management. The use of sattelite images can assist soil mapping due to the spectral features of soils. Although the sattelite images are suitable for mapping large domains of land, the soil surface generally appears as fragmented areas. Thus, the aim of this work was to describe a methodology to retrieve a continuous represenation of the soil surface, retrieved from satellite images, as well as to use the derived reflectance to map sand and clay contents. Due the fact that the soil surface is randomly exposed to satellites under cropping systems, bare soil areas were selected from different periods of the time by

using spectral indices. A processing system was built in R programming language to retrieve a continuous surface of soil by using the time-series of Landsat 5 Thematic Mapper (TM). Each piece of bare soil was combined to a single product called the synthetic soil image (SYSI). The pixels from SYSI contains the spectral reflectance equivalent to the Landsat 5 TM bands. The soil reflectance was calculated using the median statistic, providing a suitable representation of soil along the time series. To evaluate the applicability of the methodology, the processing system was applied to the São Paulo state, Brazil (25 Mha). Nearly 20 Tb of data was processed to retrieve the continuous representation of soils from the study area. The system included different modules of processing, such as data download, soil mask construction, mask application and soil surface mosaicking. The results showed that almost 90% of sugarcane areas (agriculture) of São Paulo state had its soil surface reflectance represented. The remaining areas, such as natural forests and water bodies, were not mapped during the 1984-2011 period of Landsat 5 mission. The surface reflectance of SYSI had a mean correlation of 80% with topsoil laboratory spectra (0-20 cm). The SYSI gave a better correlation with soil attributes than terrain attributes. Regarding the construction of soil spatial prediction functions for clay and sand mapping, the inclusion of SYSI bands as model predictors reduced the validation residuals at half, compared to the models that only used predictors derived from terrain. The methodology may also support sample allocation and soil unit delineations, reducing the costs of mapping. The synthetic soil image can assist the mapping of huge areas at finer scales.

Keywords: Remote Sensing; Soil Reflectance Spectroscopy; Satellite Image; Spectral Library; R Programming Language
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(9911 - 2304) Global soil mapping and monitoring from hyperspectral imagery: Science developments in support to upcoming EnMAP satellite mission

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Soil spectroscopy based on laboratory, field, and airborne data has been shown to be a proven method for the quantitative prediction of key soil surface properties in local areas when bare soils are exposed at the surface, surface conditions are appropriate, and ground data are available. With the upcoming launch of the next generation of hyperspectral satellite sensors, a great capability for the production of high quality maps of top-soil properties at regional and global scale is appearing. Nevertheless, the full capacity of imaging spectroscopy for soil mapping is not used nowadays due to limitations in data and software availability, in soil spectral modeling and availability of global ground databases for calibration/ validation. In particular, this presentation is focusing on three central questions that are at the forefront of research nowadays: a) methodological developments toward improved algorithms and operational tools for the extraction of soil properties over bare soil areas based on large-scale soil spectral libraries, b) influence of disturbing factors on the extraction and modeling of soil properties, c) demonstration of the potential and limitations of hyperspectral imagery for soil mapping and monitoring from airborne to spaceborne scale, linked with harmonization of soil spectral libraries. For this, in the frame of the science preparation program of the EnMAP satellite in Germany and supporting projects, digital soil mapping studies using airborne and simulated EnMAP imaging spectroscopy data from several test sites are used to demonstrate potential and limitations for the quantitative prediction of key top-soil properties such as soil organic carbon, clay and iron oxide content. Methodological developments will be shown related to the extension of current toolboxes and software for operational soil mapping (as in HYSOMA/ EnSOMAP) and to the potential of the EU-wide LUCAS soil spectral library for model calibration, related to the errors associated with the influence of green and dry vegetation cover on the soil properties prediction, and related to the assessment of the influence of different laboratory set-ups and instrumentation on the merging of soil spectral libraries. Overall, this paper demonstrates the high potential of upcoming hyperspectral satellite missions for global soil mapping and monitoring, although further developments in direction of soil spectral modeling and harmonization of global databases are needed.

Keywords: Hyperspectral top-soil properties soil spectroscopy
Financial support: The EnMAP science program is funded under the DLR Space Administration with resources from the German Federal Ministry of Economics and Energy (BMWi)

(8027 - 1619) Sentinel-2 for soil organic carbon retrieving and mapping in central Europe

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Soil Organic Carbon (SOC) is a useful representative of soil fertility and is an essential parameter in controlling the soil dynamics of various agrochemicals, therefore important parameter of agricultural soils, and need to be monitored. Satellite remote sensing is a well-suited technique for soil attributes monitoring in large areas at a high spatial and temporal interval. The recently-developed Sentinel-2 freely provides the possibility of useful and routine land observation with the combination of high resolution, novel spectral capabilities and wide coverage. Thus, this study examined the capability of Sentinel-2 in SOC monitoring and digital mapping in comparison to results obtained from airborne hyperspectral and lab spectroscopy over four agricultural sites in the Czech Republic. Soil samples were scanned with an ASD FieldSpec spectroradiometer in the laboratory. Hyperspectral data from CASI/SASI sensors were also acquired over the study areas. Smoothing, pre-processing, modelling, validation and final prediction performance assessment of the datasets were determined using Savitzky-Golay, 1st derivative, Support Vector Machine Regression (SVMR) and 5-fold cross-validation techniques. Two cloud-free Sentinel-2 images were atmospherically corrected, analysed using 13 extracted bands of Sentinel-2 and 18 spectral indices were calculated as covariates. Prediction models of soil attributes were created and validated, and finally spatial distribution maps of attributes were produced. The results showed that the prediction accuracy based on lab spectroscopy, CASI/SASI airborne and Sentinel-2 was adequate in the majority of the sites for SOC. Comparing the SOC maps derived from airborne and spaceborne datasets showed a relatively similar trend at both platforms. The SOC maps confirmed that in areas with high levels of SOC, Sentinel-2 was able to detect the SOC map even more precisely than airborne sensors. In general, Sentinel-2 showed a slight decrease of model performances compared to lab spectroscopy and airborne imagery, but it offers large spatial coverage and a more frequent revisit-time, which will considerably influence the obtaining of high-quality soil data.

Keywords: Agricultural soil; Sil organic carbon; Spectroscopy; Hyperspectral data; Superspectral sensor.
Financial support: Czech Science Foundation

(7741 - 2857) Soil Water Balance for South America as a Tool for Farmers: Comparison of the effects of different soil databases with remote sensing data

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Water and food are basic natural resources for life. Learning to manage these resources is one of the most important challenges of global changes. The most effective way to do this is to understand how the environmental physical processes that govern them work. Soil water balance is important to estimate, monitor, and predict the amount of water held in the soil, which is important for watershed's water balance and for crop production, determining the soil moisture uptake by the plant and crop transpiration. Thornthwaite and Mather water balance is a method to represent the water processes that occur in the soil's superficial layer. The required data are: precipitation, potential evapotranspiration, and soil water holding capacity (SWHC). Thus the main goal of this study was to perform and validate a soil water balance for the entire South America. Remote sensing advances are constantly improving the representation of soil's physical characteristics, which have a direct impact on the water budget. To develop the soil water balance, two different openly available soil databases were tested (from the World's Soil Information - ISRIC); (a) applying only the SWHC from the first horizon, from Batjes (2012), and (b) considering the SWHC data from all the soil horizons of a newer source: Batjes (2017). The results from the modeled soil water balance for South America were then compared with remote sensing data, for validation. The anomaly from the total water storage (TWS) measured by GRACE satellites was compared with the available water capacity (AWC) modeled using both soil databases. The model with the older soils database (a) had a limitation especially in the summer months because the soils were constantly saturated (AWC = SWHC) and, as consequence, there was a time-lag of about 3 months between AWC and TWS. However with the newer database (b) the response between AWC and TWS was faster and the correlation higher. The Pearson correlation coefficient between AWC and TWS went from -0.23 (a) to 0.73 (b) in average, only with the soil database change. These results show the importance of continuous improvement on soil data and characteristics and the impacts of them for the soil water balance and as decision support for agriculture. Meteorological forecasts are daily fed into the validated model providing soil water content into the decision support tool for farmers (AgroclimaPró - Climatempo).

Keywords: Soil water balance; South America; GRACE Satellite data; South American Watersheds; soil databases impact; decision support tool for farmers

Financial support:

(8733 - 2639) The use of aerial gamma-ray spectrometry to determine soil physical and soil chemical properties for soil mapping

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Soil maps are critical for various land use applications. Impact of digital soil mapping is to become prevalent in assisting soil scientists and experts to timeously create more accurate soil maps. Remote sensing techniques have been proven to be very useful in soil surveys to notably determine soil chemical and physical properties. In this study, we acquired airborne gamma-ray spectrometry data on board a light aircraft to map potassium (K), thorium (Th) and uranium (U) concentrations over a 100 ha piece of land, including pivots, next to the Vaal River (South Africa). Ground investigation was also conducted in the form of: (i) soil samples analysis (including pH, EC, %C, exchangeable K, silt and clay %) and; (ii) using a portable XRF instrument to determine ground concentrations of K, Th and U. The soil survey ground investigation revealed two distinct soil types/bodies in the study area. Both soil bodies display differences in soil texture and mineralogy attributable to their respective parent material. Along the river the parent material is alluvium with an average silt and clay content of 28%. Further away from the river the soil is deep eolian sand with less than 10% silt and clay content. The airborne gamma-ray data image the dichotomy of the two soil units. Higher levels of K and Th correlate with the more silt and clay in the alluvial soil. In contrast, deep eolian sand is characterised by higher U with low K and Th concentrations. Soil chemical properties, including pH, EC, %C and exchangeable K were also compared to the airborne gamma-ray data. No significant relationship was identified because the gamma-ray data either does not relate to similar soil physical parameters and/or relate more to the solid mineral component of soil. Results obtained with the portable XRF instrument on the ground was also used to map concentrations of soil K, Th and U. No direct correlation could be established with the airborne gamma-ray data which is likely the result of disparity of the data sampling specifications. This study shows that airborne gamma-ray spectrometry data acquired on board light aircraft can be efficient for rapid and affordable soil zoning. Quantification of silt and clay % extrapolated from the airborne gamma-ray data also favourably compare to ground measurement. Finally, it might appears also possible to use airborne gamma-ray data to determine the plant available K but this will however requires additional research.

Keywords: remote sensing, airborne, gamma-ray spectrometry, soil properties, XRF.

Financial support: North-West University, GyroLAG.

C1.3 - Soil Genesis

C1.3.1 - Soil-forming processes and their transformation under human impact

(6536 - 2791) Are Plinthosols properties and evolution influenced by prolonged flooding?

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Plinthosols cover about 60 million hectares of the intertropical belt. Their formation is often controlled by seasonal water table fluctuations in which the soils suffer the effects of flooding and saturation during the rainy season and free drainage in the dry season. Overall, wet and anoxic conditions favour dissolution whereas dry and oxic conditions favour precipitation of chemical species. Seasonal conditions may lead to formation of iron, manganese and aluminum-rich plinthite nodules and geochemical mobility of elements. Thus seasonality is key to understand Plinthosols genesis and evolution. Changes in hydrological conditions through time due to natural or anthropogenic processes may have led to prolonged flooding however, the effect of prolonged flooding on Plinthosols evolution is still an open question. Hypothetically, prolonged flooding can cause substantial changes in soil properties such as geochemical composition, mineralogy and soil morphology. This study aimed at investigating the effects of prolonged flooding on Plinthosols properties and evolution. Soil profile pits were dug in Plinthosols under natural conditions and flood irrigation for 10 and 20 years located in the district of Luiz Alves do Araguaia, Central Brazil. Soil samples were collected at each horizon. Determination of soil properties, which included micromorphological analysis in thin sections and chemical speciation studies, were performed in laboratory by routine chemical analysis techniques, optical

microscope and synchrotron radiation X-ray fluorescence spectroscopy. We found strong changes in the mobility of chemical species and soil fabric features when comparing Plinthosols under natural and prolonged flooding conditions. A trend of increasing mobility of chemical species and reorganizing soil fabric features was observed for Plinthosols upon prolonged flooding. Comparison between soils under natural and longest flooding conditions suggests transformation of Plinthosols to Gleysols upon prolonged flooding. This novel result indicates Plinthosols can be destroyed and transformed to other soil class in a relatively short time depending on the hydrological conditions found at the field scale. As observed in this study, evolution of Plinthosols may have changed world widely as prolonged flooding by anthropogenic processes is quite common in recent times.

Keywords: plinthosols, flooding, geochemistry, micromorphology
Financial support: São Paulo Research Foundation - FAPESP - project n. 2016/01270

(3355 - 457) Biogeochemical cycling of silicon and its roles on soil genesis and evolution in a typical subtropical ecosystem

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Biogeochemical cycling of silicon (Si) influences the processes of weathering, leaching, plant uptake and transformation. However, the roles and contributions of Si translocation and transformation on soil genesis and evolution in subtropical areas with ample weatherable silicates is largely unknown. A typical forested watershed (F) and two forest-agriculture watersheds (FA1 and FA2) located in southern Anhui Province, subtropical China were selected to study Si cycling and soil evolution. The main crop was rice (FA1, 18%; FA2, 24%) and the main forest species were pine, fir, chestnut, bamboo, shrubs and grass. The main soil types are Lithic Udorthents, Lithic Dystrudepts and Typic Epiaquepts derived from granite. The rock and soil physical, chemical and mineralogical characteristics were measured. Si and base cations cycling amount among rock, soil, plant, water and atmosphere were determined. The stoichiometric relations between Si, base cations and H^+ could provide a solution to estimate more accurately soil acid acidification rates. Based on this, the estimated soil acidification caused by cation exchange was only about half of the net input of protons, which was substantially lower than the previous results obtained with no distinction between H^+ consuming pathways. Compared to base cations, the concentration and flux of Si in the stream water could indicate more exactly the mineral weathering and soil formation rates because above half of base cations in the stream water came from base cation exchange of soil colloid. High Si uptake by plant significantly increased the mineral weathering and soil formation rates. Therefore, the weathering and soil formation rates estimated from net output by stream without consideration of the effects of plant would be greatly underestimated. Plant growth was very important to Si cycling, not only increased the primary mineral weathering, but also redistributed Si in the soil profile and enriched Si in the surface soil. Plant species greatly affect the amount of Si cycling and phytolith-Si concentrations in soil. High Si accumulators could assimilate and return more Si than low accumulators, and also enrich more biological Si in the surface soil.

Keywords: Si translocation; soil genesis and evolution; soil formation; soil acidification; soil desilification; silicate weathering
Financial support: This study was financially supported by the National Natural Science Foundation of China (No. 41471176; 41571130051).

(2245 - 568) Changes of soil aggregate stability on soil formation process at glacial till

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Soil is the basics of all agricultural production and therefore a valuable resource. The differences among land use for soil can be either positive, by increased aggregation and carbon sequestration, or negative with soil degradation. Especially water-stable aggregate stability (WSA) has been seen as a soil quality evaluation parameter with increasing importance, because of its influence to other soil physical and chemical properties. Considering that, many less visible changes tend to accumulate over time and eventually become visible, long-term experiments are essential for evaluation of a sustainable soil use. In severely eroded soils the long-term aggregation process in Baltic pedo-climatic region has been particularly poorly studied. Therefore, this study was conducted to examine the process in this geographic region. The long-term pedogenesis experiment on was established in 1964 in Estonia, Tartu. The original soil was replaced up to 1 m depth with organic free sandy loam glacial till, which was excavated near-by from 3 m depth. This study focused in the years of 1966, 2000, 2007 and 2014. The main focus was on WSA of 0.25–1.00 mm soil fraction, which was determined by Eijkelkamp's device "model: 08.13". The results revealed that: (i) WSA had a high variability at different sampling periods; (ii) SOC in bare fallow treatment increased, especially compared with initial till; (iii) WSA/SOC had a high and statistically significant correlation (r = 0.66), although a nonlinear WSA/SOC relation occurred with a clear saturation point; (iv) phosphorous (40 kg ha^{-1} yr^{-1}) and potassium (75 kg ha^{-1} yr^{-1}) fertilization on perennial grass treatment resulted, both a lower WSA and SOC content than on treatments without any fertilization or with additional nitrogen (150 kg ha^{-1} yr^{-1}) fertilization; (v) pure perennial grass treatment and treatment with white clover and perennial grass mixture had similar SOC and total nitrogen content, although different WSA in favor of pure perennial grass treatment; (vi) during period of 1965–2015, the air temperature and precipitation both steadily increased, by 2.1°C and 170 mm, respectively. Therefore based on this study, the growth of perennial grasses did accelerate the soil formation process. Although legumes not always had the highest WSA they still directly contributed into increased soil fertility and indirectly into the ecosystem as in whole as being pollination source for insects.

Keywords: aggregate stability, soil formation, soil organic carbon
Financial support: This study was supported by the H2020 project iSQAPER-635750.

(5969 - 859) Evolution of soil redistribution rates in alpine soils of the Central Rocky Mountains using fallout radionuclides ($^{239+240}Pu$) and stable isotopes ($d^{13}C$)

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Soil chronosequences have been widely used to quantify soil formation and weathering rates, but little attention has been paid to determine soil redistribution rates (erosion and deposition) and the stabilisation of moraines over time. We therefore selected a sequence of moraines in the Wind River Range (WRR-Central Rocky Mountains) to study these processes over time. Moraine ages were based on ^{10}Be surface exposure dating of moraine boulders. Quantitative soil

redistribution rates along slopes with similar exposures, lengths and dips were determined from profile patterns of $^{239+240}Pu$ radionuclides. We used stable carbon isotopes ($d^{13}C$) in relation with the total soil organic carbon content for qualitative information about soil disturbance. The ^{10}Be boulder exposure ages revealed that the moraines were deposited during the Younger and Oldest Dryas cooling events of the late Pleistocene. Soil morphological and physical characteristics show increasing development with time. However, some soil characteristics, such as rock fragment, sand fractions and silt content, suggest that a complex history of soil development, where progressive and regressive pathways have taken place. The morphology of the soils shows that both erosion and aeolian deposition have affected them. Bioturbation and dust influx is increasingly evident with increasing soil age, as evidenced by the comparison of $d^{13}C$ and SOC. The $^{240}Pu/^{239}Pu$ atom ratio (0.15 ± 0.02) in the top 5 cm of soil is slightly lower than that of global fallout (0.18 ± 0.014) and indicates a minor contribution from tropospheric debris from the Nevada Test Site. The $^{239+240}Pu$ measurements revealed that erosion rates strongly decrease with time as soils develop. A weakly developed soil (Cambisol) is found on the youngest moraine (11.8 ka) that exhibits an erosion rate in the range of 260 to 520 t km^{-2} a^{-1}. With time the erosion rate decreases to almost zero, as a full vegetation cover (tundra) develops. The most developed soil (Podzol) is found on the oldest moraine (15.8 ka) and shows a slightly positive mass balance between 31 and 48 t km^{-2} a^{-1}. This positive mass balance indicates that the slopes have reached a geomorphic stability with little net erosion. Measured rates of modern dust deposition in the western slope of the WRR agree well with the measured accumulation rates at the oldest moraine site. Consequently, aeolian influx appears to be the primary factor to account for mass changes in the older soil.

Keywords: Slope stability, Pu isotopes, carbon isotopes, soil chronosequence, Late Pleistocene, Wind River Range.
Financial support: Swiss Government Excellence Scholarship (2016.0646/Brazil/OP) and Foundation for Research in Science and the Humanities at the University of Zurich (grant number STWF-17-025).

(3692 - 2034) Mount Cameroon (Central Africa): a unique observatory for assessing the influence of time, precipitation and temperature on pedogenic processes in volcanic parent material

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Andosols are volcanic soils with exceptionally high nutrient and SOM contents. Thus, knowledge on the development of these soils as influenced by the different soil-forming factors is particularly relevant. We investigated the suitability of Mount Cameroon (SW Cameroon) for assessing the influence of time, mean annual precipitation (MAP) and temperature (MAT) on pedogenesis in volcanic materials. We hypothesised that the uniform mineralogical composition of the basaltic lava of Mount Cameroon, its numerous Holocene lava flows of different ages, and its special climatic setting, characterised by a vertical MAT gradient (0-29 °C) and a horizontal MAP gradient (2,000->9,000 mm), should allow for a systematic analysis of the influence of these factors. We selected eight soil profiles on lava flows of varying ages (54 years to several millennia) under contrasting MAP (2,000-2,400 mm versus 8,000 mm) and MAT (26-29 °C versus 8 °C). These profiles were compared with respect to (1) clay formation (clay/silt ratios); (2) formation of pedogenic Fe oxides (Fe_d/Fe_t); (3) silicate weathering and leaching of released elements (WI_{MER} = weathering index based on the molar element ratio (Ca+Mg+K+Na)/Al); (4) desilification (Si/Al). We plotted the maximum values of those data that increase with pedogenesis (e.g., Fe_d/Fe_t) and minimum values of data that decrease with pedogenesis (e.g., WI_{MER}) of each profile against time for assessing the influence of time. The influence of precipitation was assessed by comparing soils of similar age under contrasting MAP. Clay formation proceeded with soil age. High MAP seemed to enhance clay formation, but differences in clay contents became measurable only after >100 years. Increase in Fe_d/Fe_t ratios and decreases in WI_{MER} and Si/Al ratios over time were identified. No response of Fe_d/Fe_t ratios to MAP was observed, whereas there seemed to be a response of WI_{MER} and Si/Al ratios to MAP, suggesting that increased MAP leads to enhanced leaching of Ca, Mg, K, Na and Si. None of the indices showed an effect of temperature. The detection of such effect would require the investigation of soils along a MAT gradient with constant soil age and MAP. Such investigation is possible on the SE slope of Mount Cameroon, where MAP along the MAT gradient is within the range 2,000-3,000 mm. We conclude that Mount Cameroon provides a unique natural observatory for disentangling the influence of time, precipitation and temperature on soil-forming processes.

Keywords: Andosols, pedogenesis, soil age, temperature gradient, precipitation gradient
Financial support:

(3490 - 699) Spatial and temporal variability of soils formed on varved clays (Northwest Russia)

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The aim of this paper is to consider the spatial and temporal dynamics and evolution of Stagnosols formed on varved clay sediments of glaciolacustrine planes (10-60 m above sea level) in Northwest Russia, in proximal zone of Valdaian (Weichselian) glaciation. This paper is based on the results of soil mapping and 5-years monitoring of the soils properties. The studied territory refers to the zone of boreal and mixed forest with humid continental climate. The spatial and temporal variability of the soils was caused not only by current pedogenic processes, but it also depends on the history of the landscape. The temperature conditions are proved to be the controlling factor in the long-term cycles of soil variability. Paleogeographic analysis showed that soils on varved clays are the youngest soils in the region and that age of soils increases from the northern to the southern parts of the region. The studied soils are polygenetic, with relict features inherited from past stages of pedogenesis, such as network of large cracks, evidences of cryoturbation and solifluction, a significant amount of exchangeable Mg, and in some cases - presence of gypsum and argillization in the medium part of the profile. The current pedogenetic processes caused the development of stagnic properties and humus accumulation. The soils in mesocatenas of different plains are similar in eluvial position and different in accumulative (hydromorphic) ones. Within the catenas, an increase of stagnic and decrease of eluvial processes, an increase of litter, of humus horizon thickness, and of humus content had been observed down the slope of the terrain. The natural soil evolution during the Holocene tends to intensification of current profile-forming processes, thus to furthering the development of a given soil type. Under extremely high precipitation, the trend of soil evolution will be directed towards Histosols formation. Retisols develop in cases of increased drainage. The trend of soil evolution under agricultural impact is directed towards increasing of accumulative processes and to erasing of natural horizons boundaries. Automorphic soils are formed. These processes resulted in Retisols or Anthrosols formation. The soil cover of arable area develops towards decreased complexity and differentiation, and to increased area of soil polygons and the proportion of large polygons.

Keywords: varved clays, soil dynamics, soil evolution

Financial support:

(5347 - 503) Variants of genesis of soil cover pattern with gilgai topography in Russia

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Clay shrink-swell soils with gilgai topography occur at 8 regions of the East-European Plain in Russia. Total area of these soils is about 53 thousands ha. There are different types of microrelief: normal, lattice gilgai according to Hallsworth et al. (1955); or three kinds nuram gilgai according to Paton (1974), and particular kind in floodplain – alluvial lattice-wavy dendritic gilgai with one or several shallow channels for the discharge of flood water. Different variants of soil cover pattern at the area with gilgai topography exist. They can be classified by two criteria: (1) conjugation of soil components at microlow and microhigh in gilgai catena; (2) vertical-lateral differentiation of soil properties in gilgai catena. There are three main groups of soil conjugation in gilgai: (1) Vertisols at all elements of microrelief; (2) Vertic soil at the microlow -> Vertisol at the microhigh; (3) Vertic soils at all elements of microrelief. Vertic soils occurred in gilgai are Vertic Solonetz, Vertic Stagnosols, Vertic Phaeozems. Vertical-lateral differentiation of soil properties is formed by different combinations of soil-forming processes such as: shrinking and swelling; inner lateral plastic movement of soil mass of the middle and bottom horizons under from microlow position to the surface of microhigh; movement of water and solids along the surface from microhigh to microlow; solonetzic process; eluviation phenomena; seasonal changes of redox conditions; migration and accumulation of soluble salts; leaching and accumulation of carbonates; accumulation of organic matter and gypsum. As a result there are thirteen variants of genesis of soil cover pattern with gilgai topography in Russia.

Keywords: soil-forming processes, Vertisols, Vertic Solonetz, gilgai
Financial support: Russian Foundation for Basic Research, project no. 14-04-01694, 17-04-00555

C1.3.2 - Soil pedogenesis and diversity in extreme environments

(2570 - 470) Pharacterization and classification of soils in a topossequence under sandstone in Manicoré, south Amazon

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The Amazonian biome attracts a great deal of attention from researchers considering its high and rich biodiversity. With regard to the soils, in the Amazon predominate the Latosols and Argisols that present high degree of weathering, high levels of aluminum and low capacity of cation exchange. Nevertheless, detailed studies on the soil characteristics of these environments are important both for the use and protection of these sites. In this way the objective of this work was to characterize and classify soils in a toposequence under sandstone in Manicoré, AM. The study was located at km 150 on the Tin Road which connects to BR 230 in the municipality of Manicoré-AM. A walk was made from the spike of the slope and in the different compartments of the landscape open trenches, and morphologically characterize the soils and collected samples by horizon, after the samples collected, these followed to be dried in the shade and then discharged to be carried out the physical and chemical analyzes. After these steps the soils were classified according to SiBCS. Five environments were characterized: a) top with presence of low / dense thick vegetation, with dystrophic Haplic Cambisol; b) upper third with low / dense thick, with Neosol Regolitic dystrophic léptico; c) lower third with low thick and presence of Quartzarênicos Hydromorphic espodossólico; d) environment of transport foothills with cerradão and Plintossolos. e) deposition foothills with forest and presence of Argisol. The studied soils had color in the 10YR shade for all the profiles in the different environments, highlighting the profile of the environment of the transport foothill that presented 2,5YR 3/6 and 5/8 color mottles from its 70cm depth. The environments studied had similar characteristics inherited from the source material with the predominance of the sand fraction. There was presence of pebbles and gravel in the environments with highlight to the lower third presenting in all its profile after 18 cm of depth, this material in the form of plintite and petroplintite. The soils presented in all the environments presented high acidity, low saturation by bases and saturation by aluminum ranging from 59 to 82%. Thus, it can be inferred that the environments suffered a strong influence of the original material presenting few developed soils with their characteristics being modified from their position in the landscape.

Keywords: Solos Amazônicos; Atributos do Solo; Taxonomia de Solos.
Financial support: Foundation for Research Support in Amazonas (FAPEAM), National Council for Scientific and Technological Development (CNPq).

(2262 - 1149) Deserts—Pedogenesis and Life in Areas with Little Water

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Deserts occur on every continent and throughout geologic time. Deserts are important carbon reservoirs, dust sources, grazing habitat, and places with wildland and aesthetic value. These arid zones are also the environment where early human civilizations arose across the world. Having “non-flushing” soil profiles is the dominant phenomenon that produces pedogenic features unique to desert soils, such as the accumulation of soluble salts, gypsum, and carbonates. Biocrusts are another important factor affecting aridland pedogenesis. These lifeforms not only fix nitrogen, influence runoff, and protect soils from wind erosion, they can also play a role in biomineralization of carbonate. Studies of desert pedogenesis are giving us a better understanding of fundamental biotic/abiotic interactions on Earth and can deepen our knowledge of deserts on other planets like Mars.

Keywords: Pedogenesis, deserts, biocrusts
Financial support:

(9051 - 933) Differential soil genesis and geochemical composition in a serpentinite outcrop under tropical humid climate in Minas Gerais, Brazil

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Ultramafic rocks are rich in easily-weatherable silicate minerals, and thus their outcrops, although rare, offer a unique chance to study soil genesis. We studied 8 soils formed on a serpentinite, in Souls Hill (Morro das Almas), an outcrop of 3.3 km^2 marked by >50% of the area covered by boulders of fresh and partially weathered rock. The SW, S, and NE slopes are very steep (30-100%), currently carved as a canyon by the Deaths River (Rio das Mortes), and covered by rainforests. The W and NW slopes, as well as the summit, are less steep (<15%) and covered by Cerrado savannas, whereas the piedmont comprises <20% slopes covered by semi-deciduous forests. Therefore, aspect and slope appear to be the strongest controls on soil genesis and vegetation development. All soils had in common fine granular structure, high particle density (up to 3.8 g cm^{-3}), high Ni (up to 9.5 g

kg^{-1}), Cr (up to 10% Cr_2O_3) and Fe (14-67% Fe_2O_3) total contents, as well as most of the gravel and sand fractions comprised by serpentinite saprolite covered by dark Fe oxides, or Fe concretions. In addition, nearly all soils and horizons showed excess Mg over Ca, low exchangeable Al and thus high base saturation, low P, and organic C > 2% in A horizons. However, the soils varied considerably in other properties due to relief and vegetation effects. The soils on summit, S and NE slopes are shallow (6-30 cm deep), boulder-rich Entisols, whereas Oxisols and Inceptisols (>2 m thick) occur in the other slopes. X-ray fluorescence showed that four soils showed total MgO contents of 5-12%, suggesting that a considerable amount of serpentine remains, whereas the other soils showed null MgO, i.e. full dissolution of this and other Mg-bearing minerals under the tropical humid climate, thus accumulating Fe as hematite. Scattered through the area, phenocrysts of asbestos, talc, magnetite and coarse obsidian occur as associates to serpentine. X-ray fluorescence also shows that the Oxisols show high levels of hazardous trace metals such as Bi (12-222 mg kg^{-1}), Co (100-4,000 mg kg^{-1}), Pb (46-300 mg kg^{-1}), which are probably derived from decomposition of magnetite. Also, V is a common component, reaching 112-680 mg kg^{-1}. Further research is currently describing trace metal availability and soil mineralogy, but our data thus far has shown that restrictions to plant and fauna activity in the study area are generally less serious that commonly reported for serpentinite outcrops under temperate climate.

Keywords: Soil geochemistry, ultramafic rocks, heavy metals
Financial support: CNPq

(3502 - 721) Extreme soils of humid high mountains, caused by different factors

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Humid high mountains should be recognized to be a very peculiar environment for soil development due to the extreme climatic conditions (very high precipitation, which exceeds evapotranspiration in all months), predominance of stony material with low content of fine earth and extreme intensity of exogenic processes (erosion-accumulation). As a result, in those environments there should be met soils that can be described as 'extreme soils'. Studies based both on own data (case studies from mountain ranges of Central Europe: Tatra, Sudetes, Pieniny, Bieszczady Mts.) and literature data (Alps, mountain ranges of North America, Himalaya) were done. They confirmed the extreme character of soils and soil covers of humid high mountains expressed in following features: Humid and (in relation to the surroundings) cold climate together with a very low content of fine earth in parent material affects the formation of a specific, unobserved in other places forms of soil organic matter. Both organic horizons and humus soil horizons have, in many cases, extreme thickness and high content of non-humified organic remnants. The other factor contributing to the extreme nature of soils in humid high mountains is a unique parent material: a coarse stony material containing < 20% (by volume) fine-earth often found there. This parent material predetermines the pathways of pedogenesis and causes the occurrence of extreme and unique habitats impoverishing vegetation and thus pedogenesis. Furthermore, the extreme nature of soils is shaped by the active processes of the spatial redistribution of solid phase material. The typical high-energy mountainous relief causes the intense erosion that lead to fragmentation of the soil cover. Soils of various ages and with different state of development coexist close to each other in humid high mountains. Extreme soils of humid high mountains are therefore diverse, while the soil cover is extremely heterogeneous. The research of extreme soils of humid high mountains is a challenge, because some processes (e.g. mechanical movement of soil particles along soil profile and rapid transport of soil solutions in soils with low content of fine-earth fractions) not occur at all in other soils. These soils are simply rarely investigated due to occurrence in hardly-available sites. In addition their classification is difficult.

Keywords: High mountains, Extreme soils, Exogenic processes
Financial support:

(4519 - 1244) Patches of life in the Atacama Desert – heterogeneity analyses of soil organic carbon

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The Atacama Desert in northern Chile is considered the oldest and by far the driest desert on earth, nevertheless traces of establishment of life and soil formation have been observed at several places in it (Quade et al., 2007, Valdivia-Silva et al., 2012, Fletcher et al., 2012). Patchy occurrence of organic matter in the Atacama desert topsoil has been suggested in earlier studies (Valdivia-Silva et al., 2012, Fletcher et al., 2012). Furthermore, depending on intensity of the aridity other differences in soil properties (e.g. soil carbonates content) has been observed (Quade et al., 2007). We hypothesized that increased aridity leads to both a reduction and increased patchiness of organic carbon (OC) in desert soil surface. In the present study, we therefore analyzed surface soil OC, together with vegetation abundance and diversity along two W-E tending aridity gradients (close to Paposo and Arica, respectively) in the northern and southern Atacama Desert as well as gradients of OC between single plants. Within each aridity gradient (spanning 20 to 50 km) we compare 12 individual altitudinal based sites. At each sampling site 6 nested samples were taken in triplicate (n=3x6) to account for heterogeneities in soil OC distribution. Statistical analyses (multiple linear regression) were used to evaluate relationships between soil OC heterogeneity and aridity, elevation, exposition, vegetation cover and diversity. For the Paposo transect, OC decreased exponentially within the first 5 km of the gradients from 110.7 ± 130.4 g kg^{-1} OC for arid sites (n=3) to 5.7 ± 3,2 g kg^{-1} for hyper-arid sites (n=9), in parallel with vegetation cover. In addition, we found patches of soil organic carbon accumulation around single plants at sites where vegetation cover was thin, revealing OC gradients of 74.4 g kg^{-1} to 38.2 g kg^{-1} on the cm-scale. This patchiness seems to be typical for soil formation in arid environments.

Keywords: soil organic carbon, vegetation diversity, patches, arid soils
Financial support: German Research Council, CRC1211 "Earth evolution at the dry limit"

(8249 - 1473) Pedogenesis in extreme environments: implications for understanding soil covers of the present and the past

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Environmental conditions that occur in High Arctic, Antarctic, high mountains, deserts, on toxic and poor substrates, and under strong anthropogenic activity are conventionally considered to be extreme for biota and soil development. Although such conditions could be found on nearly one-third of the present-day land surface most of the soil genesis and geography concepts were originally developed for other habitats considered to be non-extreme. There is an emerging understanding of large variety of soils and soil-like bodies (soloids) formed in extreme environments, but soil science is still challenged to develop adequate approaches to explain their genesis and distribution. Here we present a new "extreme pedogenesis" (soil formation in extreme conditions) concept that describes establishment,

functioning and evolution of soils and soloids in extreme environment on Earth and exoplanets both under the deficit of resources (mass and energy), and under its excess. Spatial and temporal synthesis of the data revealed the following types of soil extremity: (1) factor extremity associated with extremes of soil-forming conditions; (2) regime-functional extremity associated with the extreme conditions in a certain period (season, year) at a specific area, first of all, weather conditions; (3) chorological (out of area) extremity associated with the emergence of soils in a soil cover of a certain region, which are usually typical for other areas with a different climate. We illustrate the concept with multiple data on: climatically extreme soils (lack of heat at high latitudes or moisture in arid regions, sharp hydrothermal fluctuations); topo-extreme soils (non-favorable topography for soil development, e.g. sheer cliffs, caves, etc); bio-extreme or biota-limited soils (under rootless vegetation or even without photoautotrophs); litho-extreme soils (toxic rocks or parent material extremely poor in nutrients and/or with extremely unfavorable physical properties); hydro-extreme soils (soils under saline and shallow fresh waters); anthropo-extreme soils (heavily modified or formed under human activities, e.g. soils on cultural layers, wastes). We also demonstrate that endolithic and hypolithic soloids of cyanobacterial origin provide one of the best contemporary models for understanding emergence of pedogenic processes in the Precambrian, and expand our knowledge on organo-mineral interactions and the first soil covers on Earth.

Keywords: extreme environments, Antarctic, Arctic, deserts, endolith, soil-like body, deficit and excess of resources

Financial support: Russian Science Foundation, Project No. 14-27-00133 (data processing) and Russian Foundation for Basic Research, Project No. 16-04-01776 (study of endolithic systems)

C1.3.3 - Anthrosols - the human constructed soils

(6723 - 1137) Anthrosols of ancient agricultural terraces in mountainous Dagestan (Eastern Caucasus, Russia)

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The Eastern Caucasus is one of the world centers of terraced arable farming. Most of the terraces are located in the mountainous zone of Dagestan. We carry out an interdisciplinary study of ancient agricultural terraces of mountainous Dagestan. With the help of GIS technologies, aerial and satellite imagery of terraced fields was decoded, terraced areas were established, and main types of terraces were identified. It was established that at altitudes of 400-2400 m in Dagestan there are more than 1500 square kilometers of terraced fields. The earlier first terraces in the region can be correlated with the Middle Bronze Age. The largest scale of terraced farming reached the Early Medieval Age, when in the conditions of demographic explosion, plots on slopes up to 60 degrees were terraced. At the same time, the building retaining walls in the terraces and artificial creation of a fertile layer widely spread. The terracing of the slopes caused a sharp change in the soil properties. When terracing slopes, the accumulation of fine earth on the surface of the terraces begins, and the growth of the soil profile and the formation of a system of buried horizons occurs. Therefore, the soil of agricultural terraces in the mountain zone can be regarded as an archive of paleoecological data. This is especially important for the mountain zone, where there are no other sources of paleoecological information. When terracing the slopes, the soil-forming rock material is annually involved in the arable horizon. As a result, the total volume of soil increases significantly. According to our calculations, in less than 1000 years of plowing the terraces on clay slates, the total volume of soil on the slope has doubled. On terraces, where the soil-forming rocks are limestones, this value is about half the size. Uniform distribution of stones up to 5 cm is a characteristic feature of the anthrosols of agricultural terraces in the mountainous zone. When plowing, pieces of sandstone and limestone of different sizes fall into the plow layer. Large stones interfere with plowing and they have been removed from the soil, while small stones are evenly distributed throughout the plowing layer after numerous plowing. As a result of many years of fertilizing, the athrosols of terraces contain large amounts of phosphorus, high urease activity and abundance of thermophilic microorganisms that fell into the

Keywords: Caucasus, agriculture, terraces, anthrosols, Bronze Age
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(9248 - 1639) Caatinga dark earths

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South America was populated from multiple waves of dispersion from northeast Asia throughout the late Pleistocene and early Holocene. Anthropic occupation in Caatinga is dated from 20,000 BP. Besides that, there is no register of ancient activities in soils of Caatinga biome. The hypothesis of the study is that ancient anthropic activities were installed and promoted favorable contrasting physic-chemical characteristics compared to typical soils in Caatinga biome. Three pedons were taken, described and classified according to World Reference Base soil classification system in sites of high number of artifacts littering the surface and, or, paintings in roof of caves. Texture, soil reaction and cation exchangeable capacity were determined following procedures established to tropical soils. Soils are shallow and transition between horizons was predominantly clear or abrupt, indicating that the parent material is low weathered and low bioturbed. Value and chroma are similar to antropic horizon described in previous studies. Loamic or coarser texture of shallow caatinga soils favors lessivage of organic compounds and melanization of all pedon. The pedons are strongly acid to slightly alkaline and have base saturation (V) above 50 % in all horizons. The Mehlich-1 extractable P content in the upper horizon ranged from 299.1 mg dm^{-3} ('Antropic' Typic Ustothents, which presented postsherd and human bones) to 6,445.6 mg dm^{-3} ('Antropic' Lithic Ustorthents, which presented postsherd, ash and human bones). The C content in the upper horizon ranged between 0.47 % and 15.94 %. In the 10–50 cm increment, the C concentrations ranged from 0.31 % to 2.95 %. Caatinga dark earths exhibit until three and 658 times, respectively, more soil organic carbon and phosphorus compared to adjacent soils. The three soil profiles presented all requirements to be classified as Anthroposols, except by the thickness below 50 cm. These results may support the updating of criteria for pretic horizon on the World Reference Base for Soil Resources, as well to extend to the current debate of human soil formation to the Caatinga landscape. Amazonian dark earth is commonly located between 5 and 25 m above the closest river. If this trend is kept in xeric climates, Caatinga dark earth can show paleochannels or are evidences of a past wetter climate.

Keywords: Anthrosols; xeric climate; Northeast Brazil.
Financial support:

(9730 - 2704) Impact of the pre-Columbian activities on soil-transformation and pedogenic processes in Anthrosols from French Guiana.

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During the pre-Columbian times in the Amazonian region, it is now well known that landscape and soils were transformed. In French Guiana, part of western Amazonia, recent pioneering studies have demonstrated that soil-forming as well as pedogenic processes were impacted by ancient human occupation. A large corpus of open-air archaeological sites, in different geomorphological settings were compared to assess the local variation of soil-forming processes from recent floodplain alluvial sandy soils, to hills on old clayey Ferralsols. Micromorphological observations combined with physicochemical analyses were applied to identify the intrinsic properties of these archaeological anthrosols. Micromorphology revealed direct anthropic markers such as charcoals, pottery sherds or burnt soils, while physicochemical analysis provided interesting results about indirect, non-visible, anthropic markers. Combining soil micromorphology with physicochemical analysis is a complementary methodological approach that helps to test/confirm hypothesis, by having two different scales of view. This study allow several hypotheses about the original activity of the found markers, both direct and indirect. Fundamental activities, such as kitchen or habitats middens, fire for opening forested areas to install settlements and/or cultivation, have been evidenced. Refuses can be observed by the soil microstructure, which can be open with a mix of allochthonous materials, as well as by combinations of chemicals elements such as P-Ca as bones remains. Past fires have an importance because of the production of charcoals, visible as macro or micro particles, and revealed by total carbon analysis. They may also stimulate the process of clay illuviation via the presence of fire-induced ashes contributing to soil pH modification. Moreover, it was shown that the pedofauna, such as *Pontoscolex sp. (Glossoscolecidae, Oligochaeta)*, which can be improve by charcoals abundance in soils, have played a key role in soils aggregation and porosity during and after past-human occupation. Fires have also impacted the specific volumes of the soils. Studying French Guiana archaeological anthrosol complement the repository of Amazonian archaeological anthrosols such as Terra Preta/Terra Mulata. This work reveal that still today it is possible to observe the past human modification on soils indicating a certain resilience of these Amazonian anthrosols.

Keywords: Archaeological Anthrosols; Guiana Shield; Micromorphology; Soil Geochemistry; Past Human Activities.
Financial support:

(9355 - 1162) Phosphorus (P) availability and P transformation rates in Amazonian Dark Earth determined by ^{33}P isotopic dilution

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Amazonian Dark Earth (ADE) often shows increased soil fertility compared to surrounding soils, likely linked to its increased concentration of soil organic matter and macronutrients such as phosphorus (P). For P, there is little knowledge whether the higher P availability is a result of increased biological processes (such as organic P mineralization) or physico-chemical processes (such as sorption/desorption), or both. Using the ^{33}P isotopic dilution approach we aimed to quantify the exchangeability of inorganic P as well as organic P mineralization rates of ADE under secondary forest and a cassava plantation. For that, ^{33}P labelled ADE as well as surrounding soil (highly weathered, no “dark earth” features) under both land use systems (forest and cassava) were incubated for a period of 14 days. P-concentrations and specific activity of the added ^{33}P tracer were determined on four time points in the water-extractable P pool as well as in the microbial P pool (resin-fumigation method). ADE showed generally increased concentrations of total P and loosely bound P (water extractable P; resin extractable P) compared to surrounding soils. Isotopically exchangeable P was similar in both analyzed ADEs (approx. 150 mg kg^{-1} soil after 7 days), yet significantly higher compared to surrounding soils (30 to 90 mg kg^{-1} soil after 7 days). A numerical model used to estimate P transformation rates suggests the dominance of physicochemical processes over biological processes in ADE under both land use systems. However, biological processes were at least doubled in ADE, compared to surrounding soils. We conclude that the higher P availability in ADE is largely caused by increases in the exchangeable inorganic P pool. While biological processes (mineralization/microbial immobilization) were increased in ADE compared to surrounding soils, their net effect on P availability remains small. In a next step, organic P in ADE will be characterized in alkaline soil extracts using ^{31}P NMR spectroscopy to increase the understanding which forms of P are included in the build-up of organic P in ADE soils.

Keywords: Amazonian Dark Earth,phosphorus, isotopic dillution,
Financial support:

(5854 - 935) Plaggen Soils - Europe´s counterpart of „Terra Pretas“?

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This presentation will be focused on firstly characteristics of Plaggen Soils (Plaggic Anrgosols (WRB); Plagganthrepts (US Key to Soil Taxonomy)); secondly on similarities and differences between Plaggen Soils and Terra Pretas; and thirdly on impacts on sustainability and vulnerability of Plaggen Soils and Terra Pretas. To introduce Plaggen Soils, the main morphological and physiochemical properties will be addressed, as well as aspects on their formation and distribution. Plaggen Soils and Terra Pretas are Anthrosols, both unintendedly formed in the past. Both hold improved properties compared to neighbor soils without anthropogenic formation impacts. Further similarities are indicated by comparable morphological features including appearances of anthropogenic admixtures, P enrichment, as well as enhanced C stocks and CEC. These similarities might be the reason for upcoming differentiation problems according to the given criteria in WRB to be discussed here. However, large differences occur with respect to the sustainability of properties. Where Terra Pretas remain stable, even under land use change, preliminary studies on Plaggen Soils show that they degrade under forest. Degradation characteristics are the development eluvial features, together with a changing soil chemistry. Looking in more detail into the C pools, Plaggen Soils show particular patterns for the distribution of

functional groups, HCl-resistant C, H_2O_2-resistant C, and lower BC contents and higher respiration rates than Terra Pretas. The latter provide indications that less amounts of stable C compounds are responsible for the higher vulnerability of Plaggen Soils, which is expected to be revealed in further studies.
Keywords: Anthrosol, Plaggic, Pretic, BC, vulnerability
Financial support: partly by Deutsche Forschungsgesellschaft (DFG): KE 664/5-1

(6770 - 2901) Properties and functioning of agricultural raised fields in seasonally inundated tropical wetlands

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Raised fields are elevated earthworks of variable height and extent that can be found in different landscapes worldwide. Their characteristics and properties vary depending on the environment in which they are (or were) constructed and on the purpose for which they are (or were) designed. Pre-Columbian raised-field agriculture has been the focus of heated debates regarding its functioning, its productivity, and the role it may have played in the development of complex prehistoric societies. Archaeological studies alone have been unable to fully explain how raised fields were managed and how they functioned as ecological and cultural systems. Raised fields in wetlands create a microrelief in a previously more uniform landscape. Changes in the local edaphology result in new habitats, which are often colonized by large numbers of soil engineers (e.g., termites, ants, earthworms, etc.). The role of biota in the construction and maintenance of wetland raised fields remains poorly understood. Raised-field agriculture is still practiced today in several regions in Africa, within environmental settings overall comparable to those in which it was practiced in South America. In this study, we compare previous results on pre-Columbian wetland raised fields in the Bolivian Amazon, South America, with new results on present-day wetland raised fields in the Cuvette Centrale of the Congo basin. We use a multi-methodological approach including sedimentology, geochemistry and micromorphology to evaluate the properties and functioning of currently used raised fields in wetlands, to quantify how farmers concentrate soil resources in raised fields and to show how practices of raised-field farmers affect soil organisms, microbial activity and plant-available nutrients.
Keywords: Pre-Columbian versus modern agricultural raised fields Bolivian Amazon Congo-Brazzaville
Financial support:

(6485 - 2235) Soil animals in Amazonian Dark Earths: biodiversity and role in soil functioning and formation

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Soil invertebrates may represent up to 25% of all known species, and more than 2200 species may inhabit a lowland Amazonian rainforest. Furthermore, the biomass of macrofauna may surpass that of aboveground animals, and the ecosystem engineers (mainly earthworms, termites and ants) can move/process tons of soil, altering its physical, chemical and biological properties/processes, resulting in important ecosystem services. Amazonian Dark Earths (ADEs) are unique, very fertile soils created by pre-Columbian activities over centuries, throughout the Amazonian Basin. Much is known of the chemistry of these soils, yet their biology, particularly the invertebrate communities are mostly unknown. Recent work by a multidisciplinary, multi-institutional group of the Terra Preta do Índio Network studied soil animals and soil fertility in ADEs in three Brazilian Amazonian states (AC, PA, RO), in three main land uses (agriculture, young forest and old forest). Soil animals and soil samples were collected using standard methodology (ISO/Tropical Soil Biology & Fertility) in nine sites with paired soil types (ADE and Adjacent, control soil). This work revealed that land use (agriculture vs forests) is a more important determinant to total diversity than soil type (ADE vs adjacent, natural soil), and that ADEs exert major selective pressures on animals, favoring earthworms over other major animal groups. Very few termites were found in ADEs, and these animals were associated mainly with adjacent non-ADE soils. Although overall diversity was little changed by ADEs, the species composition was very different within each major invertebrate taxa, once again highlighting the human footprint of this anthropic soil on biodiversity. The role of these different animal communities in soil function in ADEs is not yet know, but evidence of increased biological aggregates, higher soil fertility, ceramics and earthworm populations were observed. The prevalence of earthworms in ADEs implies in major changes in nutrient cycling and bioturbation in these soils, and experiments are presently underway to study these interactions in more detail. A new model of ADE genesis, including ecosystem engineers was also proposed.
Keywords: Earthworms, termites, soil fertility, Terra Preta de Índio
Financial support: CNPq, CAPES, Fundação Araucária, Fundo Newton/CONFAP, NERC, Embrapa, Cardiff University, EU

C1.4 - Soil classification

C1.4.1 - Soil systems and soil classification - their links and feedbacks

(4571 - 219) A Study of Soil Taxonomy of Artificial Soils Containing Artifacts Typical of China-Discussion on Soil Reconstruction and Soil Taxonomic Classification in Land Engineering

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As of yet Chinese Soil Taxonomy (CST) doesn't have any explicit diagnostic basis for characterizing soil profiles with artifacts. With rapid development of industrialization and urbanization, the impact of human disturbance on soil is becoming more and more significant. It is, therefore, essential to intensify the research on soils containing artificial artifacts, or it would be very hard to explain reasonably how some changes occur in pedogenesis. In this paper, 10 soil profiles containing artificial artifacts (shortened as artificial soil) typical of Henan Province, China were selected as objects for the study, including 3 at ancient cultural relic sites, 5 at urban sites and 2 at reclaimed farmland sites in industrial and mining areas. Besides, 3 natural soil profiles (free of any artificial artifacts) were chosen in the same regions as control for comparison in configuration and physic-chemical property. Then the 10 soil profiles were classified in line with world soil resources reference basis (WRB) and Soil Taxonomy (ST) and CST and analyzed for soil diagnostic layer and diagnostic characteristic specific of these profiles. On such a basis, a proposed scheme was put forward, applicable to classification of the artificial soils specific of China. By referring to some standards in WRB and ST pertaining to artificial artifacts in soil, this paper has brought forth a definition for soils containing artificial artifacts, including an augment of "technical disturbance layer" as diagnostic feature, which is added as an index for search of entisol and as a supplement into the definition for the suborder of entisol in CST formulated standards specific to artificial artifacts in CST, and created a new soil group "Technical anthropogenic entisol ", which will be first searched out under the suborder of entisol and three subgroups, i.e. calcareous, acidic and ordinary technical anthropogenic entisal under the group of Technical anthropogenic entisol. Moreover, when artificial soils do not fit in with the diagnostic features described in the preceeding paragraphs, it is suggested that artificial soils should be added as a

new type into the soil family to distinguish artificial soils from natural ones. This proposed scheme for soil classification is believed to be able to reflect effects of human activities varying in type on soil, which fills a gap by a certain degree in the study on classification of this type of soils.
Keywords: Soil taxonomy; Artifacts; China
Financial support: The National Natural Science Foundation of China (No.4137226)

(5977 - 2165) Are Geographic Information Systems and Remote Sensing Technologies Enough tools for improving landuse planning? A case study of Arnaha VDC of Saptari District, Nepal

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A detailed soil survey was carried out in Arnaha village area (1000 ha) of Saptari District, Nepal in early 2017 to evaluate and improve rural land uses for micro-level planning and productivity. RS and GIS techniques were used to create the baseline data. DTM was used to delineate the boundaries of land units. These were assigned to different land systems, and boundaries defined ased on position, slope, direction, drainage of landscape features which are especially important for local level project designing. Seven types of land system units (1a to 3c) were identified where 13 pit locations were superimposed and described by excavation of fresh pits in the field. More than one soil pit were enclosed by soil mapping. Thus classifications were made based on soil association. GPS receivers guided the field survey team. At each pit location, soil samples of each horizon and control section were obtained for further laboratory analyses and soil classification made following USDA method. Soil samples were then transferred to recognized laboratories in Kathmandu for analyzing physical and chemical properties using standard methods including texture, organic matter, pH, N, P, and K of soil. Lands were found laying on nearly level landscape (<3 degree slope). The results show that at Order level, there occur only three kinds of soils, i.e., Alfisol, Entisol and Inceptisols which occupy about 1.23%, 2.63% and 93.72% of the total area, respectively. At sub-order level, Udalf, Orthent, Ochrept, Udept and Umbrept are most commonly found soils. At great- group level, a myriads of soils are found mostly falling under Inceptisols. Aberrations were found common while classifying soils at sub-group level. No clear relationships were found between soil profile characteristics, soil fertility status (nutrients level) and crop productivity dynamics of the area. It appears that landuse planing for choosing better agriculture system/practice should also be aided by field level experimentation and in-depth knowledge of other local biophysical factors that control the land productivity.
Keywords: Soil database, micro-level planning, profile description, soil mapping units and land systems
Financial support: Janata Engineering Solution (P) Ltd. in association with Lali Guras Engineering Consultancy Pvt. Ltd. supported by National Land Use Project under Ministry of Land Reform and Management, Government of Nepal

(7180 - 2387) Brazilian Soil Classification System (SiBCS) reached 20 years - results and advances

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In 1997, a group of scientists led by Embrapa Soils with Universities and research institutions from Brazil presented the first complete document of the Brazilian Soil Classification System (SiBCS), in search of contributions from all pedologists. The first approximation was released in 1978, with new versions in 81 and 88. The first edition of SiBCS was published in 1999, with an Executive Committee that has the goal of validating, and evaluating proposal of new classes. Regional groups contribute to development of the SiBCS, and are supported by Embrapa and Brazilian Soil Science Society (SBCS). A national classification unifies soil data and allows inclusion of classes important to Brazil, in terms of agriculture and their unique environments, such as Pantanal and Caatinga. Another relevant part of SiBCS project is the Reunion of Classification and Correlation of Soils (RCC). The last RCCs visited areas that were not known by many pedologists in Brazil. In 2010, Acre state held a RCC; it was the first correlation in Amazon region. In 2012, it was in Pantanal and Cerrado region of Mato Grosso. In 2015, Roraima was visited for the first time by a large number of soil scientists, with unexpected ecosystems, including soils more related to dry regions of Brazil than Amazon Forest. The most recent, in 2017, crossed Rondônia, visiting ecosystems from Amazon Forest, high altitude grasses and shrub fields, large flood plains, to Cerrado. During the RCCs, specialists in soils examine profiles, previously sampled and characterized, along a route established by the organizing group, to review the classification and to propose new classes or change criteria. The RCCs trains new professionals, and allow exchange of knowledge about soils and environments of regions usually not known by many pedologists; and to local scientists helps to form research networks. The last contribution was to fuel the interest on detailed soil surveys. This supports the national wide program identified as Pronasolos, a response of Embrapa, leader of the project, from a demand of Brazilian government, with collaboration of a large number of Universities, research and extension institutions, and government sectors of Brazil. It became clear to decision makers, at the government level, that to manage and optimize agricultural practices toward sustainability of the agro-ecosystems, and preservation of natural resources, it is essential to know the Brazilian soils in detail.
Keywords: National soil classification; field correlation; Pronassolos
Financial support: Embrapa; SBCS; UFRRJ; IBGE; UDESC

(4508 - 1610) Development of an expert system for classification of Brazilian soil profiles

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The Brazilian Soil Classification System (BSCS) is the official taxonomic system for soil classification in Brazil. With the collaboration of professionals from several research and teaching institutions in the country, BSCS is in its third printed edition. Although it has been published many years ago, there is still no widely available computer program that simulates the decision-making of domain experts for the classification of Brazilian soils. The objective of this work is to build an expert system to assist professionals who need to classify Brazilian soil profiles. Based on the BSCS rules, the system simulates the reasoning of a domain expert when performing the classification of soil profiles. In addition to assisting the work of pedologists, the system can be used as a didactic resource, since it can explain in detail the path that leads to a particular solution. The system is in the prototype phase and has been developed in the Prolog language. It is able to classify soil profiles according to BSCS in different categorical levels, according to the data provided. Tests are being conducted on hundreds of samples already classified by domain experts. The development of this system brings many benefits, to wit: a) it increases the availability of knowledge on soil classification; b) it assists in the dissemination of BSCS, since it is documented not only in the form of publication, but also in software format; c) it is a rule-based system, so its development can be incremental, enabling consistency and performance tests as new knowledge is introduced; d) it has been developed using free software, resulting in reduced costs for its

operation and maintenance, by the research institutions and users interested in its functionalities. Apart from these benefits, this software tool can still be used to validate previously classified profiles, classify new soil profiles and subsidize the evolution of BSCS, since it is an open taxonomic system.
Keywords: soil classification, BSCS, expert system
Financial support: Embrapa, SEG Project: 03.14.01.017.00.00

(2903 - 1254) Evaluation of a national crop productivity index: revision for Kansas, USA

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For many decades, researchers have created indices to rate soil on its ability to produce vegetative growth. The National Commodity Crop Productivity Index (NCCPI) model provides producers, scientists, and others with an interpretation about the ability of a soil to successfully produce a commodity crop in the United States. The NCCPI uses data from the National Soil Information System (NASIS) to calculate the index for the United States. The index is publicly available on Web Soil Survey under Land Classifications (https://websoilsurvey.sc.egov.usda.gov) and was developed for the purpose of providing an interpretation for the production of commodity crops for rental payments, farm management planning, and when yield data is inconsistent. However, it has been shown that the NCCPI falls short in providing an index at a regional or local spatial scale. Therefore, some states in the USA have developed indices specifically for land within their borders, especially for maize. These indices are often more accurate, relevant, and usable for the client since focus is on a smaller region with less variability in soil type, climate, and management. This study aims at finding the shortcomings of the NCCPI model in order to develop a more detailed, fitting index for maize productivity in Kansas, USA. Observed yield from locations in Kansas will be used to analyze differences between the current NCCPI and an adjusted NCCPI for Kansas. This presentation will provide maps and statistics about these differences in order to draw conclusions about the value of a Kansas-specific crop productivity index. Accurate interpretations provide understanding of the uses and limitations for soil and can be made across the globe if detailed, functional, and precise data for a specific region are available.
Keywords: soil survey, crop productivity, land classification
Financial support:

(9249 - 1273) Modification of Paleustults at Subgroup Level: a Case of Tropical sandstone and siltstone-derived Soils

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Ultisols are the most extensive soils found in Thailand and Paleustults in particular not only distribute vastly in almost all regions but also are very important for field crop production in the country. According to Soil Taxonomy, the great group is provided for use elsewhere, resulting in all Paleustults being categorised in the same subgroup, Typic. This leads to a difficulty in an interpretation for agricultural use and soil management recommendation in spite of most soils in this great group having, to some extent, different morphological, physical and chemical characteristics as shown by soil data of more than 50 soil profiles collected from upland areas where cassava is a major crop. The soils are derived mainly from sandstone and siltstone and formed on different positions of landscapes. The plant grown on these soils shows different response in terms of growth and yield given, indicating that cultivation and soil management including fertilisation practices should be impremented differently in order to obtain reasonable yield and to use the soils sustainably. To provide some subgroups for use with these Paleustults is likely to be useful in the context of making soil management guidance and for technology transfer purpose. Several subgroups, namely Aquic, Oxyaquic, Ombroaquic, Plinthic, Arenic, Grossarenic, Psammentic, Udic, Kahaplic and Rhodic, can be used with these Paleustults and make them to have better interpretability of which a precision agriculture basing on the interpretation of these newly provided subgroups of the Paleustults can be done more practically.
Keywords: Soil Taxonomy, Soil Interpretibility, Tropical Soil, Upland Ultisols
Financial support: Kasetsart University

(8989 - 853) Object of natural soil classification: Is it a system or an element of a system?

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As it is known, any natural classification is unthinkable without a precise definition of its object. Revealing the essential character of the object, such definition determines differentiating criteria, structure and, on the whole, the scientificity of the classification system. There are many soil definitions, but in spite of this, attempts to give a new soil definition continue. This proves the importance and complexity of the problem. It is suggested to get back to basics, namely, to a soil definition given by V.V. Dokuchaev, however, improved basing on the General Systems Theory approach, which means studying objects as systems and/or as elements of systems. The following soil definition is offered: Soil is a material self-sufficient system and, at the same time, a derived element of a higher order system that is a natural landscape. Soil is a unique landscape element because only it originates from interaction and interrelation of the other (basic) landscape elements - rocks (parent material including peat and buried soils), air, water, and organisms. The definition reveals the essential character of soil (which is its systematic nature) and is taken as a basis for the development of a hierarchical Natural Soil-Landscape Classification System, which objects are both natural landscapes (as systems) and soils (primarily as derived elements of natural landscapes). In the classification system, differentiating criteria are strictly distinguished from diagnostic ones. As distinct from differentiating criteria, the latter are formal (external) and, on a large scale, morphological properties of natural soils and landscapes. At the higher levels of classification, differentiating criteria are essential (internal) properties of natural landscapes (for example, stability/instability of landscape vertical structure), and at the lower levels - essential properties of basic landscape elements directly responsible for essential properties of soils (for example, type of megarelief). Successive division of natural landscapes causes successive division of soils associated with these landscapes. Selection and ranking of the differentiating criteria are conformed to the rules. The classification system combines soil and landscape classification systems, integrates genetic approach with morphological one and thus differs essentially from current soil classification systems, which consider soils primarily as self-sufficient systems composed of genetic horizons.
Keywords: Soil definition; the General Systems Theory approach; soil-landscape classification; soil-landscape associations; genetic approach.
Financial support:

(7523 - 1496) Preliminary Thoughts About a New HAHT Soil Order for Soil Taxonomy

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Human-altered and human-transported (HAHT) soils are widespread across the land surface and in shallow water. The HAHT soils are extensive, and their extent is growing, especially near where people live and work. The hazardous HAHT soils pose some potential harm to plants, lower animals, and humans. Even though HAHT soils are very important to engineers and land-use planners, managers of urban plants, most are not mapped or classified to the same extent as agricultural soils. We will discuss the occurrence, types, and importance of HAHT soils and propose a classification of HAHT soils in Soil Taxonomy. There are two main forms of materials that define HAHT soils: human-altered materials and human-transported materials (HTM). A new Soil Order is proposed for Soil Taxonomy that would include the most obvious profoundly and intentionally altered HAHT soils. We propose new diagnostic artifactic horizon and anthropollic (contaminated, hazardous) materials based on WRB toxic qualifiers, and the addition of several diagnostic epipedons (anthromollic and pretic). Modifications will be proposed for the plaggen and anthropic epipedons and for artifacts. New Suborders and Great Groups will include landfill soils, soils on steep hillslope terraces, soils with subaqueous HTM, anthropollic materials, human-created sulfuric horizons, aquic conditions, anthraquic conditions, artifactic horizons, and deeply excavated and filled soils. The HAHT soils to be included in the new Soil Order mainly occur on anthropogenic landforms in urban areas, transportation corridors, mined lands, landfills, filled shallow water, and other lands. A brief discussion and justification is given for this unofficial proposal. The HAHT soils are now being recognized and classified in most soil taxonomies at very high levels, and input will be collected from international groups of scientists before finalization of the proposal. Harmonization with criteria and taxa in World Reference Base was attempted whenever possible. The long-term result of establishing a new Soil Order will be to improve the classification, allocation, and mapping of HAHT soils globally in areas using Soil Taxonomy.

Keywords: anthropogenic, soil classification, artifacts, human-transported material, Technosols
Financial support:

(2366 - 1879) Spodosols of Pantanal region: characterization, genesis and classification

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The complex dynamics of environments in extensive fluvial plains such as the Pantanal in Brazil impose great challenges on soil science, be it the understanding of soil formation or the definition of taxonomic criteria. One of soil classes identified in soil surveys of this region is the Spodosols, classified according to concepts in the Brazilian Soil Classification System (SiBCS). In the international soil classification systems, such as the Soil Taxonomy (ST) and the World Reference Base for soil resources (WRB), quantitative criteria such as values of pH and organic carbon were defined, thus some of the soils would not fit the criteria for Spodosols. In the SiBCS, the absence of these limits raise some questions about the real occurrence of the podzolization process in the Pantanal. The objective of this work is to evaluate attributes of soils classified as Spodosols in the Pantanal region, and to discuss the formation of the spodic horizon. From a previous bibliographical research of soils in the Brazilian territory, 385 spodic horizons, classified by SiBCS, were compiled. Of the total, 22 spodic horizons were described in soils from the Pantanal, all of which have low organic carbon content (mean of 2.37 g kg^{-1} and median of 1.70 g kg^{-1}), high pH in water (7.1 and median of 6.9), and high sum of bases content (mean of 2.49 cmolc kg^{-1} and median of 1.85 cmolc kg^{-1}). According to the ST and WRB criteria, these soil horizons are not classified as having spodic horizons, although their morphology resembles that of Spodosols. However, since these soils have not being sufficient studied, with only a few works regarding their genesis, it is hypothesized that the spodic horizons of soils from Pantanal could have different formation processes than that of cold climates and coniferous plants. The following reasons are cogitated: (i) the illuviation of organic matter occurs in the B horizon and it is not associated to classical podzolization, but to another pedogenetic process linked to ion dynamics in a basic / alkaline system; (ii) there is no illuviation of organic matter but a relatively accumulation in the B horizon due to destruction of inorganic colloids in the overlying horizon, with liberation and decomposition or loss of the organic matter protected by association with minerals; or (iii) the variation of organic carbon in the soil profile would be due to the deposition of different sediments along the time of soil formation.

Keywords: Podzolization; SiBCS; soil formation
Financial support: CNPq; Embrapa Solos; PPGA-CS/UFRRJ, FAPERJ

C1.5 - Pedometrics

C1.5.1 - Global soil carbon modeling

(2240 - 788) Global space-time soil carbon assessment using dynamic covariates and a mechanistic model

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Climate change and altered land-use will have a great impact on soil, in particular soil carbon. The influence of these factors will create a dynamic feedback between soil and the environment. This paper will present a global model that takes into account the spatial dynamics of soil carbon in different biomes and ecozones of the world due to climate change land use impact. We first conducted a synthesis of global space-time soil carbon data (n ~ 64,000) and build a global spatial model of soil carbon using the scorpan approach. We then develop a dynamic process-based soil carbon change model taking into account carbon input from NPP and landcover change, decomposition as affected by temperature. The results show an analysis of the relative effects of climate change and soil management on soil carbon across the globe. The global spatial-temporal soil information on soil carbon helps increase our understanding of how terrestrial systems function. This work will further developed into a global soil carbon monitoring network. The future information will support scientific pursuits in agronomy, climatology, forestry, ecology, hydrology, and earth system science.

Keywords: Climate change, Carbon Sequestration, Soil organic carbon
Financial support:

(6799 - 2942) How a robust spectral and analytical soil organic carbon libraries can contribute for a sustainable agriculture?

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The rational use of the fertile soils is mandatory for a sustainable agriculture. Soil Organic Carbon (SOC) analysis plays an important role in crop management and require significant effort and time in routine soil laboratories. Every year, millions SOC analysis are performed in hundreds of laboratories throughout Brazil. Most of them still employ a wet method based on the oxidation of the organic matter by dichromate, that generates residues aggressive to the environment. In this sense, a new analytical methodology that is cost effective, fast,

non-destructive and environmental friendly is presented as one alternative to the traditional method of SOC analysis. The visible Near Infrared Diffuse Reflectance Spectroscopy (Vis-NIRS, 400-2500 nm) accounts for numerous advantages over the traditional methods, attends the precepts of the Green Chemistry and contributes for a sustainable agriculture. This analytical technique does not employ chemicals reactants and consequently is free of chemical residues. To implement the Vis-NIRS technology as a routine method for SOC analysis some obstacles had to be overcome: a new instrument (SpecSoil-Scan®) capable of making 2.000 soil analysis per day was developed and a huge spectral and analytical soil library was created using more than 120.000 soil samples representative of the Brazilian territory. The soil samples were analyzed by the SpecSoil-Scan® and the SOC analysis were performed by the standard method from a certified laboratory by ISO 17.025. The new technology called SpecSoil® was validated using an expressive number of analysis capable to generate high quality models and accurate prediction. SpecSoil® is the first technology totally dedicated to soil analysis in routine soil laboratories that employees Vis-NIRS spectroscopy, a soil library of 120.000 spectral and analytical data and artificial intelligence algorithms.

Keywords: artificial intelligence, Soil stock carbon, SpecSoil.
Financial support: SpecLab Holding SA; Embrapa MP5: 05.14.01.001.00.00.

(6645 - 2010) Soil carbon stock: effects of different management in the Brazilian savanna

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Soil carbon stock may vary significantly across locations depending on soil usage, conservation practices adopted, and intrinsic characteristics. The objective of this study was to estimate the changes in soil carbon stock under different agricultural farming management in Maranhão State. Changes were estimated from an initial scenario (S0) to the current scenario (2010), followed adoption of a conservationist soil management (2030). Values of 0-30cm soil depth of clay soil content (%), soil density (Mg m^{-3}) and organic carbon (g kg^{-1}) were obtained on the open data (ODbL) platform *SoilGrids-1km*. Estimates on carbon stocks were calculated based on (i) clime, (ii) soil, and (iii) agricultural management. The factors of change (i) land usage, (ii) tillage, and (iii) entries were applied for annually farming operations. The initial scenario was calculated using Veldkamp's suggested equation: Carbon stock = (organic carbon x soil density x depth)/10. 2010 carbon stocks were estimated based on the loss caused by the pressure of already implemented activities. For 2030, the scenario of a traditional (not conservationist) land usage was substituted for a soil conservationist management based on sustainable agriculture principles such as zero-tillage planting, integrated crop-forest systems, crop rotation, cover cropping, and mulching. Carbon stocks under agricultural lands of Maranhão State were estimated an average of 38,28 Mg ha^{-1}. The deforestation for the opening of new areas and the pressure received by the soil under intensive agricultural systems caused a loss on soil carbon stock of 0,21 Mt until 2010. The conversion to sustainable agriculture practices will provide a positive balance of 0,03 Mt of carbon soil stock, in other words, a carbon sequestration. These results indicated that, Maranhão State should adopt practices of the low-carbon agriculture, minimizing the impacts on carbon stock.

Keywords: estimation, conservationist, maranhão state, geostatistics
Financial support:

(9497 - 1359) Soil Organic Carbon Stock at 0-30 cm Map of Brazil

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The global soil organic carbon stock (OCS) map, launched in December 2017, was proposed by the Food and Agriculture Organization (FAO) in a consultative and participatory process involving 110 countries through the Global Soil Partnership (GSP) initiative. In this work, we present the data, methods and results from the Brazilian OCS map that composes the global OCS map. The soil profile dataset was composed by merging the *Sistema de Informação de Solos Brasileiros*, *Escola Superior de Agricultura Luiz de Queiroz* and *Sistema de Proteção da Amazônia* data sources, totaling 7015 georeferenced soil observations with OCS data. Soil organic carbon stock at 0-30 cm was calculated as the sum of stocks from horizons/layers within 0-30 cm. Missing BD values were predicted from carbon, clay and silt contents, and depth. Raster layers representing soil formation factors included MODIS bands and NDVI, WorldClim layers and DEM and terrain attribute layers from SRTM, totaling 145 covariate layers resampled to 1-km spatial resolution. The environmental covariates values were extracted to the soil observations by spatial overlay. The 7015 observations were split randomly into training (5575 samples ~80%) and validation (1439 samples ~20%) sets, and OCS was transformed to logarithm for modeling. A set of 45 covariates were selected, and influential outliers removed based on multiple criteria, respectively. A combination of nine prediction methods was used, whose parameters were optimized by ten-fold cross-validation, and generalized least squares was used to combine the predictions from the nine methods in an ensemble model. Predictions were made across Brazil at 1-km spatial resolution, and then back-transformed to OCS original units. The mean OCS predictions across Brazil vary from 4.9 to 238.3 t ha^{-1}, with mean and median of 42.0 and 41.1 t ha^{-1}, respectively. Training and validation root mean squared errors from the back-transformed predictions were 19.5 and 28.3 t ha^{-1}, respectively. The estimated total OCS at 0-30 cm for Brazil is 36.3 ± 0.2 Pg (mean ± 1.96 * standard deviation of prediction).

Keywords: Digital soil mapping; Ensemble model; Legacy soil data
Financial support:

(2200 - 1802) Soil organic stock estimation through digital soil mapping approach: How many soil samples are required at different scales?

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Soil organic carbon (SOC) stock at different scales is generally estimated from point data of SOC content and bulk density (BD) within the study area. These required data are generated through sampling effort followed by laboratory analysis. Spatial variation parameters e.g. nugget (C_0), sill (C) and range (a) are then calculated using geostatistical approaches and maps of SOC stock are generated. Otherwise, SOC stock is estimated by calculating average SOC content of a soil mapping unit and then multiplying it with BD and total area of the unit. Whenever, spatial approach of SOC stock estimation is applied in a study area, question arises on number of soil samples

required for accurate estimation of spatial variation parameters of SOC content, which affects the quality of SOC stock map. In this study, spatial variation parameters of SOC content at six different scales in India with different number of soil samples (N) and different extents of area (A) were studied: (i) farmers' field at Jaisalmer (N = 116, A = 73 ha), (ii) experimental farm of Indian Agricultural Research Institute at New Delhi (N = 288, A = 278 ha), (iii) a micro watershed at western catchment of Chilika lake (N = 100, A = 4200 ha), (iv) Rajasthan state (N = 116, A = 33 m ha), (v) arid western India agro-ecological region (N = 92, A = 32 m ha), and (vi) central India (N = 919, A = 156 m ha). Standard semivariogram models e.g. spherical, exponential, Gaussian and linear were fitted on the above said six scales. Spherical models were found best fitted at five cases whereas exponential model was found best at experimental farm scale. The range parameter (*a*) of semivariogram model, which indicates the lag distance in field up to which spatial correlation exists, varied from 157 m at farmers' field to 1324 km at central India scale. The range parameter was also found to increase with the extent of study area. A linear relationship was developed between the extent of the study area and the range parameter: log [range (m)] = -3.606 + 1.159 ´ log[extent of study area(m)] (R^2=0.98). The relationship indicates that if the extent of the study area is known, then range parameter of SOC variation may be estimated, from where one can judge minimum separation distance between two sampling points in the field. Thus, an optimum sampling density and design can be prepared before going for sampling in the field for accurate estimation of spatial variation parameters of SOC content in the study area.

Keywords: Digital Soil Mapping; Soil Organic Carbon; Semivariogram; Range

Financial support: ISRIC World Soil Information/DST Govt of India

(9048 - 1203) Towards a regional soil information system for South America: building the South American soil organic carbon map

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Soil information is essential for decision-making in agriculture and efficient natural resources management. In South America (SA) there is an increasing need of harmonized, quantitative and functional soil information. This study was performed under the framework of the Global Soil Organic Carbon map of the Global Soil Partnership (GSP) to provide spatially-explicit soil organic carbon (SOC) information. The SA-SOC map is a first result of the GSP towards a bottom-up approach to provide accurate and up-to-date SOC information for the first 30 cm of soil surface. This map was generated by combining state-of-the-art digital soil mapping (DSM) methods including spatial statistics, geo-morphometry and expert based soil knowledge. DSM of SOC was the focus of a regional on-the-job training session that was directed to the national experts with the mandate to generate nationwide soil information across SA. Each national expert was responsible to identify and obtain the best information available on SOC. This process involved the rescue of legacy soil data, which in many countries is spread in different institutions and/or stored as hard copies. Digitized soil point (profile) data supporting the SA-SOC stock map included 39,364 SOC observations, which were not equally distributed across the countries. Regression-kriging, random forest and support vector machines were some of the DSM methods that were chosen by the SA national soil experts to predict and map the SA-SOC stock in a country-specific basis. The cross-validation of this country-specific approach shows root mean squared errors that vary between 0.5 and 5.4 kg m-2 (at 0-30 cm). These country-specific maps were mosaicked to generate the regional SA-SOC stock map. The SA-SOC map reveals that in SA the SOC stock at the first 30 cm adds to 87.6 Pg, representing 13% of the global pool. The data, maps and soil knowledge resulting from this GSP initiative will enable interested users to improve the development of agro-climatic information systems and rural extension programs. Generated information will be freely distributed through the GSP-supported Soil Information System for Latin America and the Caribbean (SISLAC). Accurate and up-to-date SOC information will help SA countries formulating public policy on, and planning soil use, management and environmental services, which are relevant to prevent land degradation and ensure soil security.

Keywords: soil organic carbon soil information systems digital soil mapping

Financial support: FAO GSP; FAO TCP/RLA/3613 (D)

(1946 - 956) Use of predictive models for space prediction of carbon content and soil aluminum in the municipality of Petropolis-RJ

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The aim of the study is to evaluate the relation between organic carbon (Corg) and aluminum (Al) in the soil, with environmental co-variables by using soil digital mapping techniques such as Linear Regression (LR), Random Forest (RF), and Regression Tree (RT). The study was performed in the municipality of Petropolis, Rio de Janeiro, with the selection of 24 proprieties. Samples were taken at of 0,2 m depth to build a soil databank. The environmental covariables Topographic Wetness Index (TWI), Topographic Convergence Index (TCI), Slope (SOLPE), Digital Model Elevation (MDE), and bands 2 to 7 of LANDSAT 8 were used to evaluate effect of the models in the Corg and Al soil attributes prediction. The statistic program R (R Project, version 3.4.3) was used for attribute prediction and to make the final maps. The level curves data, altimetry, and drainage channel were developed based on IBGE (Brazilian Institute of Geography and Statistics). Environmental co-variables were established using ArcGis Desktop 10.1, SAGA Gis and LANDSAT 8 satellite images, acquired from INPE (National Institute of Space Research). The performance of each predictive model was calculated from validation samples, using correlation calculus between observed and estimated values, through coefficient of determination (R^2) and root mean square error (RMSE) in the R program. The final attribute maps were produced using data set (Corg + Al), Corg and Al apart. In both procedures the same covariables were applied as input in the three predictive models studied. The LR model with Corg+Al attributes outstand, and Al to evaluate Corg the regression tree was observed to be the best among the analysis. The Corg attributes data and Al were insufficient to succeed the application in the RF and RT models. The LR model was of greater relevance, regarding the method of linear mathematic equation establishment that describes the relation between two variables

Keywords: Geostatistics, Digital modelling

Financial support: FAPERJ - Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro.

(9239 - 416) Using MIR Spectrometry to Predict Soil Carbon for the Soil Survey Program in the USA

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Over the last 6 years, the National Soil Survey Center (NSSC) Kellogg Soil Survey Laboratory (KSSL) has been assembling a growing, mid-range infrared (MIR) spectral library, similar to existing international efforts that utilize soil spectrometry as a low-cost tool for the rapid prediction of soil carbon and other properties. The KSSL MIR spectral library now exceeds 55,000 samples, and includes legacy samples from its soil archive, the largest in the world with over 300,000 specimens. Geographically and taxonomically constrained calibration models are being developed for use by USDA-NRCS Soil Survey Regional Offices in proof-of-concept pilot projects for rapid prediction of total, inorganic, and organic carbon, and other selected properties. A set of calibration models was derived from several thousand Mollisol samples from across the USA Great Plains, collected over time by the USDA Soil Survey Program; outcomes from that first pilot, based in Salina, Kansas, are encouraging future investment in MIR and deployment of the technology to other soil survey field offices in the USA. Current pilot project results show root mean square errors of prediction (RMSEPs) of 0.23 % (2.3 g/kg) total carbon; 0.24 % (2.4 g/kg) organic carbon; and 0.22 % (2.2 g/kg) inorganic carbon [or 1.8 % (18 g/kg) calcium carbonate equivalent]. MIR spectrometry presents a means to rapidly increase point sample density while assuring data quality and consistency. The presentation will review efforts by the NSSC to model soil carbon (and some key soil properties e.g., clay, CEC, and 15-bar water), including roadblocks and successes on the path toward implementing MIR spectrometry as a rapid prediction tool that any NRCS field soil scientist can use.

Keywords: spectrometry, mid infrared, MIR, soil, carbon, calibration, model, organic, inorganic, total, spectroscopy
Financial support: United States Department of Agriculture

C1.5.2 - Crucial techniques for the critical zone: Soil morphometrics, monitoring & modeling

(5534 - 651) A tale of two CZ's: Contrasting shallow and deep human-environmental dynamics

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In order to investigate the below-ground effects of ~80 years of old-field succession in the US, South Carolina, Calhoun Critical Zone Observatory (CCZO). This investigation seeks to determine how different critical zone measurements are able to quantify the vertical propagation of forest regeneration fronts downward into soil profiles. Chronosequence landuse history plots have been instrumented and studied. Chronosequence plots consist of 3 reference hardwood forest plots, 3 plowed agriculture plots, and 3 old-field secondary pine forest plots. In this framework, reference hardwood soil profiles are minimally degraded in terms of erosion, soil structure, and soil biogeochemistry while currently cultivated agricultural plots are maximally degraded. Old-field secondary pine forests are considered to be intermediate and partially regenerated in terms of soil structure and function as reforestation has occurred and proceeded for decades. Each landuse history comparison plot has been instrumented for soil profile monitoring of *in situ* CO_2, O_2, and soil moisture down to 5m depth. Additional investigations include soil rooting depth and shallow/surficial investigations of soil structure and soil macroinvertebrates. Results indicate that while there has been a great degree of surficial soil regeneration in old-field secondary forests in terms of rooting, respiration dynamics, and soil structure, deep CZ processes remain altered indicating a lag in below-ground succession and forest rooting processes are hindered by a thick B-horizon barrier. Hardwood forest soils generally have higher CO_2 concentrations and lower O_2 below 2m, past the B-horizon, than agricultural or old-field pine forests, especially during peak growing seasons. Abiotic CZ processes like storms and precipitation affect all treatments, however, as rapid declines in CO_2 concentrations are observed deep in soil profiles during periods of increased soil moisture, presumably due to CO_2 dissolution into water because O_2 concentrations also remain low during these periods.

Keywords: respiration CO_2 O_2 succession reforestation
Financial support: United States Forest History Society (FHS)

(1558 - 1913) Accurate prediction of soil reaction (pH) and sum of basis through portable X-ray fluorescence (pXRF) spectrometer in tropical soils

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In the past few years, Soil Science has experienced an increasing availability of tools that improve soil characterization both locally and spatially, such the proximal sensor portable X-ray fluorescence (pXRF) spectrometer. It quantifies the elemental content of the analyzed material in a few seconds, without generation of residues and with small preparation of samples. Works have used pXRF results to predict soil properties, but such researches are still initiating in tropical soils. In this sense, this work aimed to predict sum of basis (SB) and soil reaction (pH) through pXRF results for Brazilian soils. A total of 538 samples of soil A horizon were collected across 6 Brazilian states and subjected to laboratory analyses to determine soil pH, SB, soil organic matter (SOM), and texture. Such samples were also analyzed with a pXRF Bruker® S1 Titan for 60s, in triplicate, in the Trace mode. Predictive models for pH and SB were generated with two types of datasets: only pXRF data and pXRF data in addition to SOM and texture, through the ranger algorithm, which is an evolution of the widely used random forest algorithm. For that, 70% of the data (377 samples) were used for modeling and 30% (161 samples) for validation through calculations of root mean square error (RMSE), mean error (ME), and R^2. Importance of the predictive variables was also obtained by ranger. Accurate models were obtained for pH and SB, and a small increase in the performance of the algorithms was achieved using pXRF plus laboratory data. R^2, RMSE and ME for pH were 0.64, 0.58, and 0.44 using only pXRF data, and 0.65. 0.48, and 0.37 using pXRF plus SOM and texture. For SB, R^2, RMSE and ME were 0.84, 1.67, and 1.18 with only pXRF data and 0.87, 1.57, and 1.04 with pXRF plus MO and texture. The most important variables in decreasing order to predicting pH were CaO, K_2O, and Mn with only pXRF data, and sand content, CaO, and K_2O with pXRF plus SOM and texture data. For SB, these variables were CaO, Cl and K_2O with only pXRF data, and SOM, CaO and Cl with pXRF plus SOM and texture data. Such results indicate the feasibility of adopting pXRF to accurately predict soil pH and SB, even for a dataset with high variability of samples, which can reduce the costs and time needed for obtaining soil properties data. Future works will focus on the development of accurate models for predicting other soil properties in other soil horizons.

Keywords: Soil properties prediction; soil variability; proximal sensor; ranger algorithm.
Financial support: CNPq; Capes; Fapemig.

(7499 - 476) Coupling Dynamic Soil Property Field Studies and Modeling for U.S. Soil Survey

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The National Cooperative Soil Survey (NCSS) has recognized the need to provide enhanced information about soil change in response to land use, management or climate change. Traditional soil survey products describe inherent soil properties for an entire soil profile. Soil survey projects to collect and aggregate dynamic soil properties (DSPs) are ongoing and focus mostly on soil surface layers that respond most rapidly to changes in management, land use or climate. While changes in DSPs are best measured over time through long-term studies and monitoring, they can also be estimated using soil survey methods by carefully substituting space-for-time. This is accomplished by comparing differing land use or management conditions (i.e. vegetation, tillage, and climate) on the same soil type coupled with predictive modeling. The utility of models to predict future soil conditions is mutually useful to U.S. soil survey and offers a complementary tool to DSP field studies. In addition, a combination of data collection and modeling will allow soil survey to quickly populate a DSPs database to better inform land managers and policy makers on management effects on soil properties. The objective of this study was to evaluate the utility of the APEX (Agricultural Policy Environmental eXtender) model to simulate temporal trends in DSPs and the direction of soil change under differing management scenarios. The DSP field studies followed the procedures of the USDA Natural Resource Conservation Service Soil Change Guide and were designed to capture changes in soil properties due to management through a space-for-time sampling strategy using locations having the same soil type, for purposes of scaling, but have different conditions (land use and management). The field-scale application of APEX for DSP studies simulates one soil type under multiple land use and management scenarios with one scenario representing the reference state and one or more representing alternative states. The reference state represents the least disturbed state (i.e. native grasses) which is then compared to one or more disturbed states (i.e. conventional tillage). Initial results suggest that APEX can adequately predict changes in soil properties and can provide complimentary data to soil survey field studies. The population of DSPs from model simulations can be used in conservation tools to assist land managers in their evaluations of likely management impacts on soil properties.

Keywords: Soil monitoring Soil modeling Dynamic soil properties
Financial support: USDA-NRCS-Soil Science Division

(1625 - 1528) Digital mapping of soils from a microbasin representative of the soils of the Rio Preto Basin Federal District

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Adequate land use depends primarily on land planning according to land use capacity and suitability, so it is necessary to use maps in an appropriate detail scale. With the objective of producing a soil map at a scale of 1: 25000 the present work studied morphometric parameters and the pedomorphological relationships for the prediction of soil class distribution in the Rio Preto Basin, Federal District, Brazil. Three toposequences were established for the determination of pedomorphological relationships in a pilot area known as Alto Jardim. The region is inserted in three geological groups, Paranoá, Canastra and Bambuí, but the substrate is basically composed of pelitic rocks, so geology was a constant factor in the model. In order to obtain the morphometric parameters, a Digital Elevation Model (MDE) was generated in the ArcGis 10.3 software, with the top to Raster tool, altimetry charts and drainage network were used in a scale of 1: 10000, from which parameters were extracted such as elevation and slope, these were exported to Saga Gis software, Terrain analysis where secondary parameters such as cross-sectional curvature (CSC), longitudinal curvature (LGC), LSfactor (LSF), topograph wetness index (TWI), wetness index (WI) and texture (TX), were extracted. These parameters were exported to ArcGis, and processed with the Overlay tool, Fuzzy Overlay, using the Soma operation. Association of Hydromorphic soils was predicted by the cross between WI and CSC. The (FFd) Petroferric Acrustox, were predicted with the crossing between TWI and SCS. Typic Ustorthent (RR) were predicted by crossing between TWI, LSF and TX. The prediction of (LVd) Rhodic Acrustox and (LVAd) Petroferric Acrustox were obtained by crossing between LGC and LSf. The sum of these maps was done in ArcGis with the Raster Calculator tool. The soils (OX) Haplic Histosol and (GX) Typic Fluvaquents, were associated due to the drainage being very embedded with small flood plains, being impossible to distinguish the classes of soils. FFd and RR have strong relation with convex relief and strong undulating to undulating slope. LVd and LVAd are correlated to flat to soft corrugated reliefs, however they are also formed in corrugated relief. Fuzzy logic proved to be efficient in predicting soil classes, with a Kappa index of 0.60, indicating that the methodology can be used to predict the distribution of soil classes in areas with lithological similarity.

Keywords: Key words: Pedomorfogeological relationships, curvature, Fuzzy logic
Financial support:

(3831 - 1511) Images Classification for Digital Soil Mapping in Roraima, North Amazônia

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The lack of detailed pedological data in the Brazilian Amazon limits accurate environmental analyzes. The purpose of this work was to use Digital Soil Mapping (DSM) techniques to train models in the separation of classes according to the Brazilian Soil Classification System, in a rural settlement in the northwest region of the state of Roraima (44.000 ha), using 52 environmental covariates related to the formation factors of soils, to explain the local pedological variance. Satellite images, geological surveys, aerogeophysical data and previous pedological data were statistically selected and used. Soil control samples were collected in 105 sites, counting on 16 complete pedological profiles, all descripted and classificated, using Brazilian Soils Classification System. Then the separation of this initial dataset in training (85%) and validation (15%), these data allowed adjustment of selected models, with prediction of the soil classes for the whole area. The taxonomic units were delineated with the classifier algorithms and accuracy measured by external cross validation, the set of samples being divided into 10 folds. The best models to DSM in study area were *Random Forest* (*RF*) and *Ranger* (*RG*). The *RF* classifier showed an accuracy of 0.69 and a Kappa index of up to 0.58. The *RG* classifier reach Kappa values of 0.49 and 0.62. The DSM allowed identify the soil classes in the study area in 1: 50,000 map scale, considered semi-detailed, using Digital Elevation Model with a spatial resolution of 12.5 m. Were mapped Argissolos Amarelos Alumínicos plínticos (62%) e Vermelhos-Amarelos Alumínicos plintossólicos (3%), Cambissolos Háplicos Alumínicos lépticos (26%) Gleissolos Háplicos Sódicos típicos (8%) e Nitossolos Háplicos Distróficos típicos (1%). The most chosen predictors in the selection of covariables were the morphometrics derived from the Digital Elevation Model. The balancing of the soil classes samples was fundamental in the classification, being able to reach the nearest field reality of the Rural Settlement Project.

Keywords: Machine Learning, Pedometry, Amazonia, Digital Mapping
Financial support: CAPES (Pro-Amazônia: Biodiversidade e Sustentabilidade)

(8096 - 2855) Monitoring and modeling of Russian chernozem soil fertility

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To study mechanisms of self-consistent soil evolution we integrate feedbacks between detailed biological and physical soil models for a soil profile describing: a) local microbially-driven SOM transformations in granulo-densimetric soil fractions with turnover rates affected by SOM localization and physical factors and b) fluid and energy transport in soil as a solution of the coupled system of equations, taking into account processes of water and vapor diffusion due to matrix potential gradient, vapor diffusion due to temperature gradient, thermal conductivity and heat transport due to evaporation and condensation. Feedbacks include: Soil moisture and temperature directly affect microbial activity and SOM transformation in the soil, organic matter properties (content, localization and wettability) affect physical occlusion, water retention curve and hydraulic conductivity function through change in soil aggregate structure and waterstability, as well as pore size distribution. The models are developed together with the aim to self-consistently describe chernozem soil evolution under climatic and land use change. To apply this model on a landscape level we use local meteodata corrected for a certain landscape position using morphometric analysis of elevation map. Further we develop a model of water runoff with special consideration of variation in soil infiltration rate. It is modelled in particular representative points, that characterize groups of sites with similar weather conditions, morphologic and monitoring soil properties. Groups are characterized by a certain type of dependence of water infiltration on soil properties. Further wetness index is calculated considering prewetting effect on infiltration rates. The present study is tested on arable land area of 27 kha. Soil sampling scheme is chosen with the aim to get required precision of site description using minimal number of soil samples. We analyse available maps, that are related to soil heterogeneity e.g. morphometric indices, yield, wetness maps. On these maps we choose largest possible, not necessarily simply connected contours with considered soil properties within a given spread. Number of contours is chosen, so that their coverage at least a given fraction of total area of considered parcel of land. Covered part of the total area is defined by the threshold of rapid growth of heterogeneity tail in soil property.

Keywords: modeling, fertility, monitoring, feedbacks, nonlinear dynamics

Financial support: Travel support will be very helpful.

(8454 - 1119) Simulating soil formation in a Mediterranean watershed with the new MILESD2 – the importance of spatially-explicit soil water dynamics

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Interest in modelling pedogenesis has increased greatly over the past few years, with the emergence of detailed pedon-scale models (e.g. Soilgen) on the one hand and landscape-scale models (e.g. marm3D, MILESD, LORICA) on the other. Pore water chemistry and chemical weathering is not (well) represented in the latter and needs to be improved in order to adequately model the evolution of soils and of the critical zone. Here, we present a new landscape-scale model, MILESD2, that takes into account the spatial variability of soil water and associated element fluxes. The model takes into account physical and chemical weathering, bioturbation, clay migration and neoformation and erosion processes. Information on bioturbation and erosion rates is derived from optically stimulated luminescence data. We first calibrate this model against measured soil water dynamics, groundwater recharge and streamflow data in the Santa Clotilde CZO (2015-2017). The model is then used to explain the vertical and lateral distribution of key soil properties in the study area. We evaluate soil depth, particle size distribution and rock fragment abundance, soil carbon stock and chemical depletion fraction.

Keywords: critical zone, soil formation model, soil water dynamics

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(6069 - 764) Untangling of Spatio-Temporal Soil Processes at Different Scales Through Fourier-Based and State-Space Analysis

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Appropriately managing agricultural landscapes requires understanding of how spatial soil processes are related to other processes such as hydrodynamics, landscape topography, and biomass development. Experimental designs can become challenging when underlying soil variability prohibits the identification of treatment effects and their inter-relationships. In this contribution, experimental and analytical approaches to the diagnosis of processes in farmers' fields are illustrated. A substantial aspect of landscape process analysis is the consideration of scales and their associated process behavior. A Fourier-based design is used to study field scale solute transport processes. Scale-dependent layout of treatments allows to quantify the effect of rainfall characteristics on solute transport. An additive state-space approach is effective to separate variability components at different scales. Nitrogen fertilizer response in a variable landscape with an underlying soil trend becomes identifiable by separating large-scale soil impact from small-scale treatment effects. In another study, soil moisture dynamics and their response to rainfall and evapotranspiration reveal zones of different functional behavior within the same field through wavelet analysis. Moreover, management zones for variable rate irrigation are delineated through spatial field soil information including remote sensing. Similar methods were used to reveal the impact of land use change on relevant soil physical properties of a shallow depth volcanic ash soil and its consequences on water table dynamics. Soil hydraulic properties investigated across an 860-km-long transect in the Chinese Loess Plateau and their relationships to other soil properties are scale-dependent and depth-variable. Variability as an ecosystem component prevailing at a variety of scales is not an obstacle to experimental research and landscape analysis but a profound opportunity in soil-, hydrology-, agriculture- and landscape-related studies. It is expected that better understanding of scale-relationships will increase the efficiency of co-regionalization model algorithms.

Keywords: Space-Time Modeling, State-space, Spectral Analysis, Scale

Financial support: University of Kentucky

C1.5.3 - Reconciling pedometrics and pedology

(1958 - 3068) Bringing together brazilian soil scientists to share soil data

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Siqueira[17]; Renato Eleoterio de Aquino[17]; Nelida Elizabet Quiñonez Silvero[17]; Aline Marques Genú[18]; Tiago Broetto[19]; Luciano Campos Cancian[1]; Pablo Miguel[20]; Jovani Zalamena[21]; André Carnieletto Dotto[16]; Jaime Antonio de Almeida[22]; José Miguel Reichert[1]; Gustavo Ribas Curcio[23]; Leonardo Santos Collier[24]; Waldir de Carvalho Junior[3]; Ademir Fontana[3]; Aline Pacobahyba de Oliveira[3]; Eduardo Saldanha Vogelmann[25]; Fábio Joel Kochem Mallmann[26]; Gustavo de Mattos Vasques[3]; Igo Fernando Lepsch[16]; Jessé Rodrigo Fink[27]; João Carlos Ker[28]; Leandro Souza da Silva[1]; Pedro Luiz de Freitas[3]; Wanderlei Bieluczyk[16]; Tales Tiecher[6]
Universidade Federal de Santa Maria[1]; Embrapa Informática Agropecuária[2]; Embrapa Solos[3]; Embrapa Milho e Sorgo[4]; ISRIC World Soil Information[5]; Universidade Federal do Rio Grande do Sul[6]; Universidade Federal Rural do Rio de Janeiro[7]; Universidade Federal do Rio Grande do Norte[8]; Serviço Geológico do Brasil[9]; Instituto Brasileiro de Geografia e Estatística[10]; Embrapa Clima Temperado[11]; Empresa de Pesquisa Agropecuária de Minas Gerais[12]; Instituto Agronômico do Paraná[13]; Universidade Federal do Piauí[14]; Universidade Federal do Vale do São Francisco[15]; Universidade de São Paulo[16]; Universidade Estadual Paulista[17]; Universidade Estadual do Centro Oeste[18]; Catena Planejamento Territorial[19]; Universidade Federal de Pelotas[20]; Universidade Federal de Santa Catarina[21]; Universidade do Estado de Santa Catarina[22]; Embrapa Florestas[23]; Universidade Federal de Goiás[24]; Universidade Federal do Rio Grande[25]; Universidade Regional Integrada do Alto Uruguai e das Missões[26]; Instituto Federal do Paraná[27]; Universidade Federal de Viçosa[28]

Soil science has produced a great deal of data. Most of the information is published as a single paper, and the primary data is unavailable to other researchers. As data underutilization is a waste of resources and refrains the advancement of knowledge, many isolated soil data rescue and sharing efforts have emerged in the scientific community. Lately, soil scientists have increased their concerns with data discoverability and reusability, and reproducible research. To address these issues, Brazilian soil scientists have recently created a data repository using community-built standards and following open data policies. The Free Brazilian Repository for Open Soil Data – febr, www.ufsm.br/febr – is a centralized repository targeted at storing open soil data and serving it in a standardized and harmonized format. The repository infrastructure was built using open source and/or free (of cost) software, and was primarily designed for the individual management of datasets. A dataset-driven structure helps datasets authors to be properly acknowledged. Moreover, it gives the flexibility to accommodate many types of data of any soil variable. This is accomplished by storing each dataset using a collection of spreadsheets accessible through an online application. Spreadsheets are familiar to any soil scientist, the reason why it is easier to enter, manipulate and visualize soil data in febr. They also facilitate the participation of soil survey experts in the recovery and quality assessment of legacy data. Soil scientists can help in the definition of standards and data management choices through a public discussion forum, febr-forum@googlegroups.com. A comprehensive documentation is available to guide febr maintainers and data contributors. A detailed catalog gives access to the 14 477 soil observations – 42% of them from south and southeastern Brazil – from 232 datasets contained in febr. Global and dataset-specific visualization and search tools and multiple download facilities are available. The latter includes standard file formats and connections with R and QGIS through the febr package. Various products can be derived from data in febr: specialized databases, pedotransfer functions, fertilizer recommendation guides, classification systems, and detailed soil maps. By sharing data through a centralized soil data storing and sharing facility, soil scientists from different fields have the opportunity to increase collaboration and the much needed soil knowledge.

Keywords: Legacy soil data; National-scale datasets; Data for scenario modeling; Unified soil data repository; Database design.
Financial support: CAPES

(9553 - 413) Digital Soil Mapping: a critical analysis

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Embrapa Solos[1]; [2]

Digital Soil Mapping (DSM) has registered great expansion in recent years around the world, and was included in the fourth edition of the Soil Survey Manual (SSM, 2017), the most important reference on the subject. Nevertheless, fundamental problems related to the method's concept as well as its applications and products have been overlooked. The main issue refers to the Scorpan model, adopted as a scientific foundation of the method (SSM, 2017; p.295-6), which determine the application of environmental parameters associated to the five factors of Soil Forming Equation proposed by Jenny (1941), predictors of soil classes or properties. However, there is a deficiency on the explanation about the probability of the Scorpan model expressing quantitative relationships with minimum reliability, once one of its parameters is imponderable – age (a). On the other hand, the four other factors: climate (c), organisms (o), relief (r) (=position in the landscape), and even parent material (p), demonstrate substantial dependence with the first one. This situation reveals inconsistence of the Scorpan model regarding the soil genesis aspect, also pointed out on the inaccuracy of employing data from geology maps as an index to this forming factor (SSM, 2017; p.302), in contradiction with "Parent Material" definition presented on pages 53-54. Another not considered crucial point refers to prediction based on genesis inference, which presents a strong speculative aspect, making it impossible to compare results, therefore opposed to one of the scientific method fundaments. Due to these various uncertainty elements, DSM application has been resulting in soil maps with very discrepant, sometimes antagonistic information for the same area. In addition to the use of inadequate predictor parameters (e.g. lithology, vegetation cover) without specific knowledge as to their interrelationships, the use of pixel as the basic unit reference (= the element taken by its representation; soil class as an individual and by extension soil map as a population) results in extremely fragmented soil maps, with no correspondence with reality. Although the intent for innovation and new technologies, for disregarding the knowledge acquired through the pedolgy development, DSM directs Soil Science to pre-Dokuchaev period. The fourth edition of Soil Survey Manual is evidence of this decline.

Keywords: pedology; soil survey; soil genesis
Financial support:

(2572 - 1003) Pedometric techniques for soil horizon delineation

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Soil horizons are often assumed to be homogeneous, but fine-scale variation in physical and chemical properties within each horizon can be substantial. In this study, we used digital image and fuzzy clustering method to digitally delineate soil horizons and evaluated the purity of each horizon. We combined field descriptions, geochemical data and digital images to compare and accurately delineate soil horizons. The

RGB, CIE *L*a*b** and *HSV* color coordinates were extracted from the image and fuzzy c-means clustering was used to digitally derive horizons. Geochemical data and digital images were used to predict properties and weathering indices across the soil profile which were used in the fuzzy clustering. Confusion index, overall purity, cluster purity, horizon representation were used to evaluate the fuzziness and purity of the clusters. We found that color maps and profile maps of soil properties and weathering indices matched field delineated soil horizons. The clusters obtained by the *HSV* model represented the field delineated horizons and had the highest overall accuracy (P = 0.85). Subsoils horizon showed higher impurity.

Keywords: soil horizonation, image analysis, fuzzy clustering, horizon purity, digital soil morphometrics
Financial support: University of Wisconsin-Madison

(7009 - 2416) Probabilistic and information assessment of contemporary soil processes

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The variability and fluctuations of soil properties at all levels of the soil organization are basic features of soils because they are open complex systems. Large-scale soil investigations have shown that, even in homogeneous objects, soils are characterized by essential fluctuations of properties in space. We introduce the general approach to evaluation of the contemporary evolution of the soil (CES) according to data of large-scale soil monitoring. CES is considered as process of changes of conditions of the soil with time intervals from ten to hundred years. Assessment of changes of soil properties at fields is important because it allows to draw conclusions about the contemporary processes happening in soils caused by anthropogenic influence and climate changes. When carrying out spatial soil monitoring, points of approbation in space don't coincide at different time, so it is necessary to use probabilistic models for assessment of states and changes of soils. The characteristic of variability of property is its probabilistic-statistical distribution (PSD) within the studied object therefore the model of a condition of the soil represents the set of PSD of *n* soil properties in its *k* horizons. We have offered to use probabilistic and information indicators for assessment of condition of soils and their changes. For condition of the soil, besides the PSD functions of soil properties the information (statistical) entropy is used. For assessment of changes of soils values of information divergence of soil properties and an increment of their entropy are used. The entered characteristics allow estimating extent of influence for the soil forming factors and anthropogenic impacts on probabilistic structure of values of soil properties and its stability. The case studies have been conducted in the big territory at the south of Western Siberia. It has been shown that CES occurs under the anthropogenic influences and natural processes caused by climatic trend of warming and by cycles on moistening. It is revealed by changes of probabilistic structure of values of properties of the soil. On data of archive records the probabilistic and information assessment of changes of soils during 60-90 years of the 20th century is executed. In fact, the received models and estimates are statistical standards of condition of soils which should be used for comparison with the current and future results in the explored and neighboring territories.

Keywords: Soil processes, probabilistic models, information evaluation
Financial support:

(3349 - 2504) Prrotocol for use of legacy data for soil mapping in the São Paulo west plateau

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Information on soil resources is scarce at an adequate scale. Land information allows best planning and management of land use and supports the establishment of public policies. On the other hand, useful information for obtaining maps or information on the soils has grown a lot in the last years. The objective of this work was to establish a protocol for the delineation of soil bodies using free auxiliary information and diagnostic and non-diagnostic soil attributes. Additional information on geology, landscape dissection, pedology and relief maps was used. This information represents the main soil-landscape relationships and soil formation factors. 553 soil samples of 0-0.20 depth were collected along the roads of the state of São Paulo, within the geological province of the Western Plateau of São Paulo. Clay content, magnetic susceptibility, oxalate and dithionite iron, hematite and goethite, kaolinite and gibbsite were evaluated throughout the area. Points collected in the same geology, landscape dissection, pedology, and relief were joined and the means of the soil attribute for these points were calculated and used for the analysis of conglomerates. The hierarchical cluster analysis was performed by the Ward method. Groups obtained from cluster analysis were named numerical figures and subsequently were submitted to geostatistical analysis. The results indicated a remarkable difference between the attributes mainly for the geological and pedological data. Cluster analysis revealed the influence of each auxiliary information on group separation, with highlight for geology and for the whole area. Eleven groups or soil bodies were delineated, considering the euclidian distance of eight. The soil bodies' map showed that greater fragmentation or pedodiversity occurs in areas where there is a predominance of basalt geology. A range of 64.5 km was obtained and this might indicate the sampling planning for future soil studies within the soil bodies delineated in this work or for others studies conducted in areas that have the same geoclimatic condition. This delineation of soil bodies, in addition to consider auxiliary information and variability of soil attributes, might help to decrease the subjectivity associated with the traditional soil mapping in soil mapping units delineations.

Keywords: pedodiversity, spatial variability, soil classification, pedometry, mapping units,
Financial support: CAPES, FAPESP, BECAL

(7548 - 608) SISINTA: the Argentinian soil information system

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Soil profiles are raw material for digital soil mapping (DSM). Several DSM techniques allow to rebuild and update soil maps by combining legacy soil profiles and new soil samples. However, soil profiles are not always accessible. In Argentina, most soil profiles have been collected between 1960 and 1990 to create soil maps at different scales. Although they were systematically organised, they remained in paper support scattered in different research centres. Therefore, our goal was to create a web-based soil information system that allows (1) to digitize and to safeguard paper-support soil profiles, (2) to harmonize soil data, (3) to make them accessible for multiple users, and (4) to create a tool for visualizing soil information. The system, named SISINTA (http://sisinta.inta.gob.ar), consist of a spatial database (PostGIS) and a web fronted, whis is developed under free software standards (Affero General Public License v3.0). Our first objective was that multiple users around the country could digitize soil profiles, therefore the system was optimised for data-typing entry with a front page that resemble the field form for describing soils. In Argentina, it has been used the Soil Taxonomy for collecting and describing soils, thus descriptive data and laboratory data are compatible to this classification system and its standards. Also, SISINTA includes a web map to shows soil profile distribution, as well as a selecting tool for exporting data. Soil profiles (descriptive and lab data) can be accessed individually through a visualizer of SISINTA, or as a exportable

collection in tabular format (csv or geojson file format). Up to date, SISINTA includes more than 3700 soil profiles from several soil survey groups, covering the whole country, including the province of Tierra del Fuego, Antártida e Islas del Atlántico Sur. Since SISINTA is based on free software, it can be replicated (without data) to be used for other parties or countries. The current development of the system target to develop features for database interoperability protocols such as soilLM. In this sense, SISINTA will be able soon to be accessed through other soil databases, such as WOSIS. Future development include multi-language, advanced tools for visualizing soil profile data, as well as embedded data analysis using R functions.

Keywords: soil repository; soil profiles; databases; digital soil mapping; soil samples
Financial support:

(2785 - 2059) Soil quality mapping to characterize agricultural areas benefiting from the use of biochar in Ethiopia

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Pattern emerging from literature suggest that positive crop yield responses to biochar applications are possible, but are only anticipated when specific soil quality problems are limiting crop productivity. A meta-analysis (Jeffery et al., 2011) of 17 studies found considerable variability (range from −28% to +39%), but an overall small mean positive (10%) crop yield response to biochar applications. Land degradation is the most important limitations for optimal use of land resources for higher crop production in Ethiopia. However, prediction of positive agronomic responses from biochar application to soil might not be as straight forward as the effects of biochar on C storage. Therefore, a better understanding of the spatial variability of soil quality attributes important in relation to agronomic response from biochar application to a soil would enable for refined biochar based agricultural and environmental management practices by identification of proper sites for management. The objectives of this study were to examine the spatial variability of surface soil properties like pH, OC, CEC available P using spatial prediction methods to identify and delineate agricultural areas suitable for biochar application at national scale. Soil property status maps (pH, soil organic matter - SOM, cation exchange capacity- CEC and Phosphorus contents - P) generated by the Ethiopian Soil Information System (EthioSIS) project of the Ethiopian Agricultural Transformation Agency (ATA) are used for this study. Ensemble modelling of three different machine learning algorithms, namely: random forest-RF, gradient boosting model – GBM, and deep-learning neural network (DNN) comprised of field data and laboratory analytical results of 62,440 geo-referenced soil samples, and twenty one different covariates on the R language and environment for statistical computing. Application of biochar to acidic, poor phosphorus containing and low CEC soils of Ethiopia that accounts for 6% of the total area of the country is highly beneficial. On the other hand, the effectiveness of use of biochar requires verification studies in order to ground truth the machine learning based overlay analysis that is interlinked with the indexes used as a cutoff points in this study. Inclusion of the intrinsic property of a soil, particle size distribution, water holding capacity of soils and other biogeochemistry properties should be considered in similar study to refine results.

Keywords: Biochar, ensemble modeling, machine learning
Financial support:

(4726 - 2828) Soil-landscape relationships and digital soil mapping in Maranhão State, Brazil

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The factors of soil formation, climate, organisms, relief and parent material acting together in different intensity during certain period, define the nature of soils and their spatial distribution on earth surface as a continuum. Soil attributes may give information on soil evolution and spatial distribution patterns. Soil survey using conventional techniques results in polygons maps of soil types. These maps are limited in the reproducibility of methodology and lack of uncertainty information. In the last decades new methodologies for soil mapping appeared, identified as Digital Soil Mapping (DSM), which use soil-landscape relationships to predict soil properties and/or soil classes. The relationship between different environments and soils in Maranhão State is complex, since it is located in a transitional zone between semiarid and equatorial climate, with a large diversity of relief forms and lithology. In the northwest region, originally covered by rain forest and with Precambrian parent material, Alisols and Plinthosols dominate. Along the coast and in the Maranhão Golf, with unconsolidated Quaternary sediments from wind and fluvial-marine deposition, an extensive plain is dominated by Gleysols and Vertisols, as well as some Fluvisols and Histosols. The largest geomorphological domain is formed by the sedimentary basin of the Parnaíba River and older Plio-Pleistocene sediments, showing a great lithological and pedological diversity. This domain shows large plateaus in the center-south region of Maranhão State, with sandstones from Permian period, covered by cerrado vegetation and dominated by Ferralsols and Arenosols. In the western part of the state, basaltic rocks from Jurassic-Cretaceous period are found, forming Nitisols, Ferralsols and Vertisols, covered by evergreen forest, a transition to Amazon forest. In the central-northern portion of Maranhão State, with layers of sediments from Cretaceous age, Plinthosols are associated to Alisols, under a transitional vegetation of palm trees locally identified as *Mata de Cocais ("Babaçu")*, and, to a minor extent, Luvisols, Phaeozems and Alisols can be found. This study presents a first attempt in exploring the expert knowledge of soil-landscape relationships in Maranhão State, in order to develop predictive models to estimate soil classes and soil properties by DSM techniques.

Keywords: Pedogenesis, MDS, Maranhão State, soil modelling
Financial support:

(9221 - 2960) Soils in the Anthropocene – revisiting SCORPAN covariates for DSM in cities

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Over half of the global population now lives in urban environments yet we know little of the specific characteristics and services of soils in cites. Understanding soil genesis and their spatial distribution in cities needs historians, archaeologists, engineers in addition to pedologists. Soil classes in cities are heterogeneous and often patchy (although this may be a reflection of the ease of observation). This makes application of traditional DSM approaches challenging but can be achieved by identifying suitable covariates. This study proposes a new framework for developing DSM approaches in urban environments so that we can better represent the function and services of soils to urban communities and planners. Initial stages involve the co-production a conceptual model of soil development drawing on expertise and data from atypical actors and stakeholders such as archaeologists and

underground utility contractors. The model guides the selection of appropriate covariates that capture aspects of anthropogenic influence on urban soil development. Example spatial datasets include observations from archaeological excavation, landscape and architectural characteristics and evidence for WW2 bomb damage as proxies for subsurface modification and input of technogenic materials. Additional data can be crowdsourced from citizen science approaches to augment the covariates. Key community groups that dig or expose soil in the urban environment (e.g. urban gardeners, archaeologists and construction workers) can also provide expert knowledge into the DSM process.

Keywords: digital soil mapping cities urban soil
Financial support:

C1.6 - Paleopedology

C1.6.1 - Human-environment interactions recorded in soils and palaeosols

(4468 - 2750) Main patterns of human-environment interaction during the Holocene recorded in soils of the Kuiavia region (central Poland)

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In postglacial landscapes of the Kuiavia region (central Poland, central Europe) numerous sites with buried soils were found, evidencing episodes of geomorphological activity during the Holocene – in general characterized by the temperate climate promoting dominance of subboreal forest vegetation. Two main kinds of soil-scapes and patterns of their transformations have been distinguished: 1. morainic plateaux domianated by fertile 'Black Earths' (Mollic Gleysols, Chernozems) and 'Lessive Soils' (Luvisols, Retisols) developed in loamy materials – transformed mosty by slope processes – erosion and colluvium accumulation; 2. sandy glaciofluvial terraces and aeolian mantles and dunes occupied by Podzols, Brunic Arenosols and Gleysols covered with series of aeolian sands. 14C and archaeological datings show clear correlation of geomorphological activity leading to burial of soils and human settlement intensification since Mesoholocene. Although, moraine plateaux seem to be settled ca. 2 kyr earlier than sandy areas. Phases of Neolithic, Early Bronze, Roman Times and the Middle Ages cultures impact on the environment were interrupted by periods of landsurface stabilization and soil cover development under the secondary forest vegetation reaching various stages of natural succession. Specific soil-scapes were preferencial for location of the settlement during the Meso- and Neoholocene, that is proved by numerous multi-cultural archaeological sites. On sandy terraces and dunes dry Podzols and Brunic Arenosols were good places for settlement. More fertile Gleysols appearing in the vicinity were used for agriculture. Red-coloured Rubic Arenosols indicate places of probable former freshwater sources. On maraine plateaux ranges of fertile 'Black Earths' were settled mosty on their borders. Evidence of intentional and deliberate use of various soil materials has been documented in Neolithic kurgans construction. It is very likely that already in that period the soil could be an important element of the humans life cultural sphere.

Keywords: Holocene, human-environment interaction, paleosols, pedoarchaeology, Black Earths
Financial support: National Science Centre Poland, Project Number 2016/23/B/ST10/01067

(5599 - 1633) Micromorphology as a tool for diagnostics of former human environmental interactions within medieval settling areas in different environmental backgrounds

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Studying cultural layers of former settlements, and regularities of their formation, we deal with the historic legacies of the soil-society interactions in the past. It is important both as a contribution to practical geoarchaeology and for basic understanding of former human environmental interactions produced cultural layer in the historical past and transforming ones after settlement desolation. Micromorphology started in archaeology since 50s of the XX c., soon after soil micromorphology was established. An exponential growth of micromorphological works in archeological context began in 90-s of the last century. There are hundreds of publications on archaeological micromorphology; nonetheless, a recent paper by the world-leading experts declares that the method is still underutilized in geo(archaeology) (Goldberg, Aldeias, 2016). Actually most of on-topic publications are case studies devoted to applied geoarhaeological problems. Further progress of archaeological micromorphology in basic knowledge about human-environmental interactions within former settling areas demands efforts on compilation, generalization and synthesis of information on micromorphological features in cultural layers of different age, cultural, economical, and natural environmental backgrounds. Our study is an attempt to compare micromorphological features of early medieval archaeological sediments located in different background environments. A key advantage of micromorphology is demonstrated: an opportunity for separate identification of anthropogenic and geogenic features, their space-and-time interactions, related processes of their formation. Conducted studies revealed clear geographic and geochemic regularities in occurrence of geogenic (soil, sedimentary and post-sedimentary) microfeatures. Anthropogenic features were subdivided into those related to disturbance of original horizonation and its replacement by anthropogenic ones, features related to anthropogenic material input, and man-induced neoformations. A set of anthropogenic features imprints local past human impact: the higher a variety of athropogenic features and their abundance is, the more intensive and variable human impact occurred in the past. An occurrence of certain anthropogenic features may indicate not only human-related processes of their formation (or input), but also a contemporary soil environment favorable, or, in the opposite, deteriorative for ones.

Keywords: archaeological sediments, cultultural layers, micromorphology
Financial support: Theoretical developments of this study were financed by the Russian Science Foundation, project no. 14-27-00133; thin sections were prepared with the support of RFBR project 16-06-00380, and DFG project HA 6443/1-1

(7926 - 1237) Potential application of $^{239+240}$Pu in Austria as a soil erosion rates proxy

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The need for effective soil management has raised the demand for reliable proxies to assess soil erosion magnitudes. As compared to other isotopic techniques, anthropogenic Pu radioisotopes have the

main advantages of having long half-lives, which ensures they long-term availability to be used as potential indicator of soil erosion magnitude. This area of study is still in development with only few studies conducted in Australia, China, Germany, South Korea and Switzerland that have demonstrated the potential of using $^{239+240}Pu$ in soil redistribution researches in agroecosystems. Within the IAEA CRP D1.50.17 (i.e. Nuclear Techniques for a Better Understanding of the Impact of Climate Change on Soil Erosion in Upland Agro-ecosystems), the Soil and Water Management and Crop Nutrition (SWMCN) Laboratory is carrying out an investigation at the experimental research station of the Austrian Agency for Health and Food Safety to evaluate the potential of Pu isotopes as soil tracers. For this study, a flat and undisturbed pasture plot of approximately 100 m^2 was selected as reference site, from which a detailed soil profile for precise incremental radioisotopic determination and 12 bulk cores were collected. The samples were analysed for ^{137}Cs and $^{239+240}Pu$ contents. The results confirmed the suitability of the reference site, which exhibited an exponential decrease of the radionuclide content with depth, as well as high areal activity content on the top 12 cm of soil: 79% and 73% for ^{137}Cs and $^{239+240}Pu$, respectively. The bulk core samples collected allowed to evaluate the initial fallout with a mean value of 8179 Bq m^{-2} for ^{137}Cs (n=12; CV of 22%) and a mean value of 56.1 Bq m^{-2} for $^{239+240}Pu$ (n=12; CV of 28%). The similar behaviour of $^{239+240}Pu$ to ^{137}Cs in the reference site corroborates the potential suitability of $^{239+240}Pu$ to be used as a soil tracer to assess soil redistribution rates in Austrian agroecosystems. Results yielded by a new sampling campaign in the year to come will allow to determine soil redistribution through a combined approach using both Cs and Pu isotopes along a transect of a nearby agricultural field.
Keywords: Soil erosion, Anthropogenic tracer, Plutonium isotopes
Financial support:

(1796 - 1368) Proxies of degraded Acrisols under sloped pastures in the State of Rio de Janeiro (Brazil)

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Soils in the State of Rio de Janeiro have been suffering from severe degradation during the last four centuries initiated by deforestation of pristine Atlantic Forest, followed by exploitive and inappropriate land-use and accompanied by a changing climate with longer droughts and pronounced heavy precipitation events. Some decades ago coffee plantations and smallholder sugar cane cultivation went unprofitable due to overexploitation of soils and global market competition. In substitution, cattle pastures were established on erosion-sensitive slopes, most of them inappropriately managed. Fertilized and limed pastures represent today one of the last fairly profitable land use options on Acrisols, Ferralsols and Cambisols on slopes in the state of Rio de Janeiro, exacerbating soil degradation. Degradation is mainly driven by extensive cattle movement and frequent and strong precipitation events on sparsely vegetated sloped pasture areas. Particularly Acrisols suffer from severe water erosion, increased soil compaction, low water infiltration and depletion of soil macro nutrients and organic matter. Acrisols without any soil protecting vegetation have remarkably been losing resilience against degradation. It is assumed that Red Acrisols (Argissolo Vermelho) are more vulnerable to water erosion than Red-Yellow Acrisols (Argissolo Vermelho-Amarelo), to be recognized by deeper rills and gullies. In this study we discuss proxies for both Acrisol types on areas of low, medium and high erosion vulnerability (RUSLE approach) at micro-watershed level. The soil degradation indicators bulk density, porosity, macro-nutrient content and C_{org} in the upper soil are discussed for both Acrisol types and each vulnerability class. Acrisol properties under Atlantic Forest fragments serve as near-natural reference. Study area is the North-West of Rio de Janeiro State, dominated by pasture on Acrisols. Soil analysis data from own sampling campaigns is supplemented by secondary data from the online Information System of Brazilian Soils (Embrapa) and regional research studies within the municipalities of Itaocara, Santo Antonio de Padua and adjacent municipalities. The use of appropriate proxies as degradation indicators allows for an easier and faster assessment of the degradation degree of Acrisols under pastures. Moreover, it facilitates an assessment of actual or future tipping points in degradation resilience of Acrisols which would entail the abandonment of recent land uses.
Keywords: pasture, degradation, Acrisol, proxy, RUSLE
Financial support: German Federal Ministry of Education and Research (BMBF), INTECRAL Project-number: 033L162F

(9257 - 1195) Spatiotemporal landscape changes under human influence recorded in an agrarian kettle hole

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Humans have affected the landscape they live in since prehistoric times. Practices such as deforestation and agricultural activity triggered erosion processes, changing soil and landscape functions. Present day soil and landscape properties can help understand these past dynamics and quantify the spatial and temporal changes of the landscape. We examined a 4 ha agrarian kettle hole catchment in NE Germany (CarboZALF-D) to identify phases and rates of human induced erosion. Kettle hole catchments are suitable test sites for studying the effect of erosion on the landscape, because the detached soil material is stored locally in the closed depressional catchments. This enables the simultaneous evaluation of erosional patterns and corresponding depositional patterns. A set of 160 detailed soil descriptions was used to reveal spatial patterns of erosion and deposition throughout the catchment by looking at truncations of soil profiles and soil types. A set of 32 OSL ages recorded from five positions in the depression was used to reveal detailed temporal patterns of deposition in the kettle hole. The hillslopes show a variable pattern of soils with different grades of erosion. Most soils are strongly eroded, showing the large impact humans had in the area. The OSL ages show that the onset of deposition occurred ~5000 years ago. Different phases of deposition, with increasing rates, were identified. These phases were not always optically distinguishable in the soil profiles. Remarkably, the oldest ages were found on the fringes of the depression, while the center of the depression is only affected by the most recent, ongoing phase of deposition, which started ~200 years ago. We recommend combining numerical dating techniques with soil surveys to identify spatiotemporal patterns of landscape change, to avoid incorrect correlation of colluvial layers and thus to make a correct interpretation of the landscape dynamics.
Keywords: OSL, agricultural landscape, erosion, colluvium
Financial support:

C1.6.2 - Soil memory: proxies for deciphering records of past environmental conditions in soils and palaeosols

(8682 - 2294) Buried soils of the East European Plain as a proxy for Late Holocene spatio-temporal paleolandscape dynamics

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Buried soils of archaeological monuments are important archives of

past environments. Late Holocene archaeological sites are widely spread in the forest, forest-steppe and steppe zones of the East European Plain and have a long study history. However, the regional and local environmental trends remain uncertain. We focus on comparative study of the paleoclimatic conditions and landscape dynamic in different climatic zones of the East European Plain based on soil chronosequences that include soils buried under burial mounds of the Bronze age and Medieval time and defensive earth walls of fortified settlements of the Early Iron Age and the surface soils formed in similar sediments and similar landscape position. Objects of research are located in different natural areas: broad-leaved forests, forest-steppe and steppe. Nozha-Var settlement and burial mound in Tsivilsk are located in the broad-leaved forest (Chuvash Republic), three settlements were studied in the central part of the forest-steppe zone (Lipetsk region), in south part of forest-steppe zone buried soils under fortified wall of Scythian settlements was studied. Two large uneven-aged groups of burial mounds, which were located not far from each other in the Orenburg region, were investigated in the steppe zone. The relevance of the study is based on a multidisciplinary approach that includes a combination of conventional and state-of-the-art methods, including isotopic, biomorph (pollen, phytoliths), morphogenetic studies of both soil and sediment features at various hierarchical levels (macromorphology, mesomorphology, micromorphology, electron microscope), geochemistry and the study of soil microbiome. Age determination was based on radiocarbon dating of various substances (coal, carbonates, humus, wood, bones, and ceramics) and a set of existing archaeological data.

Keywords: paleopedology, Holocene, paleolandscape
Financial support: This study is supported by the Russian Science Foundation, project no. 16-17-10280

(4708 - 383) Diagenetic reddening of Early Eocene paleosols on King George Island, Antarctica

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The objective of this study was to determine if the Early Eocene paleosols on King George Island, Maritime Antarctica, have acquired their reddish color during the paleopedogenesis, by burial diagenesis and/or by heating of a covering lava flow. We used micromorphology, diffuse reflectance spectroscopy, X-ray diffraction, and mineral magnetic properties to identify the iron oxides in these paleosols. These are weakly/moderately developed paleosols formed on a basaltic tephra under a cool humid paleoclimate, therefore, prone to ferrihydrite and goethite rather than hematite formation. However, the iron oxide assembly was dominated by maghemite and hematite. Nevertheless, the large grain size and high crystallinity of hematites suggested they are rather diagenetic than pedogenic. The clustering, content and distribution of hematites (finely dispersed on the groundmass; coating/replacing primary minerals and as mottles and/or nodules) rather than their crystal size were responsible for the color differences. These properties were likely the result of past pedogenesis processes (forming originally ferrihydrite) linked with paleodrainage conditions. Heating by the covering lava flow affected the magnetic properties of two profiles but without affecting their color. Taken together, all these results suggest that the burial reddening took place by dehydration and transformation of ferrihydrite to hematite. Our findings highlight the importance of detailed mineralogical analysis to identify iron oxides present in reddish paleosols because identification based solely on morphology (e.g. yellowish color, gradual horizon transitions) can lead to misinterpretation of paleoenvironmental conditions.

Keywords: Red paleosols Diagenetic reddening Hematite formation Lava flow heating Magnetic susceptibility
Financial support: National Counsel of Technological and Scientific Development (CNPq); German National Foundation (DFG)

(8629 - 643) Natural trends of Holocene evolution of Chernozems and Luvisols: East European Forest-Steppe

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East European forest-steppe, like other natural ecotones, is an interesting object to study climate changes and responses of vegetation and soils to them. According to pollen and paleosol records, Early and Middle Holocene in its central part (50°–54° N, 35°–39° E) were mainly characterized by dry climate with a predominance of steppe vegetation and subordinate position of forests. Episodes of climatic humidization and expansion of forests took place in the Boreal, Atlantic, and Subboreal periods (9000–8300, 6500–6000, and 5000–4200 BP, respectively). During dry periods, forests returned to their initial positions in ravines and bottoms of river valleys. The intervals of humidization were insufficiently long for the development of Luvisols under broadleaved forests. Our studies of soil chronosequences at archaeological sites suggest that it takes no less than 1500 years of forest pedogenesis for transformation of loamy Chernozems into Luvisols. Thus, in spite of the alternation of grasslands and forests in the first half of the Holocene, the soil cover of forest-steppe in that period was uniform: Chernozems predominated. The formation of modern forest-steppe in the northern part of the region began about 5000 BP; in the southern part, about 3000 BP. These time limits may be considered regional "starts" of the Late Holocene. Since then, large forest areas have been appearing and preserved for a long time in the corresponding parts of the forest-steppe because of a general humidization and cooling of the climate. This transformation was due to new climatic conditions under forest canopy: more shadowed, cool, and moist. This is how the modern forest-steppe with two major soils — Chernozems under steppes and Luvisols under broadleaved forests — began to develop. Chernozems under forests were slowly transformed into Luvisols through the transitional stage of Phaeozems (Luvic Greyzemic Chernic Phaeozems). At the end of the Middle and in the Late Holocene, Chernozems of steppes continued their development in the direction of the A+AB horizons growth and leaching from carbonates. Thus, (1) there were two stages of the soil cover development in the modern forest-steppe zone—the Early and Middle Holocene stage with uniform soil cover composed of Chernozems and the Late Holocene stage of heterogeneous soil cover with Chernozems and Luvisols; (2) Chernozems in the study area are an older group of soils in comparison with Luvisols.

Keywords: Holocene; forest-steppe; Chernozems; Luvisols; soil evolution
Financial support: Russian Science Foundation, Project Number 14-17-00171, «Regional responses of environmental components on climate change varying periodicity: South forest-steppe of the Central Russian Upland».

(2485 - 2169) Paleosols as indicators of Superior Pleistocene's climatic change in Southern Pantanal (Brazil)

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The Pantanal is an active sedimentary basin with a 500 meters thick.

It is the largest tropical wetland in the world, with a total of approximately 150,000Km^2, being characterized by megafans. Soils and paleosols associated with megafans have been studied in several parts of the world. However, in the Pantanal, studies that associate soils with the different geomorphological units within the megafan are relatively recent and are especially associated to soils developed in the Holocene. The fact that it is an active sedimentary basin implies that vertical sections are rare, making it difficult to observe expressive successions of deposits and paleosols, which makes relatively rare the works that approach this theme in the area. Only in very specific situations are exposed good sequences that allow the observation of the soil/sediment association and the presence of paleosols. In the case of the section studied here, the avulsion of the Aquidauana river (Aquidauana, Mato Grosso do Sul state) caused the erosion of Pleistocene deposits, which exposed a section 7.5 meters thick, presenting three profiles of paleosols overlapping the deposits with preserved sedimentary structures. The objectives of the work were to define the time intervals of pedogenetic development and to associate these pedogenesis with paleoclimate information for the area. The profiles were described and the samples were collected for granulometric, chemical, mineralogical and dating analyzes. On the surface of the section there is a Planosol with low base saturation and presence of kaolinite, iron nodules and manganese films, developed on 29,757 ±2.308 years old deposits. This profile is superimposed on two Vertisols profiles: the superior profile of Vertisol developed over deposits dating 57,056 ±3.966 years old and the lower Vertisol was developed above deposits dated to 72,249 ±5.457 years old. These two Vertisols present high base saturations, carbonate rhizoliths and essentially montmorillonite in the clay fraction. Clearly the climatic conditions of development of the 3 profiles are very distinct, drier in the period associated with the Vertisol profiles and more humid associated with Planosol. It should be noted that a very humid moment (significantly wetter than the current one) is indicated for the area at approximately 20,000 years, a period associated with the development of Planosol. Prior to 30,000 years the conditions were significantly drier.

Keywords: Megafan; mineralogy; LOE
Financial support: Fapesp, Project Number 2014/06889-2

(9201 - 1812) Relict paleosols in Mexico: their significance as environmental record of past landscapes

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The case of paleosols persisting on the land surface (non-buried paleosols or relict soils) besides paleoecological interest has specific implications for studies of soil geography, ecology and management. In fact these soil bodies form part of the modern soil mantle and provide ecological services for the current (agro)ecosystems but are neither formed nor re-produced by these ecosystems, conforming locally extinct soils (although similar profiles can develop at present under other bioclimatic conditions). In consequence, they are a heritage of past climatic and biotic conditions now extinct, thus presenting a non-restorable component of the present landscape. Mexico has so abundant and diverse paleosols, both surface and buried, that really could be considered to be a "paleopedological paradise". Two groups of factors promote generation of this abundance: Major part of territory of Mexico is occupied by mountainous landscapes with high intensity of tectonic, volcanic and geomorphic processes. These processes create a complex mosaic of geological materials and landforms of different age (like alluvial and lake terraces, eroded slopes, and volcanic deposits of various eruptions). Meanwhile younger landsurfaces are occupied by the recently developed soils, the older ones could bear the relict soil bodies. The same processes produce sedimentary strata (alluvial, colluvial, pyroclastic, etc.) which frequently cover the pre-existing landsurfaces and soils, producing series of buried paleosols. In this work we present three study cases of relict paleosols that are integrated to the modern soil cover of Mexico: the case of reddish-brown soils in the arid landscapes of Sonora (in the north); the pedosediments (tepetates) in central Mexico; and the red soils developed under humid conditions in Yucatan (in the south).

Keywords: paleosols, Mexico, landscape, reconstruction
Financial support:

(5360 - 2026) The morphological features and chemical composition of Fe-Mn nodules in a deep soil derived from loess at a stable upland in northeastern China and their significance

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Fe-Mn nodules containing iron and manganese oxides in soils can be related to the redox in diagnostic characteristics of soil taxonomy and should play a crucial role in the classification of soil groups and subgroups. In this paper, morphological features and chemical composition of Fe-Mn nodules in temperate soils in a deep soil derived from loess at stable upland in an archeological site in northeastern China were investigated. Some meaningful results were listed as follows. 1) Fe-Mn nodules could be found in each horizon from top to bottom.The nodule content changes with soil depth. The largest total amount by weight of nodules 17.73 g/kg was in Bts5 horizon and the least amount of nodules appeared in 2Bt1. The nodule amount in 0.5-1 mm is greater than in 1-2 mm. The greatest content of 1-2 mm nodule is in Bts5 and the least in 2Bt2; the largest amount of 0.5-1 mm nodules is in the Bts6 and the least in 2Bt1. 2) Fe-Mn nodules were found in light (7.5YR 5/8-4/3) and dark (7.5YR 3/4-2/1) color. Light color nodules were predominantly present in the 15-110 cm horizon. The percentage of light color nodule increased with decreasing nodule size. They were in spherical or ellipsoidal shape. 3) Forty out of 53 elements accumulated in the Fe-Mn nodules. The elemental enrichment of nodules in 0.5-1 mm was slightly greater than that in 1-2 mm nodules. The SiO_2 content decreased with nodule size whereas MnO and Fe_2O_3 increased. The content of free iron oxide in nodules was greater than that in the surrounding soil. The activity of iron in nodules was stronger than that in matrix, while the activity of Mn was less than that in matrix. The mineral in nodules was mainly quartz, fieldspar, micas, and goethite. 4) Silicate minerals containing k and Na with large pore spaces were initially cemented predominantly by Fe-oxides as a nucleus of the nodule. The band structure could be found in some Fe-Mn nodules larger than 0.5 mm. The larger the size of Fe-Mn nodules was the more obvious the bands appeared. The dark brown bands interbedded with the black band, and the dark brown band interbedded with the brown band were observed. A large band of Fe-Mn nodules with sub-bands indicated that the formation of Fe-Mn nodules experienced several redox and was long enough to record the soil formation environment. The band structure of nodules likely formed in response to seasonal wet-dry and freeze-thaw as an accretionary process.

Keywords: Redox processes; chemical composition; freeze-thaw; wet-dry
Financial support: National Natural Science Foundation of China, Project Number 40971124 and 41371223

(2873 - 1389) The transition from interglacial to glaciation in the loess-paleo-soil memory as a model of the modern era

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Frontier 117-115 thousand years ago was the transition from the previous interglacial (MIS 5e) to the last glaciation (MIS 5d). It can be

considered as a model of the modern era – the transition from the Holocene to the subsequent glaciation. Modern interglacial climate era is over. The last completed interglacial period was warmer than Holocene, but was characterized by repeated sharp drops in temperature. The markers of natural events can be identify in the loess-paleosoil sections: 1. Buried soils and soil-like formation (pedosediments). 2. Buried geomorphological forms, surfaces, erosion lines, disagreement of bedding layer. 3. Lithological layers with characteristic textural features: pyrogenic, volcanic ash, etc. 4. Cryogenic deformations (the features of seasonal perennial frost): cracks, wedges, pseudomorphs, cryoturbations, solifluctions, postcryogenic textures. 5. Traces of a sharp change of hydrothermal, gravity and tectonic conditions. Paleogeosystem components responsible for the different phases of climatic rhythm. Soils are the markers of warming. They reflect the phases the most favorable for biota during the interglacials, interstadials, interphasials. Rocks (especially with cryogenic features) are the markers of cooling. They form during the least favorable phases for biota: glaciations, stadials, phasials. Landforms, high rates of sedimentation characterize unstable, transitional phases, also unfavorable for the development of the biota and soils. The ratio of the three factors determines the basic structure of the climatic rhythm. The structure of Interglacial - glaciation rhythm can be determined according to the role of leading environmental (pedo- and morpholithogenic) processes. Relief-forming processes prevail during glacial to interglacial transition and vice versa: aeolian and slope sedimentation, cryogenesis, cutting, aggregation of forms and relief planation. The leading soil forming processes during the warm cycle are: humification, textural differentiation and gleyization.

Keywords: Paleogeosystem; Previous interglacial; Cryogenic; Pyrogenic features; Phases of climatic rhythm

Financial support: Institute of Geography RAS

C2.1 - Soil physics

C2.1.1 - Soil structure dynamics

(5663 - 336) Agricultural management practices effect on soil structural stability

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Finding out the best agricultural management practices for certain climatic regions and soils is crucial to maintain soils quality. The main indicators evaluated during the regular soil survey have been chemical parameters. At the same time soil structure is one of the most complex parameters indicating soil quality. Different methods have been developed to evaluate structure in laboratory as well in field conditions. During the project iSQPER the aim is to evaluate the effect of different environmentally friendly agricultural practices on soil quality by visual assessment tools. The aim of the current study was to compare visual assessment with laboratory measurements on Estonian farm fields' upper 25 cm layer. Visually the soil structure distribution was evaluated by dropping test. For slaking test 3 air-dry aggregates with 4–6 cm diameter were placed to the water in the mesh of 1 cm diameter. For both tests the score 0, 1 or 2 was given, so that bigger number reflects the more desirable conditions. In the laboratory the water stable aggregate stability was measured from the fraction 0.25–2 mm using the Eijkekamp wet sieving apparatus. The environmentally friendly practices studied were no-tillage, minimum tillage, use of manure, change from arable to grassland. The study revealed less slaking of aggregates under environmentally friendly practices compared to the fields without these practices. However, structural distribution was better by ploughing compared with minimum or no tillage, and better without slurry use compared to the fields without slurry. Overall visual assessment score in case of minimum tillage was higher when the fields were over 8 years under this management compared to the fields where the practice was applied less than 4 years ago. Fine aggregate (0.25–2 mm) stability was 5–15% higher under minimum and no-tillage compared with ploughing in most of the cases. It was in correlation with increasing organic carbon content but was not related with number of earthworms. Use of slurry gave contradictory results. In most cases it increased structural stability, but reduced also porosity and resulted denser tillage pan compared with the fields without use of slurry. The reason can be of the timing of slurry spreaders use, while in wet conditions this equipment can induce severe compaction due to their heavy load.

Keywords: no-tillage, minimum tillage, slurry, grasslands
Financial support: European Union's Horizon 2020 research and innovation grant no 635750 iSQAPER

(6792 - 2032) Agricultural management type influence on soil microbial biomass and physical properties

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Soil biodiversity abundance plays a very important role in the maintenance of good soil structure. In turn, agricultural management type can influence soil microbial community size and aggregate stability. Thus, the introduction of cover crops in the crop rotation system is relevant for the organic matter content enhancement, microbial biomass and aggregate stability improvement, also in the Nordic conditions. In this study, the effect of different cover crops on soil microbial biomass, earthworm abundance and aggregate stability was analyzed comparing two types of agricultural management. The experiment included three organic plots: control, winter cover crops and winter cover crops with manure (40 Mg ha^{-1}) and conventional - with mineral fertilizer ($N_{150}P_{25}K_{95}$ kg ha^{-1}). The crop rotation was composed of the following main types of cultures sown in spring and cover crops in autumn: potato – cover crop rye; pea – cover crop oil rape; winter wheat – cover crop rye with oil rape; red clover – winter wheat; and barley undersowed with remaining red clover over the winter. The sampling was done at the end of the second rotation, which means that the experiment has been running already for 10 years. The results reveal that crop rotation plus winter cover crops treatment for microbial biomass C was 47.97 (mg C kg^{-1}) and much lower for conventional – 19.04 (mg C kg^{-1}), control - 23.69 (mg C kg^{-1}) and winter cover crops with manure – 18.77 (mg C kg^{-1}). The same trend was obtained also for microbial biomass N, with a higher microbial population N in winter cover crops and the lowest in control, winter cover crops with manure and conventional. It was found that organic farming system with winter cover crops and winter cover crops with manure lead to higher aggregate stability, being 55.08 % and 56.66 % respectively, compared to 52.0 % for conventional and 52.41% for control. As for earthworm abundance, the lowest values were registered for control and the highest for winter cover crops treatment. Beside that organic C, analyses revealed that the highest content was in the treatment with just winter cover crops compared to other treatments, which lead also to higher microbial biomass C. These results show that winter cover crops had a higher positive effect on microbial biomass C and N and soil aggregate stability. Although, it is not clear why in winter cover crops with manure treatment microbial biomass C and N was lower, thus future research are recommended.

Keywords: *cover crops, organic farming, conventional agriculture, aggregate stability*
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(3487 - 419) An assessment scheme for soil degradation processes caused by forestry machinery

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This study combines the results of different research projects concerning classification and quantification of soil strength and trafficability during timber harvesting in order to develop an assessment scheme for soil degradation processes caused by forestry machinery on skid trails. Six different machine types were tested on seven different study sites in Lower Saxony between 2012 – 2014 and in Baden Württemberg since 2016, Germany. During these studies, disturbed and undisturbed soil samples were taken in 20 cm, 40 cm and 60 cm soil depth to determine physical soil parameters like precompression stress (P_c), shear resistance (τ_r), total pore volume (TPV), air capacity (AC), bulk density (ρ_t), saturated hydraulic conductivity (k_s) and air conductivity (k_a) as well as texture, pH-value and content of organic matter. Furthermore, major principal stress (σ_1) and shear stresses (τ_s) caused by the tested forestry machinery were measured with the stress state transducer system (SST). As a result of these measurements an assessment scheme was developed, which can be divided into two levels. The first level distinguishes internal and external soil parameters influencing soil stability. Internal soil parameters are processes and elements which strengthen soil and soil stability describing parameters (P_c and τ_r), for example clay migration and matric potential. External parameters are elements like wheel load or contact area finally resulting in stress impacts (describing parameters: σ_1 and τ_s). The comparison of internal and external soil parameters lead to the second level of this assessment

scheme describing four different processes of soil degradation and deformation: elastic deformation, plastic deformation, failure of bearing capacity and homogenization of soil structure. The consequences for a sustainable land use includes the option to define site and climate specific machines for timber harvesting and trafficability without negative impact for soil physical, chemical and biological functions. During the oral presentation, we will document the results of these measurements and the derived recommendation scheme.

Keywords: Soil degradation, soil compaction, forest soils, forest machinery, timber harvesting, assessment scheme
Financial support:

(7676 - 2315) Assessing continental-scale influences of exogenous and endogenous controls on soil structural development

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Soil structure develops in response to exogenous factors such as atmospheric precipitation, temperature, and plant roots. This development is mitigated and constrained by endogenous soil properties such as particle-size distribution, organic matter content, and clay mineralogy. However, little is known about the relative influences that these factors and properties have on a continental-scale in controlling the expression and evolution of soil structure. Here we investigated these exogenous and endogenous influences on soil structure by examining the expression of morphologically-described ped shape, size, and grade in a large soil database of the conterminous USA. In this work, we combined pedon descriptions from the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) National Soil Information System (NASIS) with laboratory data maintained in the National Cooperative Soil Survey (NCSS) Soil Characterization Database. This dataset was merged with climatological information (30-year normals) from the Parameter-elevation Regressions on Independent Slopes Model (PRISM). In addition, both Köppen-Geiger climate classes and US Forest Service (USFS) Ecoregion classes were assigned to each sample based on geographic information contained within the database. The resulting soil, climatological, and ecological information was arranged into a flat 2-D data matrix format known as the University of Kansas Research Dataset of Soils (KURDS) containing approximately 95,000 unique soil horizons (matrix rows) from over 20,000 pedons with over 1,000 variables (matrix columns). The variables describe geomorphic, geographic, taxonomic, morphological, physical, chemical, mineralogical, climatological, and ecological properties of each soil sample. We applied multinominal logistic regression modeling and decision tree analysis to evaluate relationships between these variables and qualitative and quantitative descriptions of soil structure on a set of samples filtered to account for effects of parent material, pedogenic development, and landuse. Samples were grouped into surface and subsurface horizons to investigate soil structural relationships with exogenous and endogenous variables at depths that correspond to primarily biotic or abiotic processes. Overall, our results shed light on the relative continental-scale influences of the factors of soil structural development

Keywords: Soil structure, multinominal logistic regression, decision tree analysis, big data
Financial support:

(5178 - 279) Drying and rewetting cycles influence the particulate fraction distribution of new organic matter in soils, a ^{13}C-lignocellulose essay.

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Drying and rewetting (D/R) cycles will be intensified under extreme climate change scenarios, these cycles are one of the main drivers of soil organic carbon (SOC) destabilization enhancing aggregate disruption and exposing previously protected soil organic matter (SOM) to microbial attack. SOM have different degrees of protection (POM), the light fraction (FL) is a less processed organic compound that is residing on macroaggregates (>250 µm). Soil disturbance, e.g. soil cropping or D/R, affects first soil macroaggregates exposing the SOM to microbial attack, and after, more protected fractions like occluded POM (Intraggregate OM) or the mineral bounding soil organic matter. More intense and frequent D/R cycles will increase the turnover of soil aggregates (disruption, slaking and construction) and might produce a limitation on soil C sequestration. The aim of this work was to evaluate the effect of D/R cycles on soil C sequestration. We hypothesized that under climatic change variability the frequency of D/R cycles causes slaking of soil aggregates leaving POM unprotected from microbial attack. An incubation experiment with undisturbed forest soil cores of Nahuelbuta National Park, Chile, was performed at two temperatures 5° and 25°C. The labeled ^{13}C-lignocellulose residue was applied at the beginning of the essay and three treatments of D/R cycles (0, 1 and 4 cycles) in a one month period were performed. During the incubation the soil respiration and priming effect was determined; at the end of the incubation period the soil was fractionated into macro-(>250 µm), micro-aggregates (50-250 µm) and mineral soil (>50µm) by dry sieving and POM fraction, free POM (FL <1.6 g cm^{-3}), occluded POM (IF, 1.6-2.0 g cm^{-3}) and mineral fraction (M>2.0 g cm^{-3}) in each aggregate size distribution were determined. Soil respiration indicates that in more frequent D/R cycles treatment a preference of added OM at 25°C and a negative Priming Effect it shows. Aggregate size distribution indicates a difference in the macroaggregate weight (g) of treatment of one cycle at 5°C temperature room that could be related to higher respired (CO_2) amount treatments. At 25°C, the numbers of D/R cycles applied affect negatively the ^{13}C-OM distribution of the light fraction (FL) of the overall soil. Macroaggregates POM indicates an intensified use of the FL and an increase of the mineral fraction (MF) less FL with more frequent D/R cycles.

Keywords: Soil aggregates fractions, Particulate organic matter, ^{13}C-lignocellulose.
Financial support: CONICYT Chilean Scholarship,Leibniz Universitat Hannover, Georg-August Universitat Gottingen

(1636 - 1657) Effect of soil variability and soil water model complexity on water movement and nitrogen losses

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Land Management Models are increasingly being used to guide decision-making to ensure farming within environmental limits. However, the accuracy of such models is highly dependent on the input parameters used within them, including descriptions of physical and chemical properties of soils. One of the key issues affecting the accuracy of predictions using process-oriented modelling is handling the variability of measured soil properties and correspondent uncertainty in input model parameters. This variability can be due to imprecisions in sampling and laboratory or in situ measurements, but it can also come from the inherent natural soil heterogeneity. To investigate the effects of uncertainty and heterogeneity in measured soil physical parameters on the simulated

movement of water we set up the Agricultural Production Systems Simulator (APSIM) with two different soil types under pasture in New Zealand. For each of the soils, profile descriptions obtained from different sources were used to derive the model parameters. The three different water balance modules, with various levels of complexity, available in APSIM were tested. Model outputs were compared to temporal soil moisture measurements from several field trials. The results show that the soil profile description can greatly affect the prediction accuracy of soil moisture, and the effect varies for different water balance modules. Furthermore, the data shows that these differences have a large effect on nitrogen loss pathways from fertiliser and urinary N deposited during animal grazing.
Keywords: Soil physics; parameterisation; variability; modelling
Financial support: NZ MBIE, Programme No CO9X1612

(1302 - 1978) Effects of saline irrigation and biochar application on soil salt crust formation on sandy loam

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In arid and semiarid regions, soil salt crust (SSC) is widely distributed at soil surface which has great effects on earth surface processes, and biochar is commonly used for soil remediation. However, there is little report on artificial cultivation of SSC under simulating saline irrigation. Our objectives was to evaluate the effects of irrigation salinity and biochar application on SSC formation at the surface of sandy loam, and to find one available way for SSC formation that can be used for laboratory simulation experiments. SSC was formed in aluminum trays (100 cm × 20 cm × 2 cm) in a greenhouse after simulating irrigation with NaCl solution having salinities of 0, 5, 10, 15, 25 and 30 g/L, and then 0, 5%, 10% and 20% biochar were added to the soil to form SSC under simulating irrigation having a salinity of 30 g/L. The hardness, anti-shear strength, thickness, pH, electrical conductivity (EC), salinity and total dissolved solids (TDS) of SSC were respectively measured. The results demonstrated that the hardness, anti-shear strength, EC, salinity and TDS of SSC increased with the irrigation water salinity, however, the thickness and pH decreased with the irrigation water salinity. The hardness, anti-shear strength, EC, salinity and TDS of SSC decreased with the biochar application amount, but the thickness and pH showed an opposite trend. We concluded that both of irrigation salinity and biochar application have significant effects on the physiochemical properties of SSC, artificial cultivation of SSC is available for simulating experiments, and the suitable irrigation water salinity should be 20 and 30 g/L. SSC plays an important role in arid and semiarid ecosystems for soil and water processes which is worth of further research.
Keywords: soil salt crust, artificial cultivation, saline irrigation, biochar application, sandy loam
Financial support: The National Natural Science Foundation of China (No. 41471222) and the Special Project for Young Talent of the Institute of Soil and Water Conversation, CAS.

(3142 - 2039) Effect of Transient Soil Density on Near-Surface Water and Energy Flow Dynamics

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Surface soil is a complex, dynamic interface which dictates water and energy transfer between land and atmosphere, and determines water flow and partitioning in the hydrological cycle. Soil hydraulic and thermal properties are considered dynamic because they are strongly influenced by soil water content, which can change quickly or slowly. Tremendous effort and resources have been expended to understand soil-water controlled properties, but soil density is commonly treated as a constant in measurements and modeling. While it is well known that soil density changes over time due to disturbance (e.g., tillage) and natural processes (e.g., shrink-swell), capability to measure density dynamics in situ and to assess associated effects on water and energy flow has been limited. Development of thermal-dielectric sensors makes it possible to measure soil density dynamics in situ, and in turn, offers opportunity for development of density-dependent soil hydraulic and thermal property and process models. This paper will highlight recent developments in thermal-dielectric sensor measurement approaches and associated outcomes for assessing the effect of near-surface soil density dynamics on water and energy flow.
Keywords: soil density, thermal properties, hydraulic properties
Financial support: U.S. National Science Foundation, U.S. Army Research Office

(2842 - 564) Geometrical modeling of pore space using ellipsoids: application to the simulation of water retention in soils

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In recent years, technological advances have stimulated researchers to try to unravel the extremely complex microscale processes that control the activity of microorganisms in soils. In particular, significant work has been carried out on the development of models able to accurately predict the microscale distribution of water, and the location of air–water interfaces in pores. A comparison, by Pot et al. (2015), of two different modeling approaches with actual synchrotron-based tomography data, shows that a two-phase lattice Boltzmann model (LBM) is able to predict remarkably well the location of air–water interfaces but is extremely slow, whereas a morphological model (MOSAIC), representing the pore space as a collection of spherical balls, provides a reasonable approximation of the observed air–water interfaces when each ball is allowed to drain independently, but does so blazingly fast. Interfaces predicted by MOSAIC, however, tend to have nonphysical shapes. In that general context, the key objective of the research described in the present article, based on the same tomography data as Pot et al. 2015 (Advances in Water Resources), was to find out to what extent the use of ellipsoids instead of spherical balls in MOSAIC could appreciably speed up computations, or at least, at equal computational time, provide a quantitatively better approximation of water-air interfaces. A secondary objective was to assess whether ellipsoids might yield smoother, more physical, interfaces. Simulation results indicate that the use of ellipsoids provides a sizeable increase in accuracy in the prediction of air-water interfaces, an approximately 6-fold drop in computation time, and much more realistic-looking interfaces, compared to what is obtained with spherical balls. For one of the regions of interest considered, the mean absolute error of 0.0848 found for the prediction of interfaces with ellipsoids is nearly as low as that of 0.08 obtained with LBM. These observations are encouraging for the use of models based on geometric primitives to describe a range of microscale processes, and to address the still daunting issue of upscaling to the macroscopic scale. References: V. Pot et al. , Three-dimensional distribution of water and air in soil pores... Advances in Water Resources 84 (2015) 87–102 O. Monga et al., Biogeosciences, Simulating microbial degradation of organic matter in.., www.biogeosciences.net/11/2201/20
Keywords: pore space geometrical modelling, quadric volumes, water air interfaces, draining, 3D volume Computed Tomography images
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(5105 - 945) Influence of sodicity on the reversibility of the saturated

hydraulic conductivity in low saline environment

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The salinization of the soil often goes along with soil sodisation in arid and semi arid region. the degradation of Soil structure is the first response of an increase of exchangeable sodium combined with a low salinity. The value of hydraulic conductivity is strongly dependent on soil structure, when considering the soil structure in terms of its 2 main component : 1) the geometry of pores spaces in the soil; and 2) the stability of the structure. so The aim of this laboratory experiment is to assess the effect of sodicity on the reversibility of saturated hydraulic conductivity in a low saline condition (20 $mmole_C$ /L) . The sodicity is characterized by increasing and decreasing SAR increment (5, 15, 30). the equilibrium between soil sample and different saline solutions was attained after 4 to 16 pore volume. The result obtained has shown that increasing sodicity at different increments (+ 5, + 15 + 30) induce a significant reduction of saturated hydraulic conductivity. The decreasing of sodicity at different increments (- 5, - 15, - 30) don't produce a significant increase in saturated hydraulic conductivity. Finally, the saturated hydraulic conductivity is not reversible in our experimental condition.

Keywords: Saturated hydraulic conductivity, Reversibility , Sodium Adsorption Ratio, Low saline condition, Soil structure dynamics
Financial support:

(9579 - 1529) Intercorrelation in Mechanisms of Soil Aggregate Formation and Carbon Stabilization in Midwest Soils, USA

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Organic carbon, which is the most studied attribute of soil, has a strong influence on C and N dynamics, soil physical structure, and associated hydraulic processes. Therefore, degradation of soil aggregates is a primary mechanism for organic carbon decline due to intensive agricultural practices such as long-term use of conventional tillage and intensive application of inorganic fertilizers. However, soil physical mechanisms under natural and managed conditions are complex. The soil is an intricate system that combines other processes such as soil ecology and clay mineralogy that must be considered when trying to understand soil physical phenomena. In the U.S. Midwest region, increasing soil organic matter beyond current levels can be a challenge since soil productivity is relatively high due to naturally high soil organic carbon contents. Thus, the present study digs into understanding three different issues; (i) the mechanisms of carbon stabilization and sequestration in Midwest soils, (ii) role of carbon cycling in formation and stabilization of soil aggregates, and (iii) how these mechanisms interact with clay minerals and microbial activities. The present work focuses on two different studies; the first is targeting different land uses in Wisconsin, and the second focuses on different doses, manure types, and inorganic fertilizer applications in South Dakota. Results document an association between soil microbial properties, and the stability of soil carbon and aggregates as impacted by manure. The present study also indicates an association between soil clay minerals and aggregate formation under different land use.

Keywords: Carbon Stabilization, Aggregate Formation, Land-use, Manure, Inorganic fertilizer, Clay Mineralogy, Urease, Beta-Glucosidease
Financial support: University of Wisconsin-Madison, General Directorate of Agricultural Research and Policies, Ministry of Food, Agriculture, and Livestock, Republic of Turkey and Ministry of National Education, the Republic of Turkey

(4312 - 1164) Inverse modeling and X-ray computed microtomography highlight scale-dependent soil structure properties

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Determining soil structure characteristics is a key issue to study soil functions. However, laboratory and field measurements lead seldom to univocal representation of soil properties, making any linkage between micro- and macro- structure still unresolved. In this work, we compared soil structure properties from hydraulic inverse modeling at the lysimeter and core scale, and linked the results with microstructure analysis by means of X-ray computed microtomography (µCT). In a battery of twelve lysimeters (150 cm deep), set up to evaluate the effects of shallow water table on soil hydraulic and structure properties, soil moisture was monitored in a 3-yr experiment with TDR probes at different depths (15, 30, 60 cm). A total of 12 undisturbed soil cores (7 cm diameter, 6.1 cm high) were collected from the untilled layer (21-27 cm deep). At both scales, inverse modeling with HDYRUS 1-D was applied to estimate the hydraulic parameters according to Van Genuchten and Mualem functions. The best-fit parameters were obtained by minimizing the objective function, i.e. daily soil water contents for the lysimeters, and pressure head readings and the final total water volume (evaporative water loss experiment) for the soil cores. Pore size distribution (PSD) was derived from the water retention curves according to the Young-Laplace law. X-ray µCT analysis was performed on a sub-sample of each core using a Skyscan 1172 at the University of Padova. Projections were collected during a 180° sample rotation at 0.2° angular incremental step. X-ray source was set at 88 kV and 112 µA. Final pixel size was 27 µm. Pore morphologic parameters and PSD were obtained from binarized images. Results from inverse solutions showed differences in soil hydraulic parameters at lysimeter and core scales, and highlighted scale-dependent variant structure properties in each given soil system. Differences were emphasized with a shallow water table, questioning whether structure differences were only due intrinsic soil properties or related to bias in inverse modeling. Similarly, differences were noted by comparing unsaturated hydraulic curves. By contrast, PSD from X-ray µCT was highly correlated to that derived from the hydraulic properties of soil cores. The greater spatial extent of the lysimeters with respect to soil cores suggests that soil structure properties are scale-dependent, and that a linkage between soil functions and representative elementary volumes should be better addressed.

Keywords: Water retention curve; Pore size Distribution; Multiscale.
Financial support:

(2069 - 1216) Neoformation of soil aggregates after a volcano eruption in meadows of Northern Patagonia, Argentina.

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In June 2011, a natural event occurred in Patagonia, Argentina: The "Puyehue-Cordón Caulle" volcanic complex erupted, and particles from tephras (1-5cm) to very fine volcanic ash (44-500µm) where deposited in the direction of prevailing winds (West to East). The ash was biologically inert, with no organic compounds, neutral pH and low electrical conductivity. The objective was to study neoformation processes of soil aggregates in wet meadows after volcano eruption. For this, five years after the volcano event, we collected 6 soil samples to a depth of 0-5cm (the depth under influence of ash deposition in Northern Patagonia) in 3 wet meadows (acuic mollisols) under

different grassland conditions (good and poor) due to different long-term grazing pressures. In the laboratory, soil samples were separated into different aggregate-size classes by wet sieving: large macroaggregates (LM: > 2000µm); small macroagregates (SM: 250–2000µm); microagregates (micro: 53–250µm); silt+clay (s+c: < 53µm). The macroaggregates-M were separated into coarse POM (c-POM: > 250µm), microaggregates in M (microM: 53-250µm) and silt + clay in M (s+cM: < 53µm). Total carbon-C and nitrogen-N were determined in each fraction with a LECO. Five years after the eruption, the C content in the first 5cm soil layer was 52% lower than before. Ash texture was 59% silt, 3% clay, and 34% sand. The proportion of classes derived from the whole dry soil basis from good meadows accounted for 25%-LM+SM, 45%-micro, and 29%-s+c; classes derived from macroaggregates accounted for 31%-c-POM, 32%-microM, 37-s+cM. No differences between grassland conditions were found in the aggregate proportion; overall, C and N content of the aggregates was significantly higher (ANOVA, p< 0.05) in good conditions than in poor ones. We believe that a sequence of neoformation of aggregates is occurring. Aggregates different from micro and s+c (dominant ash granulometry) will develop after different processes, where time, organic matter and biological activity interact. Macroaggregation is low, but with a high C and N content; small macroaggregates predominate that fraction. In contrast, micros and s+c particles are dominant but with small C and N content. On the other hand, grassland conditions modified the quality of the aggregates, so management influence soil formation. To confirm these patterns, similar meadow soils without volcanic ash deposition should be studied, or continue monitoring this processes over time.

Keywords: Volcanic ash; Soil formation; Soil aggregates; Patagonian wetlands.

Financial support: Agencia Nacional de Promoción Científica y Tecnológica (AGENCIA): PICT-2016-1909; Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET); Instituto Nacional de Tecnología Agropecuaria (INTA), EEA Bariloche; Sustainable Agroecosystems, ETH Zü

(7743 - 1139) Physico-chemical parametrization of biopore walls: A very special soil volume for soil fertility and exchange processes

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Coarse biopores play a major role, not only as preferential flow paths for gas, water and heat fluxes but also as a pathway for plant roots to propagate into deeper soil layers leading to enhanced nutrient and water uptake. In order to access nutrients in these layers, roots have to grow through the wall of the biopore. Because of the biologically induced alterations of these soil volumes (e.g. increased carbon content or mechanical redistribution of soil particles), small-scaled analyses were conducted. Biopore walls differing in history (short and long-term colonized earthworm (Lumbricus terrestris) burrows and root induced biopore walls) were excavated from a field trial and several physico-chemical parameters were determined, namely redox, pH or oxygen profiles, oxygen diffusion coefficient, penetration resistance, and several parameters related to soil water repellency. The spatial resolution of the performed laboratory measurements was ≤ 100 µm. Four matric potentials were considered (-1 kPa, -3 kPa, -6 kPa and -30 kPa). The results prove that biopore walls show heavily altered soil properties if compared to the soil matrices and point out the need for a distinguished view on soils if soil fertility or interactions of the plant-root-atmosphere-continuum are considered.

Keywords: Earthworm burrows, root channels, soil organic matter, soil aeration, micro sensing

Financial support: German Research Foundation (DFG), Bonn, under grants PAK 888

(9785 - 2236) Quantifying the persistence of macroaggregates following crop residue addition to a clay soil

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Soil macroaggregate stability and turnover are widely accepted indicators of agricultural soil structure. Traditional methods to measure macroaggregate stability rely on rapid water slaking or mechanical abrasion in the laboratory, whereas macroaggregate turnover can be assessed using tracers or by applying forces to observe macroaggregate formation and disintegration through time. Isolating macroaggregates for these laboratory-based measurements alters their physical and morphological characteristics, and affects the contribution of soil biota to macroaggregate integrity *in situ*. Here, we propose a Persistence Index (PI), based on *in situ* macroaggregate persistence, as a novel indicator of agricultural soil structure. Our objective was to quantify macroaggregate persistence *in situ* with the PI, in a clay soil in the 9 weeks following crop residue addition. The experiment was conducted in a winter wheat agroecosystem on a clay soil (45% clay content on average) in Rivière Héva, Québec, Canada (48.2° N, 78.2° W). Sieved soil (<4 cm diameter) was packed in a polyvinyl chloride column (10 cm inner diameter, 13 cm depth) and amended with 0, 0.228, 0.457, 0.685, 0.913 and 1.141 g of wheat straw, which was either mixed with the top 6 cm of soil or placed on the soil surface. Daily air temperature and precipitation data were obtained from a nearby weather station. Every 11 to 14 days during the 9 weeks, soil moisture was measured in the field and photographs of the macroaggregates at the surface of each column were taken with a high-resolution digital camera. Images were analyzed with Photoshop, ImageJ and MATLAB. The PI was calculated as the ratio of macroaggregates which have limited morphological and positional changes within observation days, to the total number of macroaggregates at the beginning. The effects of crop residue addition and fluctuations in soil moisture on the PI of macroaggregates at the surface of a clay soil will be presented and discussed.

Keywords: macroaggregate persistence, crop residue inputs, clay soil, image analysis

Financial support: Natural Sciences and Engineering Research Council of Canada (NSERC), China Scholarship Council (CSC)

(1042 - 334) Rare earth oxides as tracers for studying aggregate turnover: bridging soil physical and biological processes

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The decomposition of soil organic matter (SOM) generally improve soil aggregation. However, the biophysical process is not well understood due to the difficulty in tracking the aggregate turnover pathway. This study used a combined tracer approach of isotopically labelled carbon (C) and rare earth oxides (REO) to determine soil aggregate transfer paths following input of organic matter. A model quantifying aggregate turnover rates over time was verified by a controlled incubation study. Four natural soil aggregate size ranges (<0.053 mm, 0.053-0.25 mm, 0.25-2 mm and 2-5 mm) were labelled with different REO tracers and packed to form a composite soil sample. The organic input was 1 mg ^{13}C g^{-1} soil of ^{13}C-labelled glucose. There were four treatments: i) soil without REO and ^{13}C as a control, ii) soil labelled with REO, iii) soil without REO but amended with ^{13}C-glucose, and iv) soil labelled with REO and amended with ^{13}C-glucose. Aggregate stability, REO concentrations, soil respiration and ^{13}C were measured after 0, 7, 14 and 28 days incubation. REOs were found to not impact microbial activity ($P > 0.05$). Based on the 84%-106% recovery of REOs after wet sieving of aggregates, and a close 1:1 relationship between measured aggregates and model predictions, REOs were found to be

an effective tracer for studies of aggregate dynamics. A greater portion of aggregates transferred between neighbouring size fractions. The turnover rate was faster for macroaggregates than for microaggregates, and slowed down over the incubation time. The new C was accumulated more but decomposed faster in macroaggregates than in microaggregates. A positive relationship was observed between the ^{13}C concentration in aggregates and the aggregate turnover rate ($P < 0.05$). The relative change in each aggregate fraction generally followed an exponential growth over time in the formation direction and an exponential decay in the breakdown direction. We proposed a first order kinetic model for aggregate dynamics which can separate aggregate formation, stabilization and breakdown processes. This study demonstrates that REOs can track aggregate life cycles and provide unique and important information about the relationship between C cycling and aggregate turnover.

Keywords: Aggregate turnover; Modelling, Organic amendment; Rare earth oxide; Soil aggregation
Financial support: National Natural Science Foundation of China (41571130053, 41371235))

(5619 - 1194) Scenario modelling of carbon mineralization in 3D soil structure: comparison between a geometrical model and a model based on lattice Boltzmann approach

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Models of soil organic matter decomposition have limitations because they do not consider the micro heterogeneity of soil at the scale of microorganisms. Mechanistic representation of small-scale processes was identified as one of the priorities to improve these models. The aims of our study are to use mechanistic 3D models to connect the micro-scale heterogeneity of soils and the measured macroscale fluxes. Simulation scenarios exploring contrasted micro-environmental conditions were carried out from existing 3D models: Mosaic model (Monga et al. 2014) and LBioS model (Vogel et al., 2015). Regarding pore architecture representation, LBios uses directly the voxel based description extracted from 3D computed tomography (CT) images while Mosaic takes advantage of advanced 3D computer vision to approximate pore space with a limited number of geometrical primitives. Lbios uses accurate description of diffusion using the lattice Boltzmann method while a simplified graph-based method is used by MOSAIC. Both Mosaic and LBioS simulate the decomposition of organic matter by bacteria using CT images of soil. In a first step mosaic model was tested by comparing its results with the results of Lbios model for water content distribution and diffusion of dissolved organic matter. MOSAIC underestimated by 2% the volumetric water content compare to Lbios. This discrepancy was already observed by Pot et al. (2015) because Mosaic did not cover the porosity of the interstitial space between primitives. Mosaic had lower diffusion compare to Lbios due to its higher number of cluster that decreased the connectivity. Corrections were done using Delaunay triangulation to increase the connectivity and then the diffusion. In a second step, modeling scenarios were set up for different pore architectures, (2 contrasted situations issue from CT images of soil compacted at two different densities of 1.2 or 1.6 g/cm3), water contents (4 different moisture contents of 20, 50, 80 and 100% of water), organic matter distributions and decomposers (homogeneous vs heterogeneous). We observed a low impact of soil density and organic matter placement and a high impact of water content and decomposers placement. Scenario modeling has shown the importance of water-filled pore connectivity in the mineralization of carbon. The number of pore clusters filled with water and the geodesic distance between decomposers and organic matter appears to be a relevant indicator of CO_2 emissions.

Keywords: microscale, soil pore, computed tomography, organic matter, microorganisms
Financial support:

(1834 - 1061) Slakes: A soil aggregate stability android application

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While many of the traditional soil analyses have been improved (or replaced) with fast and efficient soil sensing techniques e.g. NIR-spectroscopy with common chemical properties like pH, Clay content etc., or X Rays Fluorescence with heavy metals, most of the physical and more specifically, structural properties like soil aggregate stability are still being measured by traditional methods We have developed a new methodology for the assessment of soil slaking in the form of a smart phone application. The app is based on an image recognition algorithm that measures the projected area of soil aggregates immersed in water at regular intervals. Results show that the kinetics of the slaking process can be effectively modelled using a three coefficients model (*a*, *b* and *c*), which are closely related to selected soil properties and land-use. Coefficient *a*, is equivalent to the maximum slaking potential of the samples, and is found to be linearly related to exchangeable sodium, pH, clay percentage, calcium/magnesium and total carbon/nitrogen, and non-linearly related to total carbon. The coefficients *b* and *c* reflect the initial slaking and the slaking rate respectively and these were found to be linearly related to nitrogen and total carbon. The methodology was originally presented in Fajardo et al. (2016) using a dataset covering great part of the agro-ecological variability of New South Wales (NSW), Australia. In this dataset, the coefficient *a*, was significantly lower in the natural sites reflecting a higher aggregate stability in those soils. Having observed the potential of the methodology we have developed a freely downloadable smart phone application that is capable to measure the projected area of soil aggregates immersed in water in time, fit a model and return coefficients that can be finally used as a soil aggregate stability indicator.

Keywords: Soil Aggregate Stability, Mobile app, Soil Physics
Financial support:

(6930 - 612) Soil compaction reduction by earthworms activity in a very clayey soil

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Earthworms are considered soil ecosystem engineers, since its presence provokes bioperturbation affecting properties such as porosity, water infiltration and storage, as well as gases and heat transfer. This work evaluated the effect of earthworms *Amynthas spp.* in a very loamy soil assessing their influence on soil compaction, aeration, and water retention. The experiment was carried out in pots with two bulk density levels and three earthworms' density. Constant pressures and energies of compaction based on the standard Proctor test were applied to soil surface developing a methodology to provide three uniform soil layers in every pot. 3, 6, and 9 individuals with 5 cm of length were selected and inserted per pot under two treatments of 1.2 and 1.7 kg dm^{-3} of initial bulk density. After 30 days monitoring earthworm activity, undisturbed soil cores were sampled and taken to the pressure chamber to measure soil water retention curve (SWRC) and after that bulk density. Micro, macro and total porosity, permanent wilting point, field capacity, inflection point of SWRC,

drainable porosity, and available water were determined based on SWRC results. Furthermore, pore volume distribution function (PVD), mean pore diameter, and some energy-indices of soil physical quality were analyzed to access the earthworms' activity. The increase of earthworms' density caused reduction in soil bulk density and compaction affecting directly the pore volume arrangement. The mean pore diameter, as well as the peak at PVD function were influenced by the increasement of earthworms per pot. In most pots, the pores space related to aeration decreased, as much earthworms were put into pots, with consequent increasing of soil water retention.
Keywords: Proctor test standard; soil water retention curve, compression, soil physical quality, pore volume distribution function
Financial support:

(3454 - 929) The Gardner dual model: An extension of the exponential Gardner equation to calculate the relative hydraulic conductivity curve

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Determination of the relative hydraulic conductivity curve $K_r(h) = K/K_S$ is a major issue in soil modelling (h is the suction and K_S the saturated hydraulic conductivity). This study proposes a model to represent $K_r(h)$, the so-called Gardner dual (GD) model. It extends the Gardner exponential model to h values greater than the transition suction (h_o), the suction value at the inflection point of the $K_r(h)$ curve in the log-log scale. The performance of the GD model was compared to that of the MVG [two-parameter (K_{ro}, L) Mualem-van Genuchten] model and a corresponding modified MVG model (MVGm) (Schaap and van Genuchten, 2006. A modified Mualem-van Genuchten formulation for improved description of the hydraulic conductivity near saturation. Vadose Zone J., 5, 27-34). In 77 soils from the UNSODA database (the same used by the authors above) without evidence of macropore flow (fast flow) close to saturation, the GD model reduced the mean value of the root mean square error {RMSE, considering the log differences $[\log(K_{r,predicted}) - \log(K_{r,measured})]$} by 64% (from 0.525 to 0.191) in relation to the MVG model, and by 29% (from 0.269 to 0.191) in relation to the MVGm model. In these soils, the GD model was also more accurate than the MVG model in all suction ranges. The GD model is defined for two ranges ($h< h_o$ and $h> h_o$) and has three parameters [f(β), ho, S_k], but it has only two degrees of freedom, like the MVG model. Parameter f(β) is a dimensionless shape index, $0<f(\beta)<1$; 10 cm$\leq h_o \leq$300 cm in the study database; parameter S_k (dimensionless) is a measure of the depletion potential of the $K_r(h)$ curve. S_k and h_o allow the calculation of the macroscopic capillary length, a parameter already established in the literature. It is shown that the GD model parameters are highly dependent on the measurement of the $K_r(h)$ curve close to its inflection in the log-log scale. This is an experimental advantage, since the transition suction, h_o, has been demonstrated to be within a narrow wet range (h_o = 10 to 300 cm), which must favour the estimation of K_r in the whole suction range when $K_r(h)$ data are available only in the wet suction range.
Keywords: hydraulic conductivity curve, Gardner exponential model, Mualem-van Genuchten model
Financial support:

(2303 - 962) The role of soil structure conservation on physical properties of a volcanic ash soil subjected to different pasture improvement managements

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Southern Chile pastures comprise 1,340,000 ha on volcanic ash soils; 44% of them are degraded. Pasture improvement strategies may consider a range of soil managements to increase pasture productivity and sustainability. This study evaluated the impact of pasture improvement managements (PIMs) on soil porosity, water content dynamics, mechanical strength and pasture production in a volcanic ash soil under sheep grazing. It was established on a Duric Hapludand and considered four types of PIMs: fertilised-naturalised pasture (FNP), cultivated pasture (CP), direct-drilled pasture (DP), diverse-direct drilled pasture (DDP), where the fertilization was the same for those treatments. The initial pasture situation (non-fertilised naturalised pasture; NFNP)) was used as the control treatment. The trial was grazed by sheep. The site surrounding to the trial, which was usually trampled by sheep, was included also analysed in order to evaluate the effect on soil mechanical strength. Undisturbed soil samples were collected from the 0–10 cm topsoil layer, to study the effect of PIMs and sheep trampling on air capacity (AC), air permeability (ka) and pre-compression stress (Pc). The volumetric water content and matric potential were continuously registered at 10, 20 and 60 cm of soil depth in the pasture treatments, and accumulated herbage mass determined. Liming and fertiliser addition on the degraded naturalised pasture without soil structure disturbance, improved the pasture yield (140%), reaching similar values to those of pastures improved with conventional systems. In the short term, the volume of macropores did not change significantly due to PIMs. Tilled soils presented less pore connectivity compared to the non-cultivated PIMs. Regarding sheep trampling, an increase in Pc was assessed (NFNP treatment), which is related to a decrease in AC (19%) and ka (58%). The soil structure conservation has an important role in water accessibility by plants, so that fertilised-naturalised pastures were able to uptake the highest quantity of water, up to 60 cm soil depth during the drought season (SWC of 22,7% ± 1.26 differences between summers 2014 - 2016). The control treatment, compared to the improved pastures, presented the lowest pasture herbage mass accumulation (4 ton DM ha^{-1}), as well as, after the grazing events its soil physical properties were negatively affected, with their state comparable to those of the trampled site.
Keywords: Soil structure, andisol, pasture management, soil tillage, pasture productivity
Financial support: tudy sponsored by Fund for the Scientific and Technological Development (Fondecyt), Chile, Project No. 1130795. Dr. José Dörner thanks the Alexander von Humboldt Foundation for the Grant "Georg Foster Fellowship for Experienced Researchers" which allows a

C2.1.2 - The role of soil physics in water conservation and food security

(3567 - 2657) Benefits of soil water measurements for irrigation scheduling of shallow groundwater table cropping systems

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In general, farmers adopt subjective rather than objective methods in scheduling irrigation. Incentives other than profitability and water productivity are required to change this. Irrigation decisions should be assessed against issues that stretch beyond the crop field. These issues could include the associated salt load impact on groundwater and river water degradation due to excessive drainage and leaching. Irrigators might argue that their salt management will suffice as they irrigate subjectively through years of experience according to perceived crop water requirements, with a perception of no benefit when adopting objective scheduling. This study aimed to determine the associated benefits of soil water measurements for objective irrigation scheduling of shallow groundwater table cropping systems. Two fields with similar climatic conditions, soils, tillage practices and cropping systems but different irrigation scheduling decisions were evaluated over four cropping seasons. Subjective irrigation was based entirely on experience of the farmer and objective scheduling on soil water content measurements. Data acquisition included weekly measurements of rainfall, irrigation, soil water content, groundwater table depth, artificial drainage, and electrical conductivity of irrigation water, groundwater and drainage water. Simulations of evaporation and transpiration were done with the SWAMP model. Matric and osmotic stress during the four cropping seasons is considered unlikely based on the soil water and salinity status. When rainfall-plus-irrigation was compared to evapotranspiration, objective scheduling resulted in an under-supply of 15%, and rainfall and shallow groundwater served as supplementary water sources. Subjective scheduling did not use rainfall efficiently as a source of water and resulted in an over-supply of 10%. Approximately 50% less salt was leached with objective compared to subjective irrigation scheduling. Under shallow groundwater conditions, irrigating subjectively according to crop water requirement results in excessive irrigation, salt addition and leaching compared to objective scheduling. Farmers can address some of the environmental problems associated with irrigation by adopting objective scheduling and reducing the leaching fraction (< 0.15) of shallow groundwater cropping systems.

Keywords: Evapotranspiration, leaching, salinity, water conservation, water degradation

Financial support: Water Research Commission, Pretoria, South Africa (www.wrc.org.za; Project Number K5/1647)

(9348 - 837) Facilitating strategic use of marginal quality saline-sodic irrigation water for food and fibre production

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With competition for freshwater resources steadily increasing as the global population increases, there is a requirement to better understand how and where to utilise marginal quality saline sodic water for irrigation purposes without undue degradation to the soil resource. Application of such water will result in some degradation, and it is the role of soil physicochemistry to aid in limiting this, whilst optimising irrigation potential. For application of such marginal water, the threshold electrolyte concentration (C_{TH}) classically defines the point of acceptable degradation as a 10–25 percent reduction in saturated hydraulic conductivity (rK_{sat}). The C_{TH} is soil-specific with significant differences occurring within soils of the same order and textural class, without any apparent predictive relationship. The swelling pressure at the clay domain is related to charge density at the Stern layer boundary. Surface charge density at this point defines the electric potential, and from this — along with electrolyte concentration (EC), and type, and surface separation — the domain swelling pressures. Electrical potential at this plane, measured as the electrophoretic mobility (ζ), should provide insight into the prediction of rK_{sat}. This work tests the hypothesis that ζ is a function of electrolyte concentration EC and sodium adsorption ratio (SAR) for a given pH and that such relationship is closely related to observed rK_{sat}. Three soils of contrasting texture were chosen, their C_{TH} determined using a small core saturated hydraulic leaching method. At each unique EC and SAR within the experimental solution matrix the resultant ζ was measured for each soil. Data were analysed using computational modelling approaches to determine generalised behaviour and to visualise the results. This work confirmed that ζ is a function of EC and SAR for a given pH and ζ was very closely related to observed rK_{sat}. The EC of the soil-solution had a much lower effect on the net negative charge than Na, with a general equation determined for ζ. Clay ζ was able to be predicted for a soil from rK_{sat}, but predictions between soils were not possible due to differences in relationship slope as a pure Na soil-solution system was approached. It was hypothesised that further investigation on the effect of clay content, sesquioxide occurrence and ζ on rK_{sat} should result in prediction of rK_{sat} from ζ.

Keywords: Hydraulic conductivity, dispersion, net negative charge, zeta potential, swelling

Financial support: Cotton Research and Development Corporation, Australia

(5440 - 2757) Irrigation and tillage management to improve water use on shallow, low water holding soils

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Shallow soils are typically more vulnerable to drainage and nutrient leaching losses due to their lower water storage. To overcome this limitation, shallow soils require frequent, well managed irrigation to avoid these losses while ensuring crop water use is maximised. This represents a major challenge for farmers as best practice often implies maintaining large soil water deficits to reduce risk of drainage. While there are limited options to increase the water storage of a shallow soil, tillage can significantly affect storage by changing the soil physical and hydraulic characteristics. Furthermore, the risk of drainage due to by-pass flow is high in shallow soils when subjected to high irrigation application rates. In New Zealand, a large proportion of irrigation is applied to shallow soils, often <40 cm deep, at application rates of up to 100mm hour^{-1}. Consequences of this type of irrigation on these soils is poorly quantified, in particular drainage and leaching losses. We designed an experiment using lysimeters to examine the effects of two irrigation regimes: Irr1 triggered at a 10 mm deficit and water applied to refill to field capacity, and Irr2 triggered at a 40 mm deficit and refilled to a 20 mm deficit, and two tillage practices: intensively cultivated (IT) and no-tillage (NT), on water storage, water use, drainage and water use efficiency (WUE). Each treatment was replicated 12 times in a facility with a rain-shelter. Lysimeters contained *c*. 40 cm silt loam soil overlying alluvial gravel matrix. Dainage was measured and TDR probes monitored water use. Irrigation treatments were applied at an application rate of 50 mm hour^{-1}. Italian ryegrass was sown in autumn into the soil that had been cultivated to 15 cm (IT) or had been direct drilled into sprayed out pasture (NT). To determine whether there was a lasting effect of the irrigation treatments on soil drainage processes, conservative tracers will be applied. Over the first 60 days after the irrigation treatments started, 9 mm more water was stored in the top 15 cm of soil in the NT compared to IT lysimeters, however, there was no difference in water storage below this depth. Water use was greater from the Irr1 lysimeters and was not affected by tillage. Dry matter production was lower in the Irr2 treatment (Irr1 = 6.7 and Irr2 = 6.0 t ha $^{-1}$; p<0.001), but had higher WUE (Irr1 = 18 and Irr2 = 20 kg dry matter mm^{-1} irrigation; p<0.001). Further results and their implications will be discussed.

Keywords: Drainage, soil water storage, lysimeters
Financial support: MBIE Maximimising Value from Irrigation Programme

(8012 - 1075) Long-term vs short-term variability: phenotypic response of wheat to variable water and nitrogen supply

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Increasing drought and the rise in the cost and unsustainable use of nitrogen (N) fertiliser are of growing global concern. Overuse of N fertilisers has resulted in high environmental costs, such as leaching of soluble N forms and nitrous oxide pollution of the atmosphere. Thus, there is a need to improve plant use efficiency of N. This may be further exacerbated by drought conditions, as soil moisture regulates soil N availability. Wet-dry cycles with long periods between changes (long-term variability) affect soil moisture and plant growth. Also, soil moisture that changes every 48 hours (short-term variability) will impact plant plasticity. With climate change models predicting that water availability will become more erratic in the near future, it is important to understand how timing of watering will affect crop N supply. Plants have evolved, or been bred for, traits which optimise water and N uptake. Because of increasing climatic variation and changes in soil management, genotypic diversity is becoming even more important. We examined the responses of two wheat genotypes to changes in soil water and N availability. The experiment was carried out using the DroughtSpotter gravimetric platform, which enables fine-scale control of soil moisture dynamics by precisely measuring pot weight in real-time and irrigating plants with a pre-programmed water level. Five soil moisture regimes (wet, dry, variable water, wet after 48 hours, dry after 48 hours) and three N fertilisation rates were imposed. The experiment addressed two questions. Firstly, how do two wheat genotypes respond to changes in N concentration and soil moisture, in terms of biomass accumulation, allocation and N acquisition? Secondly, how does water variability affect soil moisture and plant adaptability - does wheat respond better to a constant or variable water supply? Results showed that plants did not respond well to 48-hour variability, with more biomass under long-term variable water supply combined with low or high N. Identifying different whole plant system adaptation strategies to these short-term and long-term changes in watering and N stress will provide better insight into how crops and the environment interact. Understanding trade-offs between water and N uptake efficiency between wheat genotypes can encourage development of crop management strategies to improve crop productivity and the environmental and economic sustainability of food production.

Keywords: Biomass allocation, drought, nitrogen use efficiency, variable water, water use efficiency
Financial support:

(1871 - 2685) Measurements of water uptake of maize roots: insights for breeders

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The ability of crops to capture water from the soil depends on the root architecture and anatomical root traits that determine their radial and axial hydraulic conductance. These properties are not constant but vary along roots and among different root types and their measurement as well as their effect on the location of water uptake remain an open scientific challenge. The objectives of this study were to measure water uptake by maize roots in soils and estimate differences between seminal, nodal and lateral roots. We traced the transport of deuterated water (D_2O) in the roots of a five-weeks-old maize in sandy soil using neutron radiography. The transport of D_2O was simulated using a diffusion-convection numerical model, which gave the radial permeability and the water uptake of the different root segments. The measurements of the fluxes were complemented with measurements of the axial hydraulic conductivities of seminal and crown roots at different positions. The root architecture of a five-weeks-old maize consisted of seminal roots with long laterals and crown (nodal) roots with shorter and fewer laterals. Water was mainly taken up by crown roots and their laterals, while laterals of seminal roots, which were the main location of water uptake in younger plants, had a minor contribution to water uptake. In contrast to seminal roots, crown roots were able to take up water also from their most distal segments. The greater uptake of crown roots compared to seminals is explained by their higher axial conductivity in the proximal parts and by the fact that they are connected to the shoot above the seminals, which favors the propagation of the xylem tension along the crown roots. The deeper water uptake of crown roots is explained by their shorter and fewer laterals, which decreases the dissipation of water potential along the roots. We conclude that laterals of seminal were the main location of water uptake in young maize whereas crown roots were the main location of water uptake in mature maize. Thus, breeding for lateral roots with high radial conductivity and seminal roots with large xylem vessels diameter would be beneficial in agroecosystems where water is available. In contrast, in arid and semi-arid areas seminal roots with a smaller xylem vessel diameter combined with crown (nodal) roots with steep growth angle would not only conserve water early in the season but also at the same time allow the uptake of water stored in the subsoil.

Keywords: Root water uptake, Zea mays, crown roots, seminal roots, neutron radiography, diffusion-convection model
Financial support:

(8057 - 1687) Soil available water and grain yield for a rainfed maize crop in Brazilian Cerrado

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Water is an essential element for plant survival, as well as for soil ecological functions. In Brazil, it has been reported that variations in maize yield are strongly related to soil water availability (AW), which is traditionally defined as the difference between the upper (field capacity, FC) and lower (permanent wilting point, PWP) limits of available water. The goal of this study was to assess the effects of changes in soil AW on rainfed maize production, through the use of a crop growth model. The model was previously parameterized and evaluated with experimental and environmental data. Weekly sowing date scenarios were simulated using 33 years of weather data, from 1981 to 2013, for conditions in Sete Lagoas, Brazil (19 °30 'S, 44 °12' W). The soil water retention curve adjusted with the van Genuchten's model was used to set up six scenarios of soil AW: FC at -4 kPa, -6 kPa, -10 kPa, -20 kPa, -33 kPa and "in situ". Then, the following production variables were evaluated for the highest yield date (October 31st): grain yield (kg ha^{-1}), number of grains per area (grains m^{-2}), number of grains per ear (grains ear^{-1}) and unit grain weight (g grain^{-1}). There was significant difference ($p<0.05$) among the AW scenarios for all variables analyzed. For FC at -4 kPa, -6 kPa and -10 kPa, grain yield was higher than that of other AW scenarios (8,301, 8,009 and 7,496 kg ha^{-1}, respectively), while the lowest yield was verified for FC at -33 kPa

(4,289 kg ha^{-1}). This same contrast was obtained for number of grains per area and number of grains per ear. From the highest to the lowest AW scenario (FC at -4 kPa to -33 kPa), there were reductions of 48.3%, 42.5% and 42.3% in the grain yield, number of grains per area and number of grains per ear, respectively. These results confirm the high sensitivity of maize to changes in the soil AW. For grain unit weight, differences were simulated for AW scenarios of FC at -4 kPa and -6 kPa and of FC at -20 kPa and -33 kPa, with only 8.8% of maximum reduction. Thus, this variable was less affected by water availability in the soil. In general, changes in soil AW strongly affect the maize grain production, which demands suitable soil water management in its production areas under Cerrado biome.

Keywords: *Zea mays* L; Modeling; Soil water; Crop yield.
Financial support: Embrapa Maize and Sorghum

C2.2 - Soil chemistry

C2.2.1 - Soil organic matter dynamics from molecules to landscapes

(1882 - 1782) Biogeochemical Fate and Stability of Iron Oxide-Organic Carbon Complexes

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Understanding soil organic carbon (OC) residence time is crucial for accurately modeling global C dynamics. Widely occurring iron (Fe) oxide minerals can strongly bind soil OC, and affect its stability. In addition, soils normally experience permanent or transient anaerobic conditions that promote reductive dissolution of Fe(III) minerals and compromise the stability of Fe-bound OC. Therefore, understanding the fate of Fe-bound OC during the redox reactions of Fe is important for predicting OC residence time in soils. We have systematically studied the fate and transformation of OC during the redox reactions of Fe oxides. During the microbial reduction of ferrihydrite (Fh)-OC co-precipitates by *Shewanella putrefaciens* strain CN32, higher C/Fe ratios in the co-precipitates facilitated Fe reduction and subsequent reductive release of Fe-bound OC. Aromatic and carboxylic OC was preferentially retained in the complex during the reduction. In the aerobic incubation of Fe bound-OC and non-mineral-bound (NMB)-OC with soil and indigenous microbes, Fh-bound OC had lower bioavailability compared NMB-OC. NMB-OC also had higher positive priming effect compared to the Fh bound-OC. Our results highlight that Fe mineral phase and C/Fe ratio regulates the fate and transformation of OC under the anaerobic and aerobic conditions. Such information will help develop process-based models for predicting C biogeochemical cycle in terrestrial environments.

Keywords: Iron redox reaction, Aerobic incubation, Carbon stability, *Shewanella putrefaciens*
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(8784 - 1686) Carbon sink strength of subsoil horizons of Brazilian Oxisols

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Interactions with pedogenic oxides are a known mechanism of soil organic matter (SOM) protection, but little is known about how the protective power of pedogenic oxides varies with soil depth in highly weathered tropical soils. To address this issue, we followed the decomposition of a double-labeled plant litter ($^{13}C/^{15}N$) in microcosm experiments using samples collected at four depths (0–10, 10–20, 20–40, and 60–100 cm) from six Brazilian Oxisols. These soils were selected to include a range of taxonomic subtypes, spanning wide variations in mineralogy and texture. After a 12-month incubation, we quantified the proportion of isotopically-labeled SOM ($^{13}C/^{15}N$) within the mineral fraction <53 µm (i.e., clay+silt). We found that litter-C retention increased with depth, while the opposite occurred for litter-N. Correlations between isotopically-labeled SOM and short-range order (SRO) Al-/Fe-(hydr)oxides were insignificant in topsoil (0–10 cm), but increased with depth, reaching peak significance in the 20- to 40-cm interval (r = 0.64 and 0.58, for litter-C and -N, respectively). We observed a similar relationship between the retention of isotopically-labeled SOM and crystalline Al-/Fe-(hydr)oxides, but these minerals exhibited better correlations with the retention of ^{13}C than ^{15}N, which appeared to be more sensitive to the presence of SRO minerals. We posit that in subsoil, both SRO and crystalline Al-/Fe-(hydr)oxides are more readily involved in the neoformation of mineral-organic associations. Overall, litter-C is less efficiently transferred into the clay+silt fraction of C-rich topsoil relative to C-depleted subsoil horizons, which may represent a significant C sink for Oxisols.

Keywords: Soil organic matter; stable isotopes; ^{13}C; ^{15}N; subsoil; deep C storage
Financial support: CAPES (Processo n° BEX–9685/16-6); CNPq; FAPEMIG.

(5479 - 854) Changes in organic matter dynamics in agricultural landscape in relation to soil degradation: from landscape to local level and vice versa

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The presentation shows the possibility of selecting sites strongly affected by soil degradation, and assessing soil characteristics relating to the organic matter of the affected localities. The analysis takes a top-down approach, from a regional scale, through cadastres, to individual blocks of land, with the use of various methods of evaluation, including GIS processing, degradation modelling, remote sensing classification and field sample analysis in erosional and depositional areas of slopes. At 48 selected localities, the spectrum of soil properties, including organic matter and related biochemical processes, was studied in erosional and depositional areas of slopes. In the depositional areas of slopes, a statistically higher content of organic carbon and nitrogen was recorded. The differences were not only in content, but also the quality of organic matter, expressed in carbon content in humic acids, and in the C:N ratio. Statistically high relevant dependence was also evident between content of $C_{org.}$ and $N_{tot.}$ and glomaline content as the product of arbuscular mycorrhizal fungi. In depositional areas of slopes there was also statistically higher activity of selected soil enzymes (e.g. dehydrogenase, acid phosphatase, urease and nitrate reductase) compared with erosional areas. From the results obtained, and from other analyses at landscape and local level (erosion processes, changes in soil type) it is possible to model changes in the content of organic matter and

other soil properties on a wider scale.
Keywords: soil degradation, organic matter, agricultural landscape
Financial support: This research was supported by the Ministry of Agriculture of the Czech Republic (Project No. QK1720303).

(9478 - 2574) Coastal wetland soil organic matter chemistry of Mississippi River deltaic plains: degradation status and control factors

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The Mississippi River deltaic plain (MRDP) coastal wetlands are one of the largest in the United States. Recent studies have suggested that the deterioration of these wetlands with the loss of soil organic matter (SOM) could be one of the reasons leading to the hypoxia in the northern Gulf of Mexico along the Louisiana coast. In this study, chemical nature of these coastal wetland soil profiles were studied and overall bulk soil as well as alkaline agent-extracted soil organic matter from these wetland profiles were characterized using NMR and Py-GC/MS. In addition, lignin chemistry was carried out using alkaline CuO oxidation followed by GC/MS characterization in order to assess organic matter source and degradation status. Results showed that bulk SOM molecular moieties in these MRDP wetlands were dominated with O/N-alkyl C followed by alkyl C, aromatic C and carbonyl C, whereas extracted soil SOM had generally similar or higher aromatic C depending on specific wetland ecosystems of forest swamp, freshwater marsh or saline marsh. Labile organic carbon (LOC) of these wetlands determined by aerobically incubation, water or salt extractions was primarily controlled by polysaccharide and organic acids, but acid hydrolysable C (AHC) was influenced positively by aliphatics and negatively by aromatics, which was different from upland soils. Between wetland soil profiles of Atchafalaya basin which underwent land building and Barataria basin which experienced land loss, the former showed strong lignin storage capacity as compared to those of the latter. In addition, Atchafalaya and Barataria basin marshes showed different organic source inputs. Varying soil environmental factors dominated the influence on the status of SOM degradation in the two contrasting basin marshlands. While soil acidity had a negative effect on the lignin degradation in the stable Atchafalaya basin wetland soil profiles, high N content was the primarily factor that adversely affected SOM degradation in the Barataria basin wetlands profiles. Overall, different degradation status of SOM in these MRDP wetlands could contribute as carbon source to influence the hypoxia in the northern Gulf of Mexico along the Louisiana coast.
Keywords: Coastal wetland soils, Mississippi river deltaic plains, Soil organic matter.
Financial support:

(7513 - 1994) Global carbon sequestration in peat-moss ecosystems under a changing climate

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Thermally assisted hydrolysis and methylation (THM) in the presence of tetramethylammonium hydroxide (TMAH) (also known as TMAH thermochemolysis) offers one of the best prospects for the molecular characterisation of "bound" organic carbon (C_{org}) in mosses and higher plants as well as the peat that these plants eventually form. *Sphagnum* moss contains phenolics that act both as structural support components and as inhibitors of microbial decomposition. Vascular plants associated with peatlands contribute lignin and polyphenols including tannins. Bryophytes do not synthesize lignin and instead the bryophyte genus *Sphagnum* biosynthesizes other phenylpropanoids including *trans*-sphagnum acid. Two new quantitative indices have been proposed, namely i) σ which is defined as the total amount of the "bound" sphagnum acid TMAH products normalised to 100 mg of TOC; and ii) SR% which gives a measure of the relative amounts of "bound" sphagnum acid to vascular plant phenols released during the TMAH thermochemolysis of peat moss and the surficial peat layers (Abbott et al., 2013). These indices are based on I (methylated 4-isopropenylphenol (IUPAC name: 1-methoxy-4-(prop-1-en-2-yl)benzene)), IIa/b (methylated cis/trans 3-(4'-hydroxyphen-1-yl)but-2-enoic acid (IUPAC names: (*E*/*Z*)-methyl 3-(4-methoxyphenyl)but-2-enoate) and III (methylated 3-(4'-hydroxyphen-1-yl)but-3-enoic acid (IUPAC name: methyl 3-(4-methoxyphenyl)but-3-enoate)) which have all been assigned as TMAH thermochemolysis products from "bound" sphagnum acid. The changing distributions of these products as a function of distance from the water table (WT) were compared between a Swedish (Swain and Abbott., 2013) and a British peat. The increase of I relative to IIa/b and III indicated that the mode of binding of sphagnum acid into the peat changes as a function of burial depth and hence position relative to the WT in both the hummocks and hollows of the bog plateau. Down-core profiles for the bog margin, fen lag and swamp forest will be compared with those for the bog plateau with some attention given to the importance of seasonal fluctuations of the WT. This will highlight the sensitivity of *Sphagnum* surficial peats to climate-induced changes in water levels. The changing carbon stocks in both of these peatlands will be compared illustrating the importance of *Sphagnum* phenols to sequestering carbon in northern peatlands. REFS Abbott, G.D. et al (2013) GCA 106, 177-191. Swain E.Y., Abbott G.D. (2013) JAAP 103, 2-7.
Keywords: peat thermochemolysis Sphagnum carbon storage
Financial support: Natural Environment Research Council

(1783 - 2700) High organic inputs explain SOC storage in a long-term agroforestry system: experimental and modeling approaches.

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Agroforestry is an increasingly popular farming system enabling agricultural diversification and providing several ecosystem services. In agroforestry systems, soil organic carbon (SOC) stocks are generally increased, but it is difficult to disentangle the different factors responsible for this storage. Organic carbon (OC) inputs to the soil may be larger, but SOC decomposition rates may be modified owing to microclimate, physical protection, or priming effect from roots, especially at depth. We used an 18-year-old silvoarable system associating hybrid walnut trees (*Juglans regia* × *nigra*) and durum wheat (*Triticum turgidum* L. subsp. *durum*), and an adjacent agricultural control plot to quantify all OC inputs to the soil - leaf litter, tree fine root senescence, crop residues, and tree row herbaceous vegetation -, and measure SOC stocks down 2 m depth at varying distances from the trees. We then proposed a model that simulates SOC dynamics in agroforestry accounting for both the whole soil profile and the lateral spatial heterogeneity. The model was calibrated to the control plot only. Measured OC inputs to soil were increased by about 40% (+ 1.11 t C ha^{-1} yr^{-1}) down to 2 m depth in the agroforestry plot compared to the control, resulting in an additional SOC stock of 6.3 t C ha^{-1} down to 1 m depth. The model was strongly validated, describing properly the measured SOC stocks and distribution with depth in agroforestry tree rows and alleys. It showed that the increased inputs of fresh biomass to soil explained the observed additional SOC storage in the agroforestry plot. Moreover, only a priming effect variant of the model was able to capture the depth distribution of SOC stocks. This result questions the potential of soils to store large amounts of carbon, especially at depth. Deep-rooted trees modify OC inputs to soil, a process that deserves further studies given its potential effects on SOC dynamics.
Keywords: silvoarable system, priming effect, deep roots, deep soil organic carbon, spatial heterogeneity, SOC modeling

Financial support:

(7220 - 200) Increasing amount of soil organic matter in forest soils of North Germany is stabilized by occlusion within soil aggregates

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The potential loss of soil organic carbon (C) during climate changes and the associated need to change forest management can be estimated by separating several soil organic matter (SOM) pools with different turnover rates: SOM is the labile free light fraction (f-LF), the occluded light fraction (o-LF) of intermediate stability, and the most stable mineral associated and heavy SOM fraction (HF). The slower turnover of o-LF compared to f-LF is thought to be caused by physical stabilization due to occlusion within aggregates while the mineral associated SOM fraction is stabilized due to an interaction between SOM and reactive mineral surfaces. Our study was conducted to quantify changes in SOM pools of acidic sandy forest soils in Germany between 1990 and 2010 based on repeated soil analyses. We conducted density fraction of soil samples collected at 24 plots under coniferous and 11 plots under mixed forest stands that stretched from West to East Germany to cover a climate gradient. The soils were classified as (Cambi-)Haplic Podzols derived from glacial sandy deposits. Data on soil and forest stands were derived from the first National Forest Soil Inventory of Germany conducted between 1987 and 1993. Density fractionation was done on recently sampled soils as well as on pre-existing samples from the soil archive originating from the same soil profiles and depth. Redundancy analysis was performed to determine interrelationships between SOM in density fractions and soil properties, forest stands, and climate. The results confirm the high relevance of clay and aluminum hydroxides for SOM in the HF pool. Coniferous forests were characterized by high amounts of C in the f-LF pool, while mixed forests sequester more C in more stable SOM fractions. Changes in the LF fractions seem to be controlled by climate, soil pH value and litter input. Within the time span of 20 years analyzed, we observed a redistribution of SOM pools at the expense of f-LF to the benefits of o-LF. Decreasing soil moisture contents might contribute to this change in SOM fractionation.

Keywords: Forest management, Density fractionation, Soil properties, Climate change, Carbon sequestration

Financial support:

(7640 - 438) Probing the Effect of Calcium on Organic Carbon Sequestration to Ferrihydrite

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Sequestration of organic carbon (OC) in environmental systems is critical to mitigating climate change. Organo-mineral associations, especially those with iron (Fe) oxides, drive the chemistry of OC sequestration and stability in soils. In the past 20 years, research exploring the sequestration of OC to Fe oxides has intensified. Poorly crystalline Fe oxides, such as ferrihydrite, demonstrate a high affinity for OC in binary systems. Calcium commonly co-associates with OC and Fe oxides in soils, though the bonding mechanism (e.g., cation bridging) and implications of the co-association for OC sequestration remain unresolved. In an effort to gain a more environmentally comprehensive understanding of C cycling in chemically heterogeneous systems, we explored the effect of calcium (Ca^{2+}) on the sorption of dissolved OC to 2-line ferrihydrite. Sorption experiments conducted at pH 4 to 9 at varying initial C/Fe molar ratios and Ca^{2+} concentrations were completed to determine the effects of Ca^{2+} on leaf litter-extractable OC sequestration to ferrihydrite. OC sorption extent to ferrihydrite in the presence of Ca^{2+} increased across all tested pH values, especially at pH >7. Sorbed OC concentration at pH 9 increased from 8.72 to 13.30 mmol OC g^{-1} ferrihydrite between treatments of no added Ca^{2+} and 30 mM Ca^{2+} addition. Batch experiments were paired with spectroscopic studies to probe sorbed OC speciation and mechanism of sorption complexes. ATR-FTIR spectroscopy analysis revealed that carboxylic functional moieties were the primary sorbed OC species and suggested an increase in Fe-carboxylate ligand exchange in the presence of Ca at pH 9. STXM-NEXAFS was used to spatially resolve Fe, Ca, and OC relationships and to probe the effect of Ca on sorbed OC speciation. Organic carbon was found to highly associate with Ca (R^2 = 0.91). Carboxylic acid moieties were dominantly sequestered; however, Ca facilitated the additional sequestration of aromatic and phenolic moieties. Also, C NEXAFS revealed polyvalent metal ion complexation. Results from batch and spectroscopic experiments provide significant evidence for the enhancement of dissolved OC sequestration to 2-line ferrihydrite and suggest the formation of Fe-Ca-OC ternary complexes. Findings of this research will improve modeling of environmental C cycling and have the potential to improve OM stabilization management strategies.

Keywords: Organic carbon, sequestration, ternary complexation

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(9534 - 1006) The effect of land use change on particulate- and mineral-associated carbon in different soil types

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We investigated the effect of land use change on particulate organic matter (POM) and mineral associated organic matter (MOM) in different soil types. Surface (0–10 cm) and sub-surface (60–70 cm) soil samples were collected from paired sites (forest/grassland and agricultural lands) of four soils - Ferralsol, Luvisol, Vertisol and Solonetz. Soil samples were isolated into POM and MOM fractions by sequential density fractionation and the isolated fractions were analysed for mineralogy, total organic carbon (OC) and total nitrogen (N) concentrations, functional groups, $\delta^{13}C$, $\delta^{15}N$ and ^{14}C. POM fractions of the surface soils were relatively unaffected by land use change, possibly due to the continuous input of crop residues in the soils. Oxides-dominated MOM fractions lost more OC than the phyllosilicates-, and quartz and feldspars- dominated MOM fractions. The variable loss of OC in the MOM fractions can be attributed to variation in OM input as well as OC saturation limit of different mineral surfaces. Changes in isotopic signature of OC (similar to the value of associated vegetation) and overall decrease in the ratios of aromatic:aliphatic functional groups across the density fractions reflected that fresh crop residues constituted the OM in surface soils, which was supported by the greater ^{14}C content of these samples. The sub-surface soils POM fractions lost relatively more OC with land use change than in the corresponding POM fractions of

surface soils. In MOM fractions, OC associated with phyllosilicates, and quartz and feldspars-rich fractions lost a substantial amount of OC, while the oxides-dominated fractions were less affected, possibly due to the protection of OC via strong organo–mineral associations. Enrichment in isotopic signatures, increase in OM decomposition indices and lower ^{14}C content in the sub-surface MOM fractions suggested the association of more microbially processed, relatively aged OC in the oxides rich fractions, followed by the phyllosilicate-dominated fractions and lastly quartz and feldspars-dominated MOM fractions. Our study revealed that the composition of OC after land use change was influenced by the nature of C input in the surface soils but not in the sub-surface soils, where it is largely governed by mineral-organic associations. The impact of land use change on soil OM varied with the vegetation type, OM input, soil mineralogy and soil depth; and sub-surface soils have potential to store C through improved land use.

Keywords: Soil organic matter, soil carbon, land use change, mineral-organic associations
Financial support:

C2.2.2 - Life on the interphase: interactions between soil geochemical and biological traits

(3241 - 1056) Evaluation of direct application of Spent Coffee Grounds as soil improvers in short term growth studies

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The rapidly growing amounts of organic wastes produced worldwide have potential value as soil amendments. Using organic amendments can assist in providing additional nutrient sources for agricultural systems and a viable alternative to incineration or landfill disposal. Spent Grounds (SGs) from coffee consumption are a relatively low-risk organic waste, and accounts for approximately 45% of production waste. SGs are produced in high amounts, estimated 8-10 dry weight kg/day/cafe. If SGs are applied to soil, stimulant compounds within, particularly caffeine and polyphenols, may be phytotoxic. In a glasshouse plant growth trial, two SGs application rates (5 and 10 t/ha) were applied to silver beet using an acidic Dermosol (4.2 pH_{ca}) and an alkaline Tenosol (6.9 pH_{ca}). Air-dried SGs and additionally water-extracted SGs were used. Control pots were without and with 160 kg/ha total N (urea), urea was mixed with SGs and all soils received P and K fertiliser. At trail conclusion, plant and surface soil was taken for nitrogen analysis. In the Dermosol, silver beet yield increased with air-dried SG application, while water-extracted SGs application produced only marginally higher or similar yields. In the Tenosol both air-dried and water extracted SGs application primarily reduced yields. Both SGs materials showing higher soil respiration, and reduced nitrous oxide emission with higher SGs treatment in comparison to the urea-only treatments. In both soils, SGs treatments increased soil pH_{ca} and total nitrogen in comparison the urea-only controls and soil total carbon excluding the lower water-extracted application rate. Ammonium concentrations with SGs treatments were slightly increased in the Dermosol and greatly increased in the Tenosol compared to the urea-only controls. In the Dermosol, SGs treatments had decreased soil nitrate concentrations. In the Tenosol, SGs treatment increased soil electrical conductivity, soil nitrate concentrations, and carbon in comparison the urea-only controls. The results showed that soil type has a major role in the impact of SGs application on silver beet growth and soil nitrogen concentrations, beneficial yield observed in the Dermosol but a suppression of plant growth in the Tenosol. Water extraction of SGs did not assist to increase the beneficial impacts of applications of SGs. Further research into the role of soil type and soil characteristics in application of SGs as an amendment is warranted.

Keywords: Spent coffee grounds, plant growth, soil improvers, nitrogen
Financial support: Research Training Program and Environment Protection Authority, Victoria

(1318 - 925) Influence of cattle grazing on soybean rhizosfere on its levels of soluble and exchangeable potassium in the soil

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Integrated crop-livestock systems (ICLS) can alter the dynamics of nutrients such as K in the soil. Grazing promotes increased root growth and may increase the uptake of K in depth from non-exchangeable forms. Subsequently, the animal excreta return the K in forms of high availability in the soil surface, being able to benefit the own winter pasture and the successor summer crop. Such effects can still be amplified in the rhizospheric soil because elements with low concentration and mobility in the soil, such as K, are absorbed mainly by diffusion. This study aimed to evaluate the influence of cattle grazing and soybean rhizosphere on the levels of soluble and available potassium in the soil. For this purpose, we used a long-term experiment established in 2000 in a strongly weathered Oxisol non-tilled since 1993 located in São Miguel das Missões, state of Rio Grande do Sul, Brazil. Undisturbed soil samples were taken using metal rings (5,8 cm of diameter) in November 2013, after a winter-grazing cycle, at 0-6 and 15-21 cm depth in the treatments with moderate grazing (MG) (grazing height of 20 cm height, mean of 926 kg of live weight ha^{-1}) and without grazing (WG). The experimental area was cultivated with black oat (*Avena strigosa*) and ryegrass (*Lolium multiflorum*) from May to November and soybean (*Glycine max*) from November to May. Half of the metal rings were cultivated in a greenhouse for 30 days with 10 soybean seeds in order to simulate a rhizosphere, obtaining a bulk and a rhizospheric soil. After that, the content of K in the soil solution (sol-K) and the exchangeable K (exch-K) extracted by Mehlich-1 were analyzed. Both sol-K and exch-K were not influenced ($p > 0.05$) by the grazing in the winter in both soil layers, but they were higher in the surface soil (0-6 cm) compared to the 15-21 cm soil layer. In the 0-6 cm layer, the exch-K and sol-K were higher in bulk soil. In addition, in bulk soil, the exch-K in the layer of 0-6 cm was higher than in the layer of 15-21 cm. The exch-K content of the 15-21 cm layer was not affected by the presence of plants (rhizosphere). Further studies of this nature are being developed in order to better understand the dynamics of K in surface and subsurface, in grazed environments and under the influence of plant roots.

Keywords: Soil, crop-livestock systen, nutrient
Financial support: Federal University of Rio Grande do Sul

(7870 - 2143) Natural concentration of barium in soils and Brazilian nuts from Amazon region

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Brazilian nuts (*Bertholletia excelsa*) is a native plant from Amazon region. The nuts are a good source of vitamins, proteins, lipids, and several essential elements such as selenium. However, barium is a toxic element reported in Brazilian nuts. Soils from the Amazon Basin are high in the mineral hollandite ($Ba_2Mn_8O_{16}$) and evidences suggest that Brazil nuts are exceedingly high in barium for this reason. There is a lack of information reporting barium concentration in soils and nuts from the Amazon region. Therefore, this study aimed to

evaluate the barium concentration in soils and nuts from different sites in the Amazon region in order to better understand the natural distribution among different plants and sites. Samples of soils and Brazilian nuts were collected from about 15 plants from 5 sites (Acre, Amazonas, Roraima, Amapá and Mato Grosso). Brazilian nuts samples were digested using 0.5 g of each material in triplicate and 6 mL of HNO_3+$HClO_4$, (ratio 2:1) in digester block. For the soils samples, the digestion procedure required 0.5 g plus 5 mL of HNO_3+HCl (ratio 1:3) in triplicate, following the USEPA 3051A procedure. Barium analysis was performed using ICP-OES. Barium variation range was: Acre (2731.9 mg kg^{-1}); Roraima (772.4 mg kg^{-1}); Amapá (421.5 mg kg^{-1}); Mato Grosso (75.4 mg kg^{-1}) and Amazonas (48.4 mg kg^{-1}). Considering the maximum daily ingestion of Ba as 14 mg day^{-1} (person weighing 70 kg) suggested by USEPA (2005), the ingestion of 1 nut/day would represent for each site: Acre (53.57%); Roraima (18.63%); Amapá (9.11%); Mato Grosso (1.14%) and Amazonas (1.03%). The variation of total barium concentration in soils for the layers 0-20, 20-40 and 40-60 cm were: Acre (289.2; 183.7 and 106.5 mg kg^{-1}); Roraima (12.8; 10.7 and 13.7 mg kg^{-1}); Amapá (54.1; 41.3 and 38.8 mg kg^{-1}), Mato Grosso (8.1; 8.0 and 8.2 mg kg^{-1}) and Amazonas (4.5; 4.3 and 4.2 mg kg^{-1}). Pearson correlation was performed between Ba concentration in Brazil nuts and Ba in the soil layers 0-20cm (r=0.73), 20-40cm (r=0.63) and 40-60cm (r=0.69) with significative values (p<0.05) showing a positive and high relationship between the two parameters studied. Brazilian nuts and soil samples with the highest Ba contents were those from Acre, which are in accordance with the high values also observed for soils. Barium concentration in Brazilian nuts widely changed among and within tree populations reflecting the great heterogeneity in soil conditions around the Amazon basin.

Keywords: Bertholletia excelsa; barium; Amazon; hollandite.
Financial support: CAPES, CNPq and FAPEMIG.

(7432 - 2286) Response of P-cycling microbial communities during soil genesis and ecosystem development along a 6500 year chronosequence under lowland temperate rainforest in New Zealand

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The Haast chronosequence (SW coast, South Island, NZ) comprises a series of dune ridges formed by sediments deposited following periodic earthquakes on the Alpine Fault. It is characterized by rapid podsolization under high rainfall and has proven to be an ideal system to study soil organic P dynamics because of a rapid depletion of mineral P and accumulation of organic P over pedogenesis. The total P decline at Haast is associated with shifts in soil organic P composition, plant communities and bacterial diversity. The importance of the microbial contribution to organic P turnover under P limited conditions is well established, and prior isotopic studies at Haast pointed to the importance of phosphatases in organic P mineralization in the older dunes. Our recent development of PCR primers targeting three classes of bacterial non-specific acid phosphatase genes (Class A, B and C NSAPs), enabled the exploration of the microbial contributions to soil P dynamics in these long-term and highly acidic soil systems. Six dune ridges were chosen for the study (ranging from 191 years before present to 4000 yBP). Mineral soil samples (n=6) from each dune ridge were collected and immediately placed into Lifeguard™ Soil Preservation Solution to preserve nucleic acid integrity until total DNA and RNA could be extracted. Initial measurements targeted total bacteria (16S rRNA) and Class A, B and C NSAPs by quantitative PCR. Total bacteria decreased over time following ecosystem retrogression, as did the class A and class C NSAP targets. Interestingly, the Class B NSAP gene was rarely detected; although we have successfully quantified this group in NZ pasture soils. Relative to total bacteria, the NSAP targets were higher in the oldest dunes and lower in the youngest dunes, suggesting a shift in the microbial composition to more phosphorus solubilizing bacterial communities over time. Finally, as found with the bacterial phosphatase genes, potential acid phosphatase activity (ACP), increased on average over time through retrogression. PCR amplicons targeting total genes and gene transcripts will be sequenced using Illumina MiSeq to characterize shifts in the diversity and activity of the bacterial phosphatase producing communities through ecosystem development. This study shows that molecular analysis targeting key functional genes can provide a useful tool for researchers to obtain insight into the role of microbes in biogeochemical cycling.

Keywords: Phosphorus cycling, bacterial acid phosphatases, microbial communities, chronosequence, pedogenesis, ecosystem development
Financial support: Funding was provided by Lincoln University (L.M. Condron), Canada Research Chairs Program and an NSERC Discovery Grant (K.E. Dunfield)

(1870 - 575) Soil faunal impact on litter decomposition and soil in cover crop system: effect of beetle larvae (*Gametis jucunda*) assessed by physical fractionation, micromorphology, and biochemical assay

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Soil macrofauna exert strong control on a wide range of soil processes. Yet quantitative understanding of their contribution to soil C and nutrient dynamics remains poor because common techniques are not compatible with their ecology. Here, we investigated a short-term effects of larvae on litter decomposition in winter cover crop systems on an Andosol in Japan by size fractionation and micromorphological technique. The treatments were wild oat (WO) and hairy vetch (HV) cover crop system, and conventional farming without cover crop (CF). Cover crops were incorporated 80.6 t ha^{-1} of wild oat (C:N ratio 24) and 11.2 t ha^{-1} of hairy vetch (C:N ratio 16) on 12th May, 2016, respectively. By conducting size fractionation of low-density fraction (<1.6 g cm^{-3}), we aimed to quantify macrofaunal excrement as well as assessing litter decomposition. We also identified soil macrofaunal species, based on morphological observations of resin-fixed excrements. Physically-isolated excrements and bulk soil samples were also analyzed for total C and N contents, soil enzyme activities {phosphomonoesterase (PME), phosphodiesterase (PDE), β-glucosidase (β-Gul), and protease}, total and P-solubilizing bacterial or fungal populations according to Karasawa and Takahashi (2015). The excrements were detected in 1–2 mm and 0.5–1 mm size fractions of WO only; and increased between 2 and 8 weeks after the crop incorporation. According to morphological observation, excrement was composed by mainly plant residues, which suggested that those excrements were made by beetle larvae (*Gametis jucunda*). Furthermore, the amounts of excrement C and N were equivalent to approximately 0.67 % and 0.43 % of bulk soil C and N on a ground area basis at 8 weeks after the crop incorporation, respectively, suggesting that beetle larvae excrements represent a significant C and N pool in WO at least in a short term (e.g. crop growing season). The activities of PME and β-Gul of excrement were significantly higher and those of PDE and protease were somewhat higher compared to bulk soil. Total and P-solubilizing bacterial populations were higher in excrement than in soil, whereas total and P-solubilizing fungal populations were not different. We thus concluded that the feeding behavior of beetle larvae promoted litter decomposition in the field with the incorporation of wild oat residue; and improved soil biological and biochemical activities.

Keywords: soil macrofauna, excrement, size fractionation, micromorphology, enzyme activity
Financial support: This study was supported by the research project "Research and Development for strengthening producers" of Ministry of Agriculture, Forestry and Fisheries, Japan.

(3289 - 760) Soil-vegetation relationships and patterns of species distribution on Dry Forests at Carajás, islands from Brazilian Eastern Amazonia

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Several abiotic factors are known to affect plant communities in the Neotropics, at different scales. Pedological and hydrological factors are important for distinguish plants communities in a given area, under the same climate and landscape. Against this background, the aim of this study was to investigate the distribution pattern of dry forests in Flona Carajás by analyzing soil and geomorphological gradients, in which two questions were raised: (1) Are composition and structure of these dry forests formations influenced by soil properties? (2) Is there a pattern of distribution of species in response to a soil gradient? In order to answer them, 36 plots were installed along the soil/ topographic sequence: Águas Claras Formation Sandstone (I and II), Carajás Granite and Xingu Basement Complex. Plots were allocated with all trees ≥ 10 cm at BHC sampled; soil samples (0-10 cm) were also collected. To determine the extent to which soil properties differed within and between the four areas, soil data were analysed by cluster analysis and ordination methods (PCA). Plot grouping clearly revealed the differentiation between soils, indicating that these dry forest formations occur in distinct environments, where there are clear differences in soil fertility and nutrient status. In general, all soils were acid and with low P amounts. However, significant differences in soil properties occurred between sampling sites, for these and many other soil properties. Nonmetric multidimensional scaling (NMDS) ordination technique was used to describe patterns in plant species composition to assess its relationship with soil variables. Different groups of species, highly differentiated and associated with each of the four groups comprising the vegetation gradient, were found. To model the distribution of species, the presence-absence of the most frequent and abundant species was used, applying multiple logistic regression to construct the response curves of species along the soil gradient. The distribution of the most frequent species tends to follow a pattern in response to soil gradient, in which some species may be considered more specialized with regard to local soil conditions than others.
Keywords: Soil-Vegetation. Tropical Dry Forest. Amazon
Financial support: CNPq

(6027 - 2459) The activity of acid phosphatase as a proxy of the interaction between soil microbial diversity and arbuscular mycorrhizal fungi

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In highly weathered tropical soils, phosphorus (P) is not widely available, becoming the symbiotic associations with arbuscular mycorrhizal fungi (AMF) a nutrient acquisition strategy for the plants. In general, microbial community interacts strongly with AMF, affecting the P cycling. The objective was to understand the dynamics of acid phosphatase activity (APA) under different soil microbial communities and along plant colonization by AMF species. The experiment was conducted in a glasshouse, in randomized block design, with four replications. Two crops were used: *i)* a grass *(Brachiaria brizantha,* brachiaria), or *ii)* a legume *(Crotalaria juncea,* crotalaria*).* The soil was submitted to a gradient of microbial community diversity: *i)* native soil; ii) soil dilutions inoculated in sterilized soil (10^{-1}, 10^{-3}, 10^{-6} or no inoculation); or iii) heat treatment (no heating, 50, 80 or 100 ºC for one hour). After the establishment of the microbial communities, the root from the seedlings were inoculated with three AMF species: *Rhizophagus clarus*; *Dentiscutata heterogama, Acalouspora colombiana*. The APA was assessed in a fresh soil collected 30 days after transplanting. For brachiaria, the interaction between dilution and AMF affected the APA. Regardless the AMF, the highest APA, was observed in the native soil, and as the soil microbial diversity reduced, the APA reduced proportionally, showing the lowest APA activity in the sterilized soil for all AMF. However, the *A. colombiana* showed the highest APA compared to the other AMF species and the lowest APA was observed under no AMF inoculation. In treatments with crotalaria, results did not show interaction between soil microbial diversity and AMF, but they had specific effect. Crotalaria also showed the highest APA under native soil, and a huge reduction in APA under low soil microbial diversity. Inoculation with *A. colombiana and D. heterogama* showed higher APA compared to *R. clarus* and no AMF inoculation for crotalaria. Regarding to the heating treatments, the highest APA was observed when the soil was heated for 80 ºC, for both brachiaria and crotalaria. However, the APA decreases under temperatures higher than 80 ºC s. In general, the highest APA was observed in the native soil and also when the soil was heated for 80 ºC for one hour for both brachiaria and crotalaria. And also *A. colombiana* was able to increase the APA compared to no AMF inoculation and other AMF species.
Keywords: Enzyme, Phosphorus, Dilution, Temperature
Financial support: FAPESP#2016/21596-7

2.2.3 - Soil and water pollution: dynamics and evaluation

(2283 - 2308) A multi-scale approach for soil contamination assessment

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The major problems of correctly assessing soil contamination are the comprehension of the spatial variability of soil pollution and the estimation of pollutants bioavailability. This information is crucial to define site-specific soil sampling strategies, to estimate risks for environment and human health, and to select the most appropriate remediation strategies. Erroneous identification of soil contamination can have negative economic implications. This work illustrates the potential of soil contamination assessment integrating field, laboratory and microscopy scales results. In the field, proximal sensing sensors, such as EMI, ARP, portable γ-ray and XRF spectrometers were used to build low-cost covariates to aid the characterization of pollution spatial variability, to provide geospatial details enabling the homogeneous and inhomogeneous zones segmentation and to recognize locations for further investigations. In lab, selective chemical extractions were applied to define the form and bioavailability of pollutants. Optical, electron microscopy and microanalysis (E/WDS) on soil thin sections gave access to pollutant associations induced by pedological processes. This multi-scale approach is demonstrated for two case studies of south Italy, one rural and one industrial, potentially polluted by heavy metals and heavy hydrocarbons by former disposal of industrial wastes. In both sites, the geospatial variability of contamination was always much more complex than expected with inhomogeneous distribution of pollutants in the first meter of depth. The agricultural field was more homogeneous in the topsoil while discontinuities and hot spots were

found in the subsoil. In both sites, the metal bioavailability was generally restricted by sub-alkaline soil pH and OM; the pollutants were strongly associated to the finest soil fractions, highly bioaccessible by ingestion; the hydrocarbons were mainly aliphatic at long-chain; the heavy metals were intercepted by localized interactions with soil constituents producing variable spatial distribution patterns at microscale. The pedological and micromorphological observations always provided essential information for the understanding of the emplacement process and possible migration of pollutants towards other environmental sectors. Our multi-scale approach advocated for pedology-based sampling strategies, instead of systematic soil depth sampling. The work supports implementation of bioavailability in regulation.
Keywords: soil pollution; spatial variability; bioavailability; heavy metals; heavy hydrocarbons
Financial support: LIFE + project LIFE11/ENV/IT/275 ECOREMED

(3974 - 1089) Contribution of Soil Active Components to the Control of Heavy Metal Speciation

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Soil active components including soil organic matter, clay silicates, metal hydroxides and microorganisms, which have large surface area and are often electrically charged, are considered as important surfaces to immobilize heavy metals by precipitation, adsorption or (bio)transformation et al. The development and application of in-situ measurement, micro-examination and element tracing technologies significantly accelerated the development of studies with related to heavy metal interactions with soil active components. The in-situ measurement and the greatly improved understanding of soil microscopic properties based on microscopic spectrum technology at molecular level laid solid foundation for the rapid understanding of immobilizing heavy metals in soil and development of soil remediation. Quantum chemistry calculation combined with spectral information has greatly enhanced the understanding of these processes at the molecular level. Meanwhile, the bioavailability and toxicity of heavy metal in soil is mostly decided by its speciation and not its total amount. Therefore, it is necessary to make accurate assessments of heavy metal speciation. The various types of models have been developed to calculate chemical speciation or the distribution of chemicals over all relevant forms on different soil active components. Fundamental understanding of these reactions and processes at the atomic, molecular, and microscopic levels is essential for remediation of heavy metal pollution in soils, sustaining and enhancing soil health, which includes human health, on a global scale.
Reference Xiong J, Weng LP, Koopal LK, Wang MX, Shi ZH, Zheng LR, Tan WF. Effect of soil fulvic and humic acid on Pb binding to the goethite/solution interface: Ligand Charge Distribution modeling and speciation distribution of Pb. *Environmental Science & Technology*, 2018. Xu JL, Koopal LK, Fang LC, Tan WF. Proton and copper binding to humic acids analyzed by XAFS spectroscopy and isothermal titration calorimetry. *Environmental Science & Technology*, 2018. Xiong J, Koopal LK, Tan WF, Fang LC, Wang MX, Zhao W, Liu F, Weng LP. Lead adsorption to soil fulvic and humic acids: XAFS spectroscopy and NICA-Donnan modeling. *Environmental Science & Technology*, 2013.
Keywords: Soil active component; Heavy metal; Speciation; Modeling
Financial support: The National Natural Science Foundation of China (Nos. 41425006 and 41330852), and the National Key Basic Research Program of China (No. 2015CB150504)

(6236 - 1338) Copper sorption in technosols made with organic matter, carbonates and bentonite

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Many technosols can be intentionally created for specific purposes. Wastes and residues are often able to improve physical, chemical and biological attributes of degraded soils, including immobilization of toxic elements. The main goal of this work was to study the ability of some artificially created soils to reduce copper bioavailability, based on polluted sites of the former copper mine “Pedra Verde” (Viçosa do Ceará, Brazil). The technosols were made from unconsolidated materials: Tec A (33.3% organic compost; 33.3% bentonite + sand; 33.3% limestone waste), Tec B (25% organic compost; 25% bentonite + sand; 50% limestone waste), Tec C (50% Organic compost; 25% (bentonite + sand); 25% limestone waste) and Tec D (25% Organic compost; 50% (bentonite + sand); 25% limestone waste). Leaching columns experiments were conducted to test copper sorption and desorption. First, a copper sulphate solution ([Cu^{2+}] =1000 ppm, pH 4.2, 30 mL) was added 24 times. Then, desorption of the metal was tested percolating deionized water through the columns (8 times). In order to understand the dynamics of copper in the tested technosols, the residual content of copper in the columns was determined through a sequential extraction. Copper concentration and pH were determined in all leachates. Results show that the technosols were efficient in retaining copper. The percentage of sorption ranged from 95% (Tec D) to 99% (Tec B). The sequential extraction demonstrated that the carbonates and organic matter were the main responsible for copper retention, 61-69% and 15-23%, respectively, of total Cu added. Until the 17^{th} leaching, none of the technosols released significant amount of copper. In the last leaching, Tec A, B, C were retaining 76%, 81% and 65% of copper added, while Tec B was still retaining 91%. The pH values of the sorption test ranged from 7.56 (Tec A) to 8.14 (Tec C) in the first leaching and from 5.85 (Tec A) to 6.99 (Tec B) in the 24^{th}, mainly because carbonate dissolution. The desorption test showed that the technosols released small amount of copper (maximum of 40 ppm for Tec D) in the first four leaching. After that, none of them was desorbing copper anymore. The pH values were slightly constant along the desorption experiment presenting mean values of 7.20, 7.92, 7.33 and 6.66, respectively. Technosol B was the most efficient in copper sorption, considering that it retained the largest amounts of the contaminant and did not released it in the desorption test.
Keywords: soil pollution; remediation; mining; technogenic soils; sequential extraction
Financial support: Programa Unificado de Bolsas de Estudantes para Estudantes de Graduação (PUB) – Universidade de São Paulo.

(5957 - 2544) Derivation of soil thresholds for arsenic applying species sensitivity distribution

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The current soil quality standards (SQSs) of potentially toxic elements used for agriculture in many countries around the world do not consider the diverse crop species and cultivars and the effects of soil properties, and therefore may be either over- or under-conservative, resulting in unnecessary economical or ecological costs. Therefore, it is urgent to revise and improve the SQSs. Species sensitivity distributions (SSDs) are commonly used to derive threshold values for contaminants. After estimation of the SSD parameters using statistical extrapolation methods, a hazard concentration from the fifth percentile of the distribution (HC5) is calculated. The HC5 is the concentration at which less than 5% of the species within an ecosystem is expected to be affected and is often used for deriving environmental quality standards. Very few studies have applied the SSD methodology to derive soil thresholds for arsenic (As) due to the

lack of data generated from different crop species and different soil types. Therefore, with a focus on widely consumed root vegetables, this study aims to derive soil thresholds for As based on the food quality standard using SSD method. The SSD curves were constructed with Burr Type III distribution based on the bioconcentration factor (BCF, ratio of As concentration in plant to that in soil) of different vegetable cultivars grown in Ferrosols and Cambosols. The SSD curves showed that the twelve vegetable cultivars exhibited sensitivity variations for As accumulation, with radishes and potatoes in both soils being the most and least sensitive, respectively. The normalization relationship was shown as log [BCF] = 0.13pH − 1.39log [Fe_{OX}] − 1.98 with R^2 = 0.67. The critical soil concentration for each cultivar under different soil conditions after normalization was back calculated from the corresponding BCF value and the food quality standard of As (0.5 mg kg^{-1}, fresh weight). Then the hazardous concentrations (HC5) were calculated from the Burr Type III fitted SSD models. The calculation formula for HC5 was HC5 = $10^{-0.13pH + 1.39logFeOX + 0.73}$. The results suggested that the current SQS were only valid for soils with limited combinations of soil pH and Fe_{OX} content. The approach proposed here is widely applicable to other crops as well as other trace elements that have the potential to cause food safety issues.

Keywords: Soil quality standard; Heavy metals; Food quality standard; SSD

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(7071 - 3172) Determination of porosity in charcoal through relaxometry.

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The low field Nuclear Magnetic Ressonance (relaxometry) is an important tool for the studies of fluids in porous media, system in which charcoal fit very well, in a non destrutive way and has been show a useful tool for the determination of fluids content and pore size distribution. By this technique is possible to determine the transverse relaxation time (T_2) of the ^1H from the fluid, value that is related with the pore size, in a direct relationship, but also with the content of paramagnetic ions (e.g. Fe^{3+}; Fe^{2+}; Mn^{2+}; Cu^{2+} etc) in a inverse relationship. And so we are faced with an ill-posed inverse problems, since an observed short relaxation time could be due to small pores and/or large content of paramagnetic ions. Taking this into account the objective of this study was to develop a methodology for the determination of charcoal porosity through the analysis of T_2. Attempts were made to remove the paramagnetic ions of the charcoals using rinsing with HCl and also to uniform the content of paramagnetic ions in the bulk water by the addition of $MnSO_4$ solutions. The wet charcoal samples were analyzed by NMR relaxometry using the CPMG pulse sequence. And the values of T_2 were obtained from exponential adjustments of the transverse decay curves and also by the Inverse Laplace Transform. In the first step, tests were carried out to remove paramagnetic ions by washing with solutions of hydrochloric acid (HCl). It was found that HCl was able to remove ions, but same charcoal was able to recover the ions in the bulk water (buffering) and after 10 washing we tried a second approach: to add a solution containing Mn^{2+} in the samples, aiming at a reduction of the T_2 of the bulk water and to uniform the samples. Again we were not successful because some charcoals had an incredible sorption capacity of the added ions, showing promise for the use as filters of water contaminated with ions.

Keywords: Porosity, charcoal, transverse relaxation, NMR.

Financial support: CNPq

(5909 - 2363) Evaluation of the content of trace elements in the soils of the river basin affected by flood events

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The trace elements content assessment in the river basin and the soils under agricultural use of floodplain can be still considered a valid research topic in terms of a growing risk of environmental pollution. Numerous samples of sediments were taken (0-20 cm) from the river banks on the stretch of a few dozen kilometers along the lower Vistula River (Poland) in order to study their trace elements content. For their part, floodplain soils were sampled (0-30 cm) in the vicinity of the riverbed. Each year the flood water deposits an enriched suspension in humic and mineral colloids on the floodplain. Basic properties in bulk soil samples and sediments (texture, pH, cation exchange capacity, electrical conductivity, total organic carbon (TOC) and the total content of trace elements) were determined. A three-step BCR sequential extraction procedure for the study of partitioning of Zn, Cu, Pb and Ni was used. Clay fraction (<0.002 mm) was separated for the X-ray diffraction analysis and chemical analysis. The river bank sediments contained relatively high concentration of trace elements, reflected in the values of the contamination factor, the contamination degree, the geo-accumulation index and the enrichment factor. The clay fraction of the soil samples contained a significantly higher total content of Zn (237-845 mg kg^{-1}), Cu (160-351 mg kg^{-1}), Pb (155-643 mg kg^{-1}) and Ni (52.0-91.6 mg kg^{-1}) in comparison with the concentration of trace elements in the clay fraction separated from the river bank sediments: Zn (97-392 mg kg^{-1}), Cu (79.2-144 mg kg^{-1}), Pb (35.9-108 mg kg^{-1}) and Ni (31.4-64.4 mg kg^{-1}). The statistical analysis of the results showed a significantly positive correlation between TOC and the total content of Zn and Pb in the river bank sediments. The total content of Ni, Cu and Pb was also significantly affected by the content of the clay fraction, whereas the total content of Zn, Cu and Pb was significantly correlated with the content of TOC in the soil samples. The Vistula River bank section under study undergoes river erosion and the deposited sediments during flood events on the floodplain are enriched in numerous elements and compounds. These flooding events are a source of contamination for arable soils and permanent pastures with trace elements. Consequently, these findings suggest that a more detailed river basin monitoring should be faced in order to get more accurate knowledge of the negative effects of flood events on the soil quality.

Keywords: river basin, floodplain, trace elements, contamination factor

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(1637 - 484) High temperature industrial biochar from industrial processes for mine soil remediation

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Mine soils are hard to revegetate due to their adverse physicochemical properties. They are a source of pollution due to the formation of acid mine drainage and wind and water erosion of metal-bearing particles, both fostered by the lack of vegetative cover. Strategies for their restoration include amendment with organic and

inorganic materials for pH adjustment and metal stabilization. Having a basic pH and metal stabilization capacity, biochar is an ideal candidate for mine soil restoration. By co-composting biochar, the final compost is enriched in N and humic compounds and the composting process is accelerated. Upon application of co-compost, the labile fraction provides nutrients while the stable fraction increases the long-term nutrient and metal retention as well as carbon capture. In the Mexican context, biochar is a material with little to no perceived value; by tying it to the production of energy via gasification, its production becomes a possibility. Mine site restoration is mandated by Mexican law; thus, it is imperative to identify environmentally beneficial strategies for compliance. There are over 1,550 active mine sites and 1,150 projects in exploration in Mexico. One such case is the iron ore mine in the Las Truchas mining district, were impurities consist of S, Cu, Zn and possibly Pb and As. We designed an experiment to evaluate biochar and biochar compost performance as soil amendment for mine soil restoration using spoils and tailings from Las Truchas to reduce metal mobility, neutralize acidity and favor vegetative growth. Biochar was produced by downdraft gasification of woody gardening residues from UNAM main campus in southern Mexico City, compost was from leafy residues of the same origin, products were characterized exhaustively. Application was done in a pot experiment with varying doses of biochar compost and raw biochar (0, 10, 50 ton ha^{-1}). Vegetative cover consists of *Lollium perenne*. Preliminary results show metal and nutrient concentrations in leaching water as well as qualitative differences in above-ground biomass production. Upon completion, metal concentrations in plant tissue will be determined along with soil concentrations and distribution. C and nutrient enrichment of soils will also be determined.

Keywords: Mine soils, rehabilitation, biochar, gasification, compost
Financial support:

(2563 - 1476) Impact of floating aquatic vegetation suppression on water quality and canal sediment properties in south Florida

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A significant portion of phosphorus (P) loads discharged from the Everglades Agricultural Area (EAA) in south Florida is in the form of organic particulates from biological sources during farm drainage events. This study was initiated on four treatment-control farm pairs over a five year period to investigate the role of suppressing floating aquatic vegetation (FAV), such as water lettuce (*Pistia stratiotes*), on drainage water quality and the formation of more recalcitrant inorganic P forms in farm canal sediments. Treatment canals implemented aggressive FAV suppression, while control canals operated under normal management practices. It is hypothesized that with FAV suppression, co-precipitation of P with calcium and magnesium (Ca-Mg) into less labile, more recalcitrant minerals is increased due to more light penetrating the water column, while P sorption with iron and aluminum increases with higher dissolved oxygen and redox potential. Phosphorus fractionation was used to measure labile and recalcitrant P pools in the eight farm canal sediments at the 0-2.5 cm depth, as well as particulates exported with drainage water during pumping events. Canals sediments in farms suppressing FAV had increased bulk density and lower total P than farms allowing growth. On most farms, sediment residue and Ca-Mg-bound P pools had the highest percent of total P ranging from 23.6 to 73.4% for Ca-Mg-bound and 6.1 to 63.6% residue P, while labile P had the lowest between 0.5 to 5.5%. In the discharged particulates, Ca-Mg-bound-P had the highest percentage (28.2 to 61.0%) and labile P was the lowest (0.9 to 19.1%). While labile P was the smallest pool, it was higher in the discharged particulates than canal sediments. Discharge water P concentration was reduced when FAV was maintained at less than 5% coverage in farm canals. The generation of denser inorganic mineral P may reduce P transport out of farm canals and reduce P loads into the downstream Everglades ecosystem.

Keywords: Phosphorus Water Quality Canal Sediments Best Managment Practices Aquatic weeds
Financial support:

(4946 - 1807) Lead pollution of an ephemeral waterway draining an arid-zone mining town in New South Wales, Australia

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(9006 - 2353) Metal accumulation in soils adjacent to via dutra, Rio de Janeiro

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The emission of traffic-related metals has generated great concern around of the world, due to their deposition on soils adjacent to roads, and the subsequent impact on the environment and human health. This study evaluates the levels of metals in soils neighboring the Presidente Dutra highway (hereinafter designated as Via Dutra, its common name), located in the State of Rio de Janeiro. Via Dutra was inaugurated in 1951 and currently features a daily traffic of approximately 30 thousand vehicles at the chosen sampling point (km 206). The pH and concentrations of several metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, V, and Zn) were determined. Soil samples were collected at different distances from the highway (1, 3, 5, 10, 15 m) and at two depths (0-15, 15-30 cm). The results showed that samples closest to the highway and to the surface presented higher pH values, suggesting the effect of road abrasion. Unlike sampling depth, the distance from the highway significantly influenced soil metal levels. The concentration of metals decreased with increasing distances from the road, for all the elements studied. It is noteworthy that Zn, Mn, Ni concentrations increased by 1336, 1160 and 1002%, respectively, between samples collected at 15 and 1 m from the road. In addition, soil samples contained substantial levels of Cd, Ni, Pb, and Zn, when compared to the reference values for Brazilian soils. The content of V was above the acceptable limit indicated by the pertaining literature. The concentrations of Co, Cr and Cu complied with background levels established by the Environmental Company of São Paulo State (CETESB). In conclusion, the results suggest that traffic is the main source of metal contamination in soils adjoining Via Dutra.

Keywords: Metals, soil pollution and roadside soil
Financial support: Portuguese Foundation for Science and Technology (FCT), National Council for Scientific and Technological Development of Brazil (CNPq) and Foundation for Research Support of the State of Rio de Janeiro (FAPERJ)

(3839 - 705) Nitrogen removal in shallow groundwater below three arable land systems in a high nitrogen loading region

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The Taihu Lake region (TLR) is one of the most intensive agricultural regions with high nitrogen (N) loading in eastern China. Large inputs of synthetic N fertilizer have led to a series of environmental problems including eutrophication of surface waters, nitrate (NO_3^-) pollution of groundwater. However, how NO_3^- is eventually removed is not well known to date due to the difficulty in measuring denitrification end product. To fully evaluate the risk of NO_3^- on groundwater environments, we assessed denitrification capacity for two years

through measuring the concentrations of active nitrogen species (NO_3^-, $NH4^+$, TN, and dissolved N_2O), and particularly inactive nitrogen (excess N_2) using membrane inlet mass spectrometer, in groundwater below three typical agricultural land-use types in the TLR. The results suggested that the conversion of paddy field (PF) to vineyard (VY) and vegetable (VF) significantly increased the groundwater NO_3^--N concentration. However, due to the low O_2 and high DOC concentrations in groundwater, denitrification activity was high in the study sites, consuming 76%, 83% and 65% of the groundwater NO_3^--N in VY, VF and PF, respectively. This resulted in high excess N_2 accumulation in groundwater, and the concentration even exceeded the total active N in the deep layer. The large amounts of excess N_2 observed in the VY and VF over all the sample times indicated that considerable N was stored as gaseous N_2 in groundwater and should not be ignored in balancing N budgets in aquifers where denitrification is high. Our results also demonstrated that the indirect N_2O emission factor (EF5-g) in VY （0.0052）and VF （0.0057）was significantly higher than PF （0.0011）as well as the IPCC default values（0.0025）. In view of the increasing trend of paddy fields being converted to uplands combined with the low ground water table in the TLR, we thus concluded that the risk of NO_3^- contamination in groundwater and indirect N_2O emission will intensify.

Keywords: denitrification, underground, nitrous oxide, land use change
Financial support:

(6916 - 1322) Pesticide load onto soils at a national scale using combination of remote sensing and coarse statistical data and its impact on groundwater quality

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Objective of the Study In order to calculate an annual pesticide load over a certain area, one needs detailed data on pesticides' application that is hard to find in a real world. One way is to collect desired data from the farmers, but this is feasible just in relatively small areas. Due to missing detailed data, we computed more precise pesticide load using load data aggregated at certain spatial unit (in case of the Czech Republic districts) and maps of crops derived from a remote sensing imagery. Material and Methods Data on annual pesticide usage for 77 districts in the Czech Republic and remote sensing multispectral data (IRS AWiFS and multitemporal images Envisat MERIS, Landsat 7 – LEC, lately Landsat 8 – LDCM and Sentinel-2) together with a custom database of plant protection products were used. Crop cover (12 classes) grids of 100 m cell size (lately 14 classes, 25 m cell size) were derived from remote sensing images; the crops were linked to plant protection products (PPP) and active substances. Then redistribution of pesticide usage from districts to grid cells was carried out using established link between a crop, PPPs and respective active substances. Groundwater samples were taken in the 2014-2016 period twice a year at 692 sites throughout the Czech Republic as a part of long-term national groundwater monitoring program and analyzed for more than 130 pesticides and metabolites. Results The grid of pesticide usage on perennial crops is produced before the end of spring every year in order to provide data needed for monitoring of pesticides that starts regularly in April. The grid of pesticide usage on all the other crop classes is produced regularly in November. The results are published on WWW and annually updated in order to provide for example water managers with information necessary for a meaningful design of pesticide monitoring programes in the Czech Republic. The monitoring results clearly show the influence of pesticide load on groundwater quality, especially for herbicides used for sugar beet, maize and rape. These pesticides and mainly their metabolites exceeded the groundwater standard in more than 40% of monitored sites. Conclusion The product provides more detailed information on a spatial load of pesticides than other publicly available data on pesticide usage enabling water managers to set up optimized monitoring programs. Further enhancements are planned in the future as new remote sensing sensors become available.

Keywords: pesticides, groundwater, remote sensing, monitoring
Financial support:

(4485 - 1403) Phosphorus Release in Pyrogenic Organic Matter and Gypsum Amended Soils under Simulated Seasonal Flooding Conditions

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Flooding changes the oxidation–reduction status of soils and alters the fate and transport of phosphorus (P) in soils. We studied P dynamics in pore and surface water in gypsum- or pyrogenic organic matter (PyOM)- amended soils and unamended soils under simulated spring snowmelt (SSM) and summer flooded (SF) conditions. Two contrasting soils (Fyala and Neuenberg series) were incubated under SSM (previously frozen soils; flooded at +5 ^{O}C) and SF (unfrozen; flooded at +20 ^{O}C) conditions unamended or amended with either wood chip PyOM (1% w/w) or wallboard gypsum (0.25% w/w) for 10 weeks. Despite low Olsen P content, the sandy low organic matter Neuenberg soil showed a significantly ($p<0.001$) high dissolved reactive P (DRP) concentration in both pore and surface water. Application of gypsum significantly decreased the pore and surface water DRP concentrations in Neuenberg soil while PyOM significantly increased them in Fyala soil. Under SSM condition, redox potential (Eh) decreased very slowly hence pore water DRP contents also changed only marginally during the entire incubation period. The surface water DRP concentration however increased steadily due to diffusion of P from pore water. Under SF condition, pore water DRP concentration in Fyala soil increased slowly until 6th week and rapidly thereafter in both amended and unamended soils. In contrast, the pore water DRP concentration in Neuenberg soil decreased rapidly in both PyOM amended and unamended soils after the 6th week. Differences in Fe^{3+}/Mn^{4+} reduction and Ca^{2+} release in the two soils were related to the observed trends in P release during the latter part of the flooding. PyOM was not effective in reducing floodwater P concentration, while the effectiveness of gypsum in reducing floodwater P concentration was soil dependent.

Keywords: Gypsum, Pyrogenic organic matter, Flooded soils, P dynamics, Redox potential, Soil amendments
Financial support: Financial support received through the QEII program at University of Winnipeg is gratefully appreciated.

(1776 - 2556) Relative efficiency of Typha latifolia and Brachiaria mutica hydrophytes in engineered constructed wetland for treating domestic wastewater.

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Irrigation with sewage effluent has become a more acquainted farmers' practice as a source of irrigation water and nutrients. The presence of broad spectrum of contaminants *viz,* biodegradable

organic compounds, toxic metals, suspended solids, micro pathogens and parasites which restrict its direct application to field. Constructed wetland is has been designed and constructed to utilize natural processes involving wetland vegetation, soils and the associated microbial assemblages to assist in treating wastewaters. A study was conducted (March 2015 to October 2016) to evaluate the relative efficiency of *Typha latifolia* and *Bracharia mutica* hydrophytes in engineered constructed wetland (vertical flow with a treatment capacity of 50 m^3 per day) for treating domestic wastewater at University of Agricultural Sciences, Dharwad, Karnataka, India. The hydrophyte *Typha latifolia* induced greater reduction of TSS (51.5 %), K (48.0 %), NH_4-N (46.1 %), BOD (39.0 %), COD (38.9 %), TS (35.7 %), TDS (27.5 %), EC (14.3 while, *Bracharia mutica* was efficient in reducing nitrate nitrogen (49.7 %) and total phosphates (41.6 %). Both *Typha latifolia* and *Bracharia mutica* induced moderation in the quality of the sewage water in respect of SAR (3.78 and 3.76, respectively) as against the raw sewage water (4.70). There was not much difference between them in their ability to lower RSC. Results indicated that use of combination of macrophytes is ideal for wetland planting for overall improvement in the quality of the domestic sewage water for its utilization. There was not much difference in their biomass production ability (4.55 and 4.90 kg dry matter/m2/year in *Typha latifolia* and *Bracharia mutica*, respectively). Though, both the hydrophytes accumulated more Fe among micronutrients, *Bracharia mutica* outstood *Typha latifolia*. Uptake of Fe was more with *Bracharia mutica* while Mn uptake was more with *Typha latifolia*. Among the heavy metals, *Bracharia mutica* accumulated more Cr while *Typha latifolia* accumulated more As.

Keywords: Constructed wetland, domestic sewage water, hydrophyte, water quality improvement

Financial support: Water4Crops Indo-European Project (India side), DBT, Govt.of India, New Delhi.

(3286 - 2372) Sea level rise induced arsenic release from historically contaminated coastal soils

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Climate change-induced perturbations in the hydrologic regime are expected to impact biogeochemical processes, including contaminant mobility and cycling. Elevated levels of geogenic and anthropogenic arsenic are found along many coasts around the world, most notably in south and southeast Asia, but also in the United States, particularly along the Mid-Atlantic coast. The mechanism by and the extent to which arsenic may be released in contaminated coastal soils due to sea level rise are unknown. Here we show a series of data from a coastal arsenic-contaminated soil exposed to sea and river waters in biogeochemical microcosm reactors across field-validated redox conditions. We find that reducing conditions lead to arsenic release from historically contaminated coastal soils through reductive dissolution of arsenic-bearing mineral oxides in both sea and river water inundations, with less arsenic release from sea water scenarios than river water. For the first time, we systematically display gradation of soil-arsenic speciation across pre-defined redox windows from reducing to oxidizing conditions in natural waters via the coupling of biogeochemical microcosm reactors and X-ray absorption spectroscopy. Our results demonstrate the threat of sea level rise stands to impact arsenic release from contaminated coastal soils by changing redox conditions.

Keywords: sea level rise, arsenic, soil chemistry, XANES, redox

Financial support: The US National Science Foundation EPSCoR Grant No. IIA-1301765, and the state of Delaware.

(4398 - 252) Studies on Redox behaviors between dissolved sulfide and manganese oxide minerals assisted by in-situ electrochemical technique

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Sulfur is distributed widely in soils and sediments. Sulfide oxidation causes acid mine wastewater, toxicity, and corrosion. Manganese oxide minerals usually affect the migration, transformation, and fate of sulfur. To understand the oxidation behaviors of dissolved sulfide (S^{2-}) and influence factors, reaction process and kinetics were investigated by using different manganese oxides. Different types of manganese oxide minerals (acid birnessite, alkaline birnessite, cryptomelane, todorokite and manganite) were synthesized and participated in the oxidation of S^{2-} [1–4]. The influences of pH, the amount of manganese oxides, temperature, and mineral structure on the initial oxidation rate of S^{2-} were investigated. The electrochemical behaviors of S^{2-}, $S_2O_3^{2-}$ and SO_3^{2-} on a platinum electrode were studied by cyclic voltammetry and constant potential electrolysis, and *in situ* detection of the intermediates was conducted in aqueous systems of S^{2-} and manganese oxides [3]. The elemental S^0, $S_2O_3^{2-}$, SO_3^{2-} and SO_4^{2-} were formed as the important products, and polysulfide ions were determined as an intermediate in the oxidation processes. The initial oxidation rate followed a pseudo first-order kinetic law, and the apparent rate constants of S^{2-} oxidation increased with elevating temperature and increasing the quantity and active Mn(III) content of manganese oxides [1,2]. The reaction rate increased at first and then decreased as the pH changed from 4.0 to 12.0, and the greatest oxidation rate was achieved at pH 8.0. The oxidation activity followed the order of acid birnessite > alkaline birnessite > cryptomelane [1], and acid birnessite > todorokite > manganite [3]. The reaction rate was controlled by the speed of diffusion together of dissolved sulfide and manganese oxides, and the admission of oxygen reduced the initial oxidation rate of dissolvable sulfide by todorokite due to the decrease of active Mn(III) content in manganese oxide for the oxidation of Mn(III) to Mn(IV) [2]. The presence of oxygen increased the chemical stability of todorokite in the initial oxidation stage of dissolved sulfide. However, manganite exhibited excellent catalytic activity and stability for the rapid oxidation of dissolved sulfide to SO_3^{2-} by oxygen [4]. References 1. Guohong Qiu et al., *J. Soils Sediments*, 2011, 11, 1323. 2. Tianyu Gao et al., *J. Hazard. Mater.*, 2015, 290, 106. 3. Yao Luo et al., *Environ. Chem.*, 2017, 14, 178. 4. Yao Luo et al. *Clay Clay Miner.*, 2017, 2017, 65, 299.

Keywords: Manganese oxides; Dissolved sulfide; Redox; Electrochemical technique; Kinetics

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(8550 - 3083) The Role of Soil Chemical Processes and Properties in Impacting Chromium Cycling in Highly Contaminated Soils

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Hexavalent chromium [Cr(VI)] is one of the most pervasive contaminants at EPA Superfund Sites, with almost 2/3^{rds} containing

chromium. However, depending on its redox state, Cr exhibits vastly different behavior. Trivalent chromium [Cr(III)] is fairly nontoxic and insoluble, while Cr(VI) is readily soluble and highly carcinogenic. Despite the significance of Cr(VI) in the environment, there is currently an incomplete understanding of its behavior under varying environmental conditions. To further investigate Cr chemistry, we obtained soil cores with highly elevated concentrations of Cr(VI) from the E.C. Electroplating Superfund Site, Garfield, NJ. Soils were characterized using both macroscopic and molecular scale in-situ techniques. Chromium release was determined in a stirred-flow chamber utilizing competing electrolyte solutions of various molarities. The effluent was speciated for Cr(III), Cr(VI) and co-released metals via Inductively coupled plasma mass spectrometry (ICP-MS) to quantify Cr release levels over the course of the reaction. At several time points the stirred-flow reaction was quenched, to conduct surface speciation analyses. Sorbed Cr was speciated using synchrotron-based X-ray absorption fine structure spectroscopy (XAFS). Identifying labile and recalcitrant Cr in the soil matrix is crucial to understanding the cycling of Cr in the subsurface. Such experimental analyses are essential in designing effective Cr treatment strategies, such as bioremediation or pump and treat to minimize the long term risk of environmental contamination.

Keywords: Chromium, urban environment, superfund, xafs
Financial support: University

(6421 - 1413) Wastewater treatment and recovery of uranium by iron and aluminium (hydr)oxides

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Uranium (U) mining may provoke environmental contamination, especially when acid mine drainage (AMD) is generated. Several studies demonstrate the effectiveness of iron (Fe) (hydr)oxides to immobilize soluble U. However, changes in redox conditions may compromise the efficiency of wastewater treatment involving such minerals. Ferric hydroxides are unstable under low redox potential. On the contrary, aluminium (Al) is stable in such conditions and is recognized to enhance the stability of Fe (hydr)oxides. In this study, the immobilization of U from contaminated water was evaluated by co-precipitation with Fe and Al (hydr)oxides. The U recovery and stability in the solid phase precipitated were also assessed. Solutions of Fe^{2+}, $Fe^{3+}$and Al sulfates were mixed with an U standard solution in order to obtain 21 different treatments. The treatments consisted of three Fe:Al molar ratio (100:0, 80:20 and 60:40), two Fe valence states (Fe^{2+} and Fe^{3+}) and one only with Al (Fe:Al = 0:100), combined with three concentrations of U (80, 40 e 20 mg L^{-1}). After precipitation of Fe and Al (hydr)oxides, the incubation period lasted 84 days. The pH of the suspension was raised to 9 and adjusted weekly. Samples of supernatants were also collected every week. Concentrations of U, Fe and Al were assessed in supernatants by ICP-OES. The precipitated phases were characterized by XRD and the U contents in precipitates were evaluated by discrete extractions with H_2O, CH_3COOH, $NH_2OH.HCl$, NH_4F and a leaching test. Results demonstrated that all treatments were efficient to immobilize almost 100% of the soluble U in 24 hours of incubation. In the end of the incubation period, treatments in the presence of Al were more efficient to remove U from water (more than 95%) than the ones only in the presence of Fe. However, precipitation of Al alone was less efficient than the treatments with both Al and Fe. The dominant mineralogical phases in precipitates were magnetite and hematite, in the absence of Al and in presence of Fe^{2+} and Fe^{3+}, respectively; goethite was dominant in the presence of Al and Fe^{2+}; ferrihydrite in the presence of Al and Fe^{3+} and gibbsite in the presence of Al alone. Uranium associated to magnetite, hematite and gibbsite was less stable compared to goethite. Leaching test and discrete extractions procedures confirmed the need of an appropriated mine waste storage facility for the sludge produced by water treatment. Uranium recovery from sludge is also suggested.

Keywords: co-precipitation; acid mine drainage; goethite; hematite; magnetite.
Financial support: CAPES, CNPq and FAPEMIG

C2.3 - Soil biology

C2.3.1 - Soil microbiological processes and nutrient cycling under crop rotation

New approaches for measuring microbial ecosystem services in modern and sustainable agricultural cropping systems

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Microorganisms are directly involved in the ecosystem services on which all of life depends, and yet we know much less about their biodiversity than we do for plants and animals. A combination of technological advances in next-generation sequencing and bioinformatics with state of the art real-time field-based measurements are allowing us to integrate taxonomic and metabolic functional compositions of active microbial communities and enable ecosystem scale measurements of nutrient sink-source processes for adoption of modern and sustainable agricultural cropping systems. We can use this advanced information to better understand how microbial biodiversity responds to environmental changes, specifically after tropical deforestation for agricultural cropping system purposes, and to predict how these responses will alter biogeochemical cycles of greenhouse relevant gases. We propose the use of a three-tiered approach to integrate the three dimensions of microbial biodiversity. First, for each dimension we can identify emergent patterns in the sample data. Concordant patterns across the different dimensions of biodiversity are expected to offer important clues about how they are interrelated. Second, we use data gathered at the interface of each dimension to integrate dimensions in a pairwise manner. Third, with these datasets we can explicitly test for significant relationships among all three dimensions of biodiversity and the role of microbial communities active in agricultural cropping systems by using recently developed network analysis tools and statistical approaches.

Keywords: tropical deforestation, land use changes, GHG, functional genes
Financial Support: This project was supported by FAPESP (2014/50320-4) and CNPq

(4855 - 414) Bacterial communities in century-old crop rotations

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Soil microorganisms mediate many important biological processes for sustainable crop production, including nutrient cycling and biological control of pests and diseases. In a greenhouse experiment, we investigated soil moisture effects on microbial biomass C (MBC), profiles of soil bacterial communities, and extracellular enzyme activities in crop rotations that had been established in 1911. Soil samples (0-15 cm depth) were collected after crop harvest in 2013 in three rotations: fallow-wheat (FW), fallow-wheat-wheat (FWW), and wheat-wheat-wheat (WWW), all with or without N and P fertilizer (Fertilized or Control). The soils were potted and watered to 50% field capacity for 10 days. Watering was then stopped for one set of pots from Day 11 to Day 40 to simulate drought, and another set was watered throughout. The soils were sampled at Day 30 to quantify MBC, the relative composition of bacterial communities, and the

activities of β-glucosidase (C cycling), β-N-acetyl-glucosaminidase (C and N cycling), acid phosphomonoesterase (P cycling) and arylsulfatase (S cycling). Soil moisture had no effects on MBC, but crop rotations were in the order: WWW > FWW = FW, and Fertilized > Control. The predominant soil bacterial phyla were Actinobacteria (34% relative abundance), Proteobacteria (25%), Acidobacteria (13%), Bacteroidetes (4%) and Gemmatimonadetes (2%). Crop rotation effects on the relative abundances of Actinobacteria were in the order: WWW = FWW > FW, and that for Gemmatimonadetes was WWW ≥ FW ≥ FWW. Gemmatimonadetes were more abundant in wet soil than in dry soil, but fertilizer had no effects. The bacterial α-diversity was in the order: WWW > FWW = FW, with no fertilizer or soil moisture effects. Crop rotation effects on enzyme activities were the same as those on MBC, and fertilizer increased the activities of β-glucosidase and acid phosphomonoesterase. Soil moisture had no effects on enzyme activities, except that of arylsulfatase which was greater in dry soil than in wet soil although this effect was only observed in WWW rotation. These results show surprisingly limited soil moisture effects, but they show that continuous cropping (WWW) with fertilizer is more beneficial to soil microorganisms than fallow-based cropping, presumably because of the continuous supply of C to the soil. Field results on N, K and Mg bioavailability (sorbed on ion exchange membranes) are in agreement with these crop rotation effects.

Keywords: Soil biodiversity, enzyme activity, crop rotation
Financial support:

(7335 - 2062) Communities of methanogenic archaeas in different uses of Amazonian soils

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Amazonian forest conversion disrupts processes related to carbon stock, being considered, after fossil fuels burning, the activity contributes most to greenhouse gases emission, among them is methane. Methane production is mediated by methanogenic archaea, and to understand changes in the flow of this gas, it is necessary to study microbial communities involved in methane cycle. This study aimed to monitor and characterize methanogenic archaeal communities by population enrichment from soil samples collected in a primary forest, secondary forest and pasture of the Amazon region. Soil samples were enriched with specific medium and were added separately acetate, methanol, and H_2:CO_2 as carbon sources. Monitoring was performed by methane emission analysis by gas chromatography, mcrA quantification by the quantitative PCR and the community characterization was performed by microscopy and sequencing of the 16S rRNA (V4-V5 region). Analyzing methane emission by the three soil types, pastures presented a higher methane yield than forests samples. Methanol enrichments stimulated a greater gas production than acetate samples and much larger than cultures with H_2:CO_2. These results indicate that methylotrophic pathway may be important in methane production in Amazonian soils. The *mcrA* gene was quantified from pasture samples at the initial incubation time, which was not possible for forest samples. At the end of incubation, *mcrA* copies number was similar for the three soils profiles. Enrichments phenotypic characterization revealed aggregated cells, characteristic of the genus *Methanosarcina sp.*, later identified by 16S rRNA sequencing. The cells in rod-shaped and cocci formats were also observed. Was identify by sequencing 7 different methanogenic archaeas groups affiliated with Euryarchaeota and Bathyarchaeota phylum. Initial pasture samples were identified sequences affiliated with all these groups, while forest samples presented sequences affiliated with only one genus. Pasture samples showed a final community composition similar to initial, however more abundant. Soil samples enrichment from primary and secondary forest presented a distinct composition due to groups enrichment that was not identified at initial samples. These results showed although methanogenic archaeas are in low abundance in forest soils, they can be enriched when submitted to favorable conditions, archive methane production and reaching similar communities composition of pasture samples.

Keywords: Enrichment; Methane; *mcrA;* 16S rRNA
Financial support: National Council for Scientific and Technological Development (CNPq); Coordination for the Improvement of Higher Education Personnel (CAPES); São Paulo Research Foundation (FAPESP)-Process: nº 2016/18745-0

(1808 - 1286) Cover Crop Impacts on Soil Microbial Populations and Mycorrhizal Speciation in Dryland Cotton.

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Although there is increasing interest in using reduced tillage approaches and cover crops for cotton production due to potential soil health benefits, relatively little is known about the resulting impacts on soil microorganisms in modern cotton production systems. Therefore, a multi-year, field study was conducted in Chillicothe, Texas (USA) to evaluate the impact of cover crops on various soil microbial populations in dryland cotton. A randomized-complete block design with four replicates was used with cotton planted in June and harvested in November. Treatments included conventional tillage, no-till, and no-till with a variety of different cover crops. Prior to planting, soil samples were collected and characterized using phospholipid fatty acid analysis (PLFA). Mycorrhizal (AMF) colonization of cotton was determined at multiple points during the growing season via microscopic examination of roots stained with trypan blue. Additionally, DNA was extracted from roots and used to identify mycorrhizal species by ribosomal RNA gene sequencing. The PLFA results showed little difference in microbial biomass between conventional tillage and no-till samples; however, inclusion of a cover crop increased microbial biomass up to 2-fold. Similarly, at mid-season (August) the use of cover crops tended to increase mycorrhizal colonization of cotton, being lowest in the conventional tillage plots (65%), slightly higher with no-till (75%), and increasingly higher with no-till and cover crops: mixed species (85%), wheat (88%), hairy vetch (95%), Austrian winter pea (97%), and crimson clover (98%). However, by the end of the growing season (October), the differences had largely disappeared with conventional tillage plots having 82% colonization and the no-till and various cover crops ranging from 79 to 93% colonization. At mid-season (August), AMF species colonizing cotton roots were similar across treatments; however, AMF species in cotton roots showed dissimilarity between conventional tillage and cover crop treatments by the end of growing season (October) with some cover crops increasing prevalence of specific *Glomus* spp. The results indicate that cover crops have the potential to increase microbial biomass and mycorrhizal colonization of cotton grown under dryland conditions, especially early in the growing season, with potential benefits to cotton resilience and productivity.

Keywords: Glomus no-till PLFA
Financial support: Agronomic Science Foundation; Texas A&M AgriLife Research

(6373 - 1023) Dynamics of AMF spore populations under crop-livestock integration or crop rotation and soybean grain productivity

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Cropping practices modify the diversity of arbuscular mycorrhizal fungi and sometimes the changes are not good for productivity. Selection of species can be positive or negative, since the compatibility between symbionts and the mycorrhizal benefit can be lost. The main objective of this work was to evaluate and compare the composition on the AMF community and the mycorrhizal colonization in soybean cultivated under crop-livestock integration (CLI) and crop rotation (CR), and those were related to the grain productivity. Differences on percentages of root colonization over the plant development were observed between the systems. The AMF communities showed distinct behaviors in the systems. All of the variables related to the composition of the communities were influenced by the development stage, and the diversity was also affected by the cultivation systems. Richness and diversity of species increased over the cycle in CR, but in CLI they have only increased during pod formation (PF). Altogether 53 AMF morphotypes were recorded, with 46 species in CLI and 45 in CR. *Claroideoglomus claroideum* dominated in both systems. The mycorrhizal benefit on grain productivity seemed to be more related to the sum of effects of the associated fungi and their functional complementarity than to the taxonomic diversification of the AMF communities.

Keywords: Mycorrhizal fungi, integrated crop-livestock systems, *Glycine max.*
Financial support: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)

(7562 - 588) Effect of paddy-upland rotation on methanogenic archaeal community structure in paddy field soil: evaluation by DNA- and mRNA-based analyses

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Methanogenic archaea are strict anaerobes and demand highly reduced conditions to produce methane in paddy field soil. However, methanogenic archaea survive well under upland and aerated conditions in paddy fields and exhibit stable community. In the present study, abundance and composition of methanogenic archaeal community were investigated in fields where paddy rice (*Oryza sativa* L.) under flooded conditions was rotated with soybean (*Glycine max* [L.] Merr.) under upland conditions at different rotation histories, by analyzing 16S rRNA and *mcrA* (encoding α subunit of methyl-coenzyme M reductase) genes and transcripts of *mcrA*. Soil samples collected from the fields before flooding or seeding, during crop cultivation and after harvest of crops were analyzed. In the DNA-based analysis, the abundance of the extant methanogenic archaeal community decreased to about one tenth in the rotational plot than in the consecutive paddy (control) plot. The composition of the methanogenic archaeal community also changed. Most members of the methanogenic archaea consisting of the orders *Methanosarcinales*, *Methanocellales*, *Methanomicrobiales* and *Methanobacteriales* existed autochthonously in both the control and rotational plots, while some were strongly affected in the rotational plot, with fatal effect to some members belonging to the *Methanosarcinales*. Soil samples collected from the rotational plot in the first year, with paddy rice, and in the two successive years, with soybean, at six time points, as well as from the control plot were subjected to the analysis of *mcrA* transcripts. By the time that soybean was grown in the second year, the methanogenic archaeal community in the rotational plot maintained high *mcrA* transcript levels, comparable with those of the control plot community, but the levels drastically decreased by over three orders of magnitude after 2 years of upland conversion. The overall composition of active methanogenic archaeal communities that survived upland conversion in the rotational plot was similar to that of the active community in the control plot. These results revealed that the upland conversion for longer than 1 year in the rotational system affected structure of the extant and active methanogenic archaeal communities, indicating that unknown mechanisms maintain the stability of methanogenic archaeal community in paddy fields last up to 1 year after the onset of drainage.

Keywords: Methanogenic archaea, *mcrA* transcripts, CH_4, Paddy-upland rotation
Financial support: Soil e-DNA Project (MAFF Japan, eDNA-07-101-1); Environmental Research Projects (the Sumitomo Foundation, 143218)

(3282 - 2634) Methane emission and dynamics of microbial communities in rice crop rotation systems

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The cultivation of irrigated rice has a strong environmental impact since two thirds of its cycle occurs under anaerobic conditions generating emissions of methane (CH4) and nitrous oxide (N2O), two of the main greenhouse gases (GHG). These gases are products of microbial processes of the carbon and nitrogen cycle, with methane production being the main contribution to the warming effect. Methane production occurs by anaerobic decomposition of organic matter through the action of fermentative bacteria and methanogenic archaea, though this gas can also be consumed by aerobic methanotrophic bacteria present in rice paddy soils. Therefore, methane emission during rice cultivation depends on the redox potential of the soil, the nutrients availability and the microbial (bacteria and archaeal) community structure. Crop rotation has been introduced recently to improve the sustainability and the economic yield of rice production. However, the cultivation of other crops under aerobic conditions affects the main factors involved in methane emission. In this work, a field assay established in 2012 for rice rotation with soybean or with pastures for livestock production was studied and compared with a system with annual rice cultivation. Methane emission for these three rotations was measured at the field during rice flooding. The dynamics of the microbial community structure was also analyzed during the annual crop cycle in all phases of the rotation: rice, soybean and pasture. The net flow of CH4, measured by the static chamber method, was affected by the previous use of the soil mainly at early steps of the rice production, i.e. tillering. The abundance of specific genes of methanogenic populations (mcrA) was also affected by the previous crop at tillering but was similar in all paddy soils at rice flowering. Methanotrohic specific genes (pmoA) showed the same trend with higher differences detected between soils at early steps of rice cultivation but similar densities observed in winter, at dry season, in all soils. Microbial community, analyzed by massive sequencing of 16S rRNA gene, showed that the community composition in rice soils was marginally affected by the previous crop. In general, the physicochemical and physiological parameters measured showed that rotation influenced the methane cycle at early stages of rice cropping but all soils became more similar after rice was cultivated.

Keywords: methanogenesis; methanotrophy; community structure, soybean; pasture
Financial support: CSIC-UdelaR (Comisión Sectorial de Investigación Científica, Universidad de la República); INNOVAGRO-ANII (Agencia Nacional de Investigación e Innovación)

(6407 - 2458) Methane production and methanogenic microbial communities in rice field soils as affected by crop rotation and other desiccation stress

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Flooded rice fields contain a complex microbial community consisting of anaerobic bacteria and archaea which are involved in the degradation of organic matter to CO_2 and CH_4. After flooding, oxygen and other oxidants such as ferric iron and sulfate are rapidly reduced, so that CH_4 production is becoming the final step in organic matter degradation. Therefore, flooded rice fields are an important source of the greenhouse gas CH_4. However, the methanogenic microbial communities in rice fields may experience desiccation stress, which is usually accompanied by exposure to oxygen. Desiccation generally suppresses methanogenesis which, however, recovers after rewetting. Such desiccation typically happens during drainage at the end of the season, but also during short-term drainage. Desiccation stress is enhanced, if drained conditions are prolonged by crop rotation with dry upland conditions. However, little is known how the bacterial and archaeal methanogenic communities adapt to such stress conditions. We hypothesized that different histories of flooding and drainage will result in the establishment of different methanogenic microbial communities, which then respond differently to desiccation stress. Therefore, we determined the rates and pathways of methanogenesis, the abundance of bacteria and archaea, and the composition of bacterial and archaeal communities in different soil environments and assessed changes upon drying and rewetting. Our results indicate that the methanogenic communities display maximum complexity in the regularly flooded and drained rice fields. Drying and rewetting alters the microbial communities, usually resulting in lower complexity with a dominance of *Methanosarcinaceae* and relative increase of *Firmicutes*. However, CH_4 is always produced if soils are submerged demonstrating a high resilience of the methanogenic microbial communities.

Keywords: methanogenesis; archaea; bacteria; anaerobic degradation

Financial support:

(2373 - 2424) Soil microbial community and enzyme activity in a subtropical Oxisol under long-term no-till and crop rotation

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Soil tillage and crop rotation can affect carbon and nutrient cycling and soil microbiological features in agricultural soils. No-till is known to promote soil carbon sequestration and increase carbon storage in comparison with intensively tilled soils. Crop rotation may increase agricultural productivity by increasing crop frequency and diversity (i.e. agricultural intensification). Thus, it is expected that the association of no-till and increasing crop frequency may favor soil microbial community and enzyme activity known to regulate carbon and nutrient cycling. We tested this hypothesis by assessing soil microbial communities and enzyme activity in long-term (32 yr.) experiment with contrasting soil tillage systems and crop rotations in Southern Brazil. The experiment was established in 1985 on a Typic Hapludox from Cruz Alta-RS (Brazil) under no-tillage (NT) and conventional tillage (CT). Three cropping systems with increasing crop rotation intensities were tested: wheat/soybean (R1); oats/soybean/oats+vetch/corn/radish/wheat/soybean (R2) and oats/soybean/ wheat/soybean (R3). The NT was performed by sowing crops with minimal soil disturbance and the CT consisted of disk plow (20 cm) followed by disk tandem (10 cm) prior sowing the summer crops and disk tandem before the winter crops. Other soil and crop management practices followed regional best management practices. Soil microbial community (gram+ and gram- bacteria, actinomycetes, arbuscular mycorrhizal fungi, other fungi, total bacteria, total fungi and total microbial community) were examined through phospholipid fatty acid (PLFA) and three enzymes (hydrolases) were considered in this study: β-glucosidase (βG), acid phosphatase and, N-acetyl-glucosaminidase. The potential activities of hydrolases were measured following a fluorometric method. Soil tillage (CT) decreased the abundance of all tested microbial communities as well enzymes activity. Community composition also shifted with tillage and crop rotation practices. The highest microbial biomass was observed in the NT in the layer of 0-5 cm (40.19 nmol PLFA g^{-1} soil), once the CT in the same layer showed 25.41 nmol PLFA g^{-1} soil. NT also increase the βG activity mainly when associated with summer/winter (intensive) crop rotation reaching 301.09 $nmol^{-1}$ hr^{-1} g^{-1} soil (0-5 cm). Conservation practices such as NT and crop rotation can increase microbial community and enzyme activity, improving the soil quality and nutrient cycling.

Keywords: Soil quality; nutrient cycling; cover crops; tillage.

Financial support: Federal University of Santa Maria / Capes - Brazil; Kansas State University

(6427 - 1015) Soil type affects biological phosphorus cycling more than crop rotation or pasture.

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Soil tests quantify inorganic phosphorus (P) but do not estimate P added to the soil solution via microbial mineralization. The information about P mineralization and immobilization in the microbial biomass is scarce though crucial for a better understanding of soil P dynamics. The objective of the study was to identify the effects of soil texture and crop rotation on these processes. The experiment was established in 2010 at the INTA Anguil experimental station near Santa Rosa, La Pampa, Argentina, on a sandy-loam petrocalcic Paleustoll and a sandy typic Ustipsamment, and consisted of 4 treatments: corn monoculture, corn-rye and corn-vetch cover crops, and a 50-year-old Weeping-Lovegrass pasture (*Eragrostis curvula L.;* WL), in fully randomized block design with 4 replicates. During fall (April 2017) soil samples were taken at 0-0.05 and 0.05-0.10 m depth and microbial biomass carbon and phosphorus (MBC, MBP) were determined. Another fraction of the same soil samples was used for incubations during 15 days when soil CO_2 and P mineralization were measured by titration of trapped CO_2 and adsorption to anion exchange membrane respectively. The results showed that soil texture had a stronger influence on MBC and MBP and their relation with P mineralization rates than treatments in both depths. Initial available P was not different among treatments, but MBC:MBP ratios presented differences among treatments in the sandy, but not in the loam soil, indicating non-homeostatic conditions in the sand. A positive significant relationship between MBP and MBC, and between MBP and P mineralization rate was found in the sandy soil, but not in the loam. P mineralization rate per unit MBP (qP) was higher in the sand and corresponded with lower MBC:MBP ratios (MBC:MBP = 147.1 qP +11.5, R^2=0.68, p<0.0001) and higher metabolic activity (qCO_2) (qCO_2 = -0.01 MBC:MBP + 0.5; R^2=0.32; p=0.0014). We conclude that physical-chemical processes of P sequestration (e.g. Ca-phosphate precipitation) are more important in the loam, causing low solution-P availability that resulted in high MBC:MBP ratios and higher energy expense, contrary to the sandy soil where biological P cycling apparently was more important for determining plant available P.

Keywords: Microbial biomass P and C; soil texture; P mineralization
Financial support: INTA, UNLPam PI N° 117/14FA.

C2.3.2 - Molecular techniques as a useful tool to reveal soil biodiversity and biotechnological potential of microbial genomes

(8169 - 1104) Innovative tools to diagnose the impact of land use practices on soil microbial communities

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Preservation and sustainable use of soil biological communities represent major challenges in the current agroecological context. Indeed, most of soil ecosystem services results from biological functions particularly driven by taxonomic and functional assemblages of microbiological communities (*i.e.* nutrient cycling, soil aggregation, depollution, etc.). Consequently, soil microbial communities are logical candidates as effective indicators of soil quality and sustainability. But, good biological indicators must be associated with references that encompass an operating range of measured values that allow performing the desired diagnosis. Even if numerous studies have focused on soil microbial communities over the last two decades, due to the variety of ecosystems, sampling designs and methods, we still lack reference databases and diagnosis tools for the robust evaluation of agricultural practices impact on soil microbial communities To reach this goal, we used an extensive set of samples originated from the French Soil Quality Monitoring Network (RMQS). This monitoring network is based on a 16-km regular grid across the 550,000 km^2 French territory representative of its pedoclimatic diversity. All sites have been geo-positioned with a precision <0.5m and the soil profile, site environment, climatic factors, vegetation and land use described. We determined: (i) the microbial biomass by quantifying the DNA extracted from soils, and (ii) the bacterial taxonomic richness (*i.e.* the number of Operational Taxonomic Units or OTUs). Both measures are good microbial indicators as they satisfy technical, practical and economic prerequisites (*i.e.* to be simple, rapid, reproducible, cheap, high-throughput, etc.). Based on this reference database, two innovative diagnosis tools were developed, using statistical predictive models according to environmental parameters (soil physico-chemical, climatic characteristics). Indeed, they provide reference values fitted for a given pedoclimatic condition, which is to be compared to the corresponding measured data for a robust diagnosis of soil biological quality. These tools were validated on external datasets and their applicability directly in the field was demonstrated on a farm network. In conclusion, these innovative tools providing reference values for a given pedoclimatic condition allow a robust diagnosis of soil biological quality.

Keywords: Soil biological diagnosis, statistical predictive model, soil microbial indicators
Financial support:

(3328 - 660) Soil conditions comparison in gros michel banana plantations infected with *Fusarium oxysporum f. sp. Cubense* race 1.

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The investigation evaluated the existence of differences in the physical and chemical conditions of the soil or in the microbial communities associated on plantations of Gros Michel banana with incidence of Fusarium Wilt Race 1. Seven farms were analyze with different levels of intervention, management and severity of the disease. It determined the biochemical profile of the microbial community using Ecoplates (Biolog®) and it was also determined the main substrates consumed by the microbial communities through a multivariate analysis of Principal Components. The main chemical indicators of the soils were obtain through a complete mineral analysis, pH and organic matter. Molecular identification of the dominant groups of microorganisms was performed by sequencing DNA products, amplified by PCR using specific primers for 10 groups of soil microorganisms which an agricultural importance from total DNA extracted using the Power Soil® kit (Mobio) . In the chemical analyzes, the CICE values are highlight, which allowed determining that all the farms have a high level of natural fertility. The pH values are quite close to the values established as optimal, except in farm 3 (intervened) and 7 (forest), on the other hand the percentage of organic matter in all farms is higher than the theoretical reported. According the physiological profile it was observe that farms with equal management tend to be very similar metabolically. The two main components chosen allow explaining 90% of the variance of the data. PC 1 has a positive correlation with carboxylic acids, polymers and amino acids, while PC 2 has a higher correlation with amines and carbohydrates. Likewise, it was determined that the genus Bacillus is the most predominant group of microorganisms in all the farms. Finally, it was highlighted that the farm 4 (medium intervention), presented the most favorable values in all the factors analyzed; the physiological profile of the microbial populations showed the absence of significant differences with respect to the organic farms and also presented a positive correlation with CP 1. According the microbiological level was the only farm (4) in which the *Azospirillum* bacterium was detected and *Ralstonia*, the cause of Moko's disease, was not detected.

Keywords: *Ecoplates*, biochemical profile, principal component, chemistry analysis, *Fusarium oxysporum*
Financial support: by the institution

(6636 - 1092) Sympatric differentiation of active ammonia oxidizing archaea and bacteria in a neutral soil

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Increasing evidence suggests that NH3-oxidation in acidic soils is primarily catalyzed by acidophilic NH3-oxidizing archaea (AOA) belonging to the Nitrosotalea cluster, while NH3-oxidizing bacteria (AOB) drive ammonia oxidation in neutral and alkaline soils in which AOA within the Nitrososphaera cluster overwhelmingly outnumber AOB. However, it remains unclear whether abundant Nitrososphaera-like AOA plays important roles in neutral or alkaline soils. Using DNA-based stable isotope probing (SIP), we gathered strong evidence of archaeal ammonia oxidation by Nitrososphaera-like AOA, in addition to active AOB within the classic Nitrosospira group in a neutral purple soil (pH 7.2).Incubation of SIP microcosms showed that nitrification was stimulated by ammonium sulfate but inhibited by acetylene. Real-time PCR quantification of amoA genes in heavy SIP fraction DNA indicated that obvious growth of soil AOB and AOA occurred only in the absence of acetylene, suggesting both AOA and AOB play a role in autotrophic nitrification. Among all 5 Nitrososphaera subclusters in the native soil, phylogenetic analysis further indicated that archaeal NH3-oxidation was dominated by AOA within Nitrososphaera subcluster 3.2/3.3. The Nitrosospira cluster 3a.2 dominated active AOB communities in the 13C-DNA, despite the numerical dominance of the Nitrosospira cluster 3a.1 in native soil. Our results suggest that

"diversification" and "dormancy" may be the important strategies for niche differentiation of sympatric AOA/AOB under different environments of microcosm manipulations and in situ field conditions.
Keywords: Nitrification; diversity; dormancy; community structure
Financial support: This research was financially supported by the National Natural Science Foundation of China (No. 41671232, 41271267).

(7202 - 2484) The stability of soil fertility and soil microbial communities influenced by long term fertilization

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Fertilization has been a popular word in global agriculture since 70's, it has greatly contributed to the food production and the growth of human population. However, application of chemical fertilizers to soil can also induce the degradation of soil fertility and environmental disasters. Long-term field experiment is valuable in revealing the successions of soil biogeochemical properties influenced by continuous fertilization. A long-term fertilization experiment in a paddy rice field was established in 1990 with various treatments. The observations indicated that paddy soil can maintain about 40-50 % productivity without inputs of fertilizers; the yield of the treatment with nitrogen fertilizer only dropped quickly to the same level as no fertilizer control within 6 years; using balanced chemical fertilizers can maintain high productivity, but the balanced fertilization with rice straw incorporation consistently achieved the highest crop yield and the soil properties have been obviously improved. Besides, the soil bacteria composition clearly shifted by the fertilization treatments. Furthermore, the soil denitrifying communities were also remarkably influenced. Among them, the population sizes and compositions of the denitrifers containing nitrate reductase gene (*narG*) and nitrite reductase gene (*nirK*) were more obviously affected than the others. The balanced fertilization with rice straw incorporation resulted in more than two times higher abundances of denitrifiers than rest treatments, and it also possessed significantly higher denitrification potential and N_2O emission rates. In conclusion, long-term application of balanced chemical fertilizers can maintain relatively high soil fertility and productivity for rice production, amendments with rice straw based on balanced chemical fertilizers can significantly improve soil properties and increase rice yields, on the other side, it also speed up nitrogen transformation and losses through stimulate the growth and activity of denitrifiers. Therefore, a smart application strategy of organic fertilizers is necessary for high crop yield and increasing nitrogen efficiency.
Keywords: microbial communities; nitrate reductase gene; soil fertility; long term fertilization
Financial support:

(8808 - 541) Transition in land colonization reflects a multi-trait switch in soil microbial genomes

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Ancestor microbes started colonizing inland habitats about 2.7 to 3.5 billion years ago, initiating a key transition in the evolutionary history of life. From a contemporary ecological perspective, such transition can be investigated (in an analogous manner) across boundary gradients of land formation. For instance, the past and current transitions from marine towards terrestrial habitats are known to exert selective pressures on local organisms, that have to deal with habitats with low resource availabilities and physicochemical constraints. With some exceptions, the key ecophysiological adaptations associated with the marine-to-land eco-evolutionary transition of microbial communities have remained elusive. This is essentially caused by the lack of a suitable study system that depicts the adaptation of microbiomes across sufficient time scales. Here, we investigate the adaptive routes taken by microbiomes along a contemporary gradient of land colonization (ca. 100 years). Using a functional trait-based metagenomics approach, we show that a switch from a microbial 'dispersal' to a 'competition' response *modus* best characterizes the microbial trait changes during this eco-evolutionary trajectory. The 'dispersal' *modus* prevails in microbiomes at boundary sites between land and sea. It encompasses traits conferring cell chemosensory and motile behaviors, thus allowing resident microbes to exploit short-lived nutritional patches in diffusible microhabitats. A gradual and systematic transition towards the 'competition' *modus* occurs progressively as the soil matures, once the forces of viscosity or strain favor traits for ecological competition and chemical defense. This is supported by continuing increases in the abundance of genes encoding antibiotic resistance and complex organic substrate degradation. Taken together, our findings constitute a novel perspective on the ecology and evolution of microbial community traits during soil formation, tracking back one of the most seminal transitions in the evolutionary history of life. Collectively, our study provides a novel perspective on the mechanisms mediating the structure of microbiomes along pristine marine-to-land gradients of soil formation.
Keywords: metagenomics, soil formation, bacterial communities, funtional diversity, competition-dispersal trade off
Financial support: Netherlands Organisation for Scientific Research (NWO) ; Gratama foundation

(1200 - 3113) Whole Genome Sequencing of *Fusarium avenaceum* strain *F.a.*1: A Fungal Strain Showing Biocontrol Potential for Wild Oat

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Weed pressure poses a significant hurdle to crop production worldwide, which is exacerbated by the rapid development of herbicide resistance in many weeds. Developing means of weed control in addition to herbicide application is ongoing, with few biocontrol agents currently available. In the inland Pacific Northwest (iPNW), wild oat (*Avena fatua)* presents a noteworthy challenge to wheat production and is often not adequately controlled by current herbicide application regimens; primarily due to its persistence and abundance in the seed bank along with its capacity for emergence throughout the growing season and prolific seed production. *Fusarium avenaceum* strain *F.a.*1 shows potential to selectively cause decay in wild oat, a serious global weed that competes with crops in temperate regions. Additionally, select seed defense enzymes, particularly PPO (polyphenol oxidase) and POD (peroxidase), are upregulated in wild oat caryopses versus wheat caryopses during exposure to *F.a.*1. DNA was extracted from pure cultures of *F.a.*1 and the whole genome was sequenced using next-generation sequencing (NGS; Illumina MiSeq) in duplicate. Short reads were assembled and then contig assemblies were BLASTed and annotated using Blast2GO. Gene prediction was performed using the Augustus gene prediction tool. Gene annotation revealed many oxidation-reduction process related genes, as was previously found in another sequenced strain of *F. avenaceum*; however, an enzyme-only analysis also showed higher numbers of hydrolase enzymes than oxidoreductases. Many other proteins important for pathogenicity and general fungal physiology

were also identified, including several chitinases, chitin synthases, and cellulases. Future work will aim to examine the metabolomic and proteomic responses of wild oats exposed to *F.a.*1, as well as, the metabolomic responses of *F.a.*1. Given the growing prevalence of acid soils and subsequent aluminum toxicity, future studies will also examine the influence of aluminum on the plant-fungus interaction. Understanding these molecular processes will assist future efforts to reduce wild oat pressure, particularly in wheat production systems.

Keywords: Fusarium avenaceum, Avena fatua, fungal genome, aluminum toxicity, biocontrol

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C2.3.3 - Rhizosphere mineral dynamics: soil-plant-microorganism

(8423 - 494) Bacterial traits and quality contribute to the diet choice and survival of bacterial-feeding nematodes

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The dietary choices of bacterial-feeding nematodes could control the structure and ecological functions of soil bacterial communities. However, the physiological basis for the selection of particular bacterial species as food, and the consequences of these dietary choices for the survival of bacterial-feeding nematodes, is poorly understood. The objectives of this study were (1) to determine how nematode feeding preference was related to bacterial traits (cell size, gram stain and growth rate, water content, carbohydrate content, protein content and metabolite concentration), and (2) to evaluate how dietary choices affected the reproduction and lifespan of two soil-dwelling bacterial-feeding nematodes of the species *Mesorhabditis* and *Acrobeloides*. Their food sources included one model bacterium, *Escherichia coli* OP50, and four soil-dwelling bacterial species: *Bacillus amyloliquefaciens*, *Bacillus megaterium*, *Variovorax paradoxus* and *Pseudomonas fluorescens*. Both nematode species exhibited a similar hierarchy of diet choice, with *P. fluorescens* and *E. coli* OP50 being the most preferred food, whereas *B. megaterium* was the least preferred bacteria. Nematode feeding preference was strongly related to the water content, growth rate and metabolite concentration of bacterial cells, which explained 63-75% of the variation in the feeding preference index (PI, which indicates the number of nematodes attracted to specific bacteria), and the rest of the variation was attributed to bacterial cell size, gram stain, carbohydrate content and protein content. We propose two physiological mechanisms to explain dietary choices of bacterial-feeding nematodes: 1) chemical attraction to higher carbon dioxide levels around rapidly-growing bacteria or repulsion to volatile organic molecules released from bacterial cells, and 2) selective ingestion of bacterial cells with preferred characteristics (e.g., high water content in cells). Nematodes feeding on preferred bacteria always had higher reproduction, but was not a good predictor of their lifespan. This may be due to the fact that dietary resources are allocated first towards reproduction, and second to prolong the lifespan of bacterial-feeding nematodes. Our findings suggest that dietary choices are important for the survival of bacterial-feeding nematodes, and their ability to find and selectively ingest preferred bacterial species may have implications for soil bacterial community structure and ecological functions.

Keywords: Feeding preference; Bacteria; Bacterial-feeding nematodes; Tradeoff

Financial support:

(4486 - 1120) Denitrification is lower in *Bradyrhizboum japonicum* than in *B. diazoefficiens* due to impaired nitrate reductase activity.

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Members of the genus *Bradyrhizobium* are able to denitrify when oxygen is limiting. Denitrification is the sequential reduction of NO_3^- $\rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$ mediated by periplasmic nitrate reductase (Nap), nitrite reductase, nitric oxide reductase and nitrous oxide reductase (encoded by *napA, nirK, norCB* and *nosZ* genes), respectively. Generally, *Bradyrhizobium diazoefficiens* (*nos+*) possesses complete denitrification pathway, whereas, *Bradyrhizobium japonicum* (*nos-*) lacks the *nos* gene cluster and has an incomplete process from nitrate to nitrous oxide. In an initial analysis, anaerobic growth with NO_3^- as the electron acceptor was significantly lower in *B. japonicum* than in *B. diazoefficiens*, but it was not explained by the absence of *nos* genes in *B. japonicum*. Under anaerobic NO_3^--respiring conditions, *B. japonicum* was less capable of reducing NO_3^- to N_2O than *B. diazoefficiens*. Nap activity was markedly lower in *B. japonicum* than in *B. diazoefficiens*, indicating that the reason for the limited growth in *B. japonicum* is a low NO_3^- due to an impaired Nap activity. *napA* expression in *B. japonicum* and *B. diazoefficiens* was not significantly different, indicating that the reason for impaired Nap activity may rely on posttranscriptional events. Accordingly, the growth of *B. japonicum* USDA 6 overexpressing *napEDABC* genes was similar to that of the wild-type USDA 6, further suggesting that the low performance of USDA 6 in NO_3^- reduction is independent of the transcript level. Haem-staining of NapC revealed that *B. japonicum* produced a very low amount of Nap compared to *B. diazoefficiens*. This suggested that impaired Nap activity in *B. japonicum* is the result of a low amount of Nap protein. It has been suggested that *B. diazoefficiens* (*nos+*) is predominant in Gleysol soils, rich in low-oxygen conditions, whereas *B. japonicum* (*nos-*) is predominant in Andosols, rich in aerobic environments. The growth of *B. diazoefficieins* USDA 110 lacking *nosZ* gene (*nosZ-*) and *B. japonicum* USDA 6 wild-type cohabiting the same culture environment under a NO_3^--respiring condition indicated that USDA 110 *nosZ-* possessed higher competitiveness than USDA 6. Taken together, these results indicate that the capacity in NO_3^- reduction may be the main factor that drives the distribution of bradyrhizobia in soybean fields in Japan.

Keywords: denitrification, *Bradyrhizobium*, nitrogen cycle, bacterial physiology

Financial support: National Council for Scientific and Technological Development-Brazil and Japan Society for the Promotion of Science

(4980 - 1803) Diversity of bacterial community in the iron plaque of *Typha latifolia* growing in mine tailing wetland

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Polymetallic mine tailings, poor in nutrients, rich in sulfide and consequently leading to high risk of heavy metals release, provide only extremely bad condition for plant growth. Few wetland plant, e.g. *Typha Latifolia*, could survive in mine tailing wetlands, which is mainly

attributed to the proved sequestration of heavy metal by rhizoplane iron plaque (IP). The composition and structure of IP have been studied intensively, yet the microbes therein, particularly the microbial community structure and abundance, dominant flora of rhizosphere and IP, have only been limitedly elucidated. In this research, a pot experiment was carried out by planting *Typha Latifolia* in either non-polluted farmland soil (FS) or mine tailing (MT) under flooding phenomenon. Root samples with IP and FS/MT samples were collected. IP was then separated into two layers, namely inner and outer layer, in each root sample. DNA were extracted from inner IP layer, outer IP layer, rhizospheric FS/MT and bulk FS/MT, and subsequently 16S rDNA sequencing was conducted. Physichemical characteristics of the plant, FS and MT were also analyzed. Results showed that the diversity of bacterial communities in non-polluted farmland soil (FS) was greater than that in mine tailing (MT). In terms of the outer and inner layer of the iron plaque, the abundance of species and bacterial community structure varied significantly in the two layers, indicating different bacterial life activities therein. At the phyla level, similar dominating bacteriophyta were found among all the samples in the following order: *Proteobacteria*, *Actinobacteria*, *Nitrospirae* and *Chloroflexi*, accounting for up to 85% of the total abundance. Based on clustering analysis for either FS or MT treatment, impacting factors for bacterial community structures included two groups, Pb, Zn, Cu, Cd and S in one, and pH, C and N in the other. However, the ubiquitously existing Fe had only slight impact in this study. This study contributed partly to the understanding of bacterial community in the iron plaque of *Typha latifolia* growing in mine tailing wetland. Our ongoing effort is to elucidate the distribution of iron and sulfide oxidizing/reducing bacteria in the iron plaque to further reveal the rhizoplane heavy metal sequestration mechanism from the microbial aspect.

Keywords: bacterial community, iron plaque,*Typha latifolia,* wetland
Financial support: Special Fund of Environmental Protection Research for Public Welfare from MEP of P.R.C. (No. 201509037); National Science Fundation of China (No. 41671313); the Fundamental Research Funds for the Central Universities (No. 16lgjc57).

(8373 - 717) Effect of planting density on microbial activity and SOM decomposition in an arable topsoil and subsoil

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Much less is known about the processes controlling SOM turnover in subsoils than in topsoils. To test the hypothesis that the input of easily available C (exudates) accelerates SOM decomposition and microbial activity in the subsoil more than in the topsoil. We investigated the effects of increasing C input via exudation on microbial activity and SOM decomposition. We established the following planting densities of Spring Wheat: unplanted soil, super low plant density (2 plants pot^{-1}), low (5 plants pot^{-1}), common for agricultural systems (10 plants pot^{-1}), and high plant density (20 plants pot^{-1}). Further pots with common plant density and mineral N fertilizer addition were prepared, since SOM decomposition and microbial activity strongly depend on mineral N status of the soil. Two different horizons of a Mollisol were used in this experiment: 1) topsoil (0–20 cm, Ap), 2) subsoil (70–90 cm, B). To determine SOM decomposition plants were continuously labeled with ^{13}C-depleted CO_2 and soil CO_2 efflux was partitioned for root- and SOM-derived CO_2. We analyzed extracellular enzyme properties (V_{max}, K_m, K_a). The shoot biomass and the shoot-to-root ratio were significantly higher for plants grown in the topsoil than in the subsoil. Yet, similar proportion of rhizosphere soil to total soil was determined for both the planted topsoil and subsoil, which demonstrated that plants grown in the subsoil allocated relatively more C to roots possibly for nutrient acquisition. Although the rates of SOM-derived CO_2 evolution were significantly higher in topsoil than in the subsoil. The difference in the SOM-derived CO_2 evolution rates between the unplanted control and the planted treatment was higher in the subsoil than in the topsoil, reflecting intensified decomposition of organic compounds. When SOM-derived CO_2 was related to the unplanted control it was higher in subsoil, which indicated an increase in root-induced SOM decomposition. Most enzyme activities increased with planting density and were positively correlated with root biomass. The proportional enzyme activities of C vs. P acquiring enzymes strongly decreased in all subsoil treatments, suggesting P scarcity and strong production of plant-derived acid phosphatases in the subsoil. In conclusion, the plants´ below-ground C allocation strongly depended on nutrient availability linked the quality of SOM.

Keywords: enzyme activity, root-derived C, subsoil, rhizosphere, root exudation
Financial support: This study was supported by grants from the German Research Foundation (PA 2377 1/1) and the German Academic Exchange Service (DAAD) within a PPP program (57051794).

(7408 - 1698) Fungal communities in *Eucalyptus grandis* and *Acacia mangium* rhizosphere in different planting systems

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The root surface of forest trees exudes many kinds of organic compounds and stimulates the growth of microorganisms in the rhizosphere. Fungi account for about 75% of the microbial biomass in Eucalyptus and Acacia plantations, where they exert functions as decomposition of organic compounds and incrementing the nutrient cycle. Plant genetics and management practices help to select the fungal communities that predominate in the rhizosphere. Our objective was to compare the density and diversity of the fungal communities in plantations of Eucalyptus grandis and Acacia mangium at the Experimental Station of Forest Sciences in Itatinga, in 2016, when the plants were two years old. The field treatments were pure Eucalyptus (E), pure Acacia (A) and a consortium of both species (EC and AC) where we sampled soil and roots from the bases of both tree species, in pure and mixed stands, at increasing depth, in layers 0-10, 10-20, 20-50 and 50-100 cm deep. We extracted the DNA from the rhizosphere samples with the PowerSoil® DNA Isolation kit. For the T-RFLP technique, which determines the structure of the fungal community, the DNA was subjected to the amplification of the ITS region, using primers ITS1f-FAM and ITS4 and restriction with HaeIII enzymes. For the abundance analysis, the qPCR method was performed using the SYBR® Select Master Mix kit and the ITS1f and 5.8S primers. The data obtained in the T-RFLP were submitted to the multivariate statistical analysis PCoA, which explained 32.75% of the data of variance and revealed differences in the structure of the fungi communities, forming groups defined for treatments E and EC and dispersed groups for treatments A and AC. There was some overlapping between EC, E, A and AC treatments. These data show a restricted compact fungal group in Eucalyptus, and more dispersed groups in Acacia and the mixed group, (EC and AC). By means of the qPCR, we verified that the abundance of fungi was similar for all treatments, within the same layer (Tukey 5%). Comparing the layers within the same treatment, there was a reduction in abundance with depth increase, except for AC, which showed no differences between the layers, indicating that Acacia in consortium increases the abundance of fungi, especially in deeper layers. We conclude that the consortium system favors diversity and abundance of fungi in the

rhizosphere of E. grandis and A. mangium.
Keywords: T-RFLP; qPCR; monoculture; consortium.
Financial support: CAPES, FAPESP (16 / 01636-4)

(3147 - 447) *Funnelimoris mosseae* alters soil fungal community dynamics and composition during litter decomposition

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Although arbuscular mycorrhizal fungi (AMF) are believed to be non–saprophytic, recent studies have indicated that AMF are able to influence litter decomposition through interacting with the soil fungal community. However, it remains unclear exactly which constituent groups of the soil fungal community respond to AMF during litter decomposition, and in what ways. In order to fill this knowledge gap, we investigated the effect of AMF on soil fungal communities in a subtropical forest in southwestern China. Our experimental set–up included a dual microcosm unit with two treatments: *Trifolium repens* inoculated with AMF (AM) and uninoculated (NM). Soil sampling was carried out at different times (T_0, T_{90}, T_{120}, T_{150} and T_{180}) and Illumina sequencing was used to detect changes in soil fungal community composition. We found that the composition and operational taxonomic unit richness of the fungal communities, at higher taxonomical levels (e.g. phyla, order), remained stable across treatments. However, the relative abundance of key genera, including *Mycena, Glomerella, Pholiotina,* and *Sistotrema*, were significantly affected by AMF inoculation. Soil fungal community structure was also significantly altered by AMF inoculation during the later stages of litter decomposition, but the diversity of the soil fungal community was unaffected. Our study provides new insight into understanding the interaction between AMF and soil fungal communities during litter decomposition.
Keywords: Culture independent technique; Illumina sequencing; Litter decomposition; Soil fungi–Soil microbial communities
Financial support: the CPSF-CAS Joint Foundation for Excellent Postdoctoral Fellows (Ref. No.: 2017LH029) and the National Key R&D Program of China (Ref. No.: 2017YFC0505101).

(2305 - 1844) The use of inoculant arbuscular mycorrhizal fungi and phosphate solubilizing microorganisms on growth of maize and soil phosphorus status

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Arbuscular mycorrhizal fungi (AMF) and phosphate solubilizing microorganisms (PSM) are ubiquitous in soil and play important roles in phosphorus nutrition by enhancing its availability to plants especially in phosphate deficient soil. The objective of this study was to assess the application of AMF and PSM inoculants alone and in combination on growth of maize and soil phosphorus status. A pot experiment was conducted using composite soil samples (0-20 cm) from agricultural land areas of Manokwari, Papua-Indonesia. AMF obtained from pot culture (mixture of spores of *Glomus sp., Acaulospora sp.* and *Gigaspora sp.*) and PSM (mixture of Chromobacterium sp., Pseudomonas sp., Bacillus sp., Micrococcus sp. and Caulobacter sp.) isolated from the field soil were used as inoculants. Plant growth, dry matter, spore number, percentage root colonization by AMF, total number of PSM, and some soil properties (soil pH, P-total, C-organic, N-total and soil moisture content) were analysed. Interactions between AMF and PSM significantly increased all growth parameters including dry matter of maize, as well as spore number, % colonization by AMF, total number of PSM, soil N and P content compared to uninoculated plants and inoculation with AMF and PSM alone. Inoculation with PSM alone significantly increased soil P content compared to inoculation with AMF alone and to the uninoculated control. This study indicates the great potential for these AMF and PSM to increase plant growth and nutrient content in soil when used in combination as a source of biofertilizers to overcome P deficiency in agricultural soils.
Keywords: AM fungi, phosphate solubilizing microorganisms, phosphate, biofertilizers
Financial support: Ministry of Research Technology and Higher Education of Indonesia, and Goverment of Papua Barat Province

C2.4 - Soil mineralogy

C2.4.1 - Dynamic minerals: shifts in soil mineral composition as a result of soil use and management over the human time scale

(6946 - 2879) Can a remineralizer from Greenland improve the fertility in Brazilian tropical soil?

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Remineralization is the use of powdered rock to improve soil conditions and crop performance. The Greenland Rock Flour (GRF) is a natural glacial sediment in which 90% of particles are in silt and clay fractions. We applied it in 4 dm^3 PVC columns filled with 3 kg of an Oxisol collected at 0-2 m depth in a degraded pasture field. The following treatments were applied: T0 (control); T1 (40 kg K_2O ha^{-1}); T2 (40 kg N + 60 kg P_2O_5 ha^{-1}); T3, T4, T5 and T6 (1.6; 7; 28 and 84 Mg GRF ha^{-1}, respectively); T7, T8, T9 and T10 (1.6; 7; 28 and 84 Mg GRF ha^{-1}, respectively, plus 40 kg N and 60 kg P_2O_5 ha^{-1}); and T11 (40 kg K_2O + 40 kg N + 60 kg P_2O_5 ha^{-1}), with three replications. The columns were sowed with *Brachiaria decumbens* and were leached weekly with 1 L deionized water. Two parallel sets of the whole experiment were made (total of 72 columns), and the first was disassembled after 12 weeks and the second after 24 weeks. The exchangeable Ca, Mg, K, P, Al e Si, cation exchange capacity (CEC) and pH was measured in the soil, and biomass, macro and micro elements in plant tissue. After 12 weeks there was a significant increase in the pH and exchangeable Si in the T6, and Mg and CTC in T10, as compared to all the treatments. The use of ammonium sulfate as the N-source decreased the pH down to 4.3 in T11, but in T10 the GRF neutralized the acidity and kept the soil buffered at pH to 4.6 (pH of control T0 = 4.6), a significant difference as compared to the other treatments. After 24 weeks the pH, Mg, P and Si values increased in T6 as compared to the same treatment after 12 weeks. However, the CEC decreased due the leaching and plants absorption. In both periods, despite the content of 15.3% Al_2O_3 in the GRF, there was no increase in the soil exchangeable Al. The Ca and K concentration increased in plant tissue but not in the soil. Also, there was a significant increase in biomass in T10, both after 12 and 24 weeks, compare with all treatments. Considering the experimental conditions, the 84 Mg ha^{-1} GRF, both in T6 as in T10 resulted in the best soil fertility indexes, including the

buffering of the acidity introduced by using NH_3 as a source of N.

Keywords: Rock powder; mineral dissolution; Agromineral
Financial support: University of Copenhagen

(8563 - 1547) Fe(II) interaction with natural clay minerals: role of structural Fe and aluminosilicates on Fe(II)-layered double hydroxide (LDH) formation

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Interaction between aqueous Fe(II) and soil-Fe(III) under suboxic conditions favor the formation of reactive Fe(II)-Fe(III) mixed-metal hydroxides called 'green rust'. Occurrence of this mineral can greatly affect Fe(II) cycling and abiotic attenuation of reducible contaminants/nutrients in natural systems. High surface area, positive surface charge and available Fe(II) as an electron donor drive its geochemical reactivity, which is largely due to its layered double hydroxide (LDH) structure. Recently, it has been observed that Fe(II) sorption onto aluminum oxides or aluminosilicate minerals can form an Fe(II)-Al(III) LDH. It has yet to be identified in a natural soil but could be an important component of Fe(II) cycling and natural Fe(II) LDHs. Additionally, the role of structural-Fe in clay minerals will be considered since redox activity between structural-Fe(III) and Fe(II) may complicate the interaction. It is unknown how this may affect Fe(II) LDH coprecipitation, but may result in a mixture of pure Fe(II) LDH phases or intermediate Al(III)/Fe(III) content. Therefore, it is the goal of this study to characterize the Fe(II) LDH precipitates following Fe(II) sorption to the clay minerals to advance the understanding of Fe/Al chemistry in natural systems. The soil used to source clay minerals was the Bt horizon of a Matapeake silt loam with aluminosilicates in the proportion: kaolinite> hydroxy-interlayered vermiculite> quartz, mica. The clay minerals contain 5.85 % Fe (mass basis) measured by X-ray fluorescence and of the total, 90.5% was identified as Fe(III) with Fe X-ray absorption spectroscopy (XAS). Sorption of mM Fe(II) to these clay minerals were studied as a function of pH (6.5, 7.0, 7.5) and reaction time (up to 55 days) in batch experiments. Sorption products were characterized by XAS, X-ray diffraction (XRD), Fe^{57} Mössbauer spectroscopy, and microscopy. Our findings have the potential to advance the understanding of Fe(II) cycling in soils and sediments which influence the fate and transport of a variety of trace metals and clay minerals via both redox and sorption reactions.

Keywords: iron, aluminum, redox, clay, green rust
Financial support: National Science Foundation (NSF)

(1199 - 2515) Key role of 2:1 clay minerals in fertility of subtropical soils of Rio Grande do Sul in south Brazil and impact of land use

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Most of the soils of the Rio Grande do Sul in Brazil are highly weathered, acidic and have a clay mineralogy dominated by kaolinite and iron oxides. However, a specificity of these subtropical soils, compared to Oxisols, is that the clay fraction contains variable, but not negligible, proportion of 2:1 clays minerals such as vermiculite, hydroxyl-Al-interlayered vermiculite, and smectites in lower proportions. In these subtropical soils, clay minerals and especially 2:1 species play a key role in cation exchange capacity even if they are in low proportion compared to kaolinite. Another key factor of the fertility of these soils is acidity and presence of exchangeable Al. The presence of exchangeable Al induces the presence of hydroxyl-Al-interlayered clay minerals and decrease of the CEC. The aim of our works was to study the clay mineralogy of soils under different conditions (crops, forest, meadows) to reveal the impact of soil use. The studies were more specifically focused on the 2:1 clay minerals and we used a quantitative sub-micrometric fractionation (< 0.05 µm, 0.05-0.1 µm, 0.1-2 µm). The mineralogy of the subfractions was performed by X-ray diffraction and the reactivity was estimated by CEC measurements. The results revealed that: kaolinite is present as two distinct populations with well crystallized kaolinite in > 0.1 µm fractions and poorly crystallized ones in < 0.05 µm fractions; almost absence of 2:1 clay minerals in < 0.05 µm fractions; and most importantly, presence of 2:1 clay minerals with variable degree of aluminization in the 0.05-0.1 and 0.1-2 µm fractions. Moreover, the presence of hydroxyl-Al-interlayered minerals and/or the degree of aluminization was linked to the chemical conditions of the soils that control Al availability. The chemical conditions are in turn linked to soil use (forest vs meadow) or K-fertilization and liming. These results highlight that the mineralogy of the clay fraction of subtropical soils is reactive and that formation of hydroxyl-Al-interlayered minerals may be reversible as a function of soil use. Therefore, it is necessary to maintain the fertility of these intensively cultivated subtropical soils through fertilization and liming aiming to prevent acidification and release of Al in order to avoid the Al toxicity and also to preserve the CEC originated in the 2:1 clay minerals.

Keywords: clay minerals subtropical soil south Brazil aluminization
Financial support: CAPES/COFECUB - PVE CNPq

(7764 - 2810) Magnetite and maghemite as weatherable minerals in tropical and subtropical soils

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Magnetite and maghemite are iron oxides common in soils. Magnetite is a primary mineral usually found in basic rocks. Maghemite is a secondary mineral generally formed by the oxidation of magnetite. But, several chemical process can lead to the formation of magnetite and maghemite in soils, including biological oxidation, burning, redox conditions, etc. Both minerals share two importants attributes. First: Isomorphic substitution of Fe for other elements (Mg, Cu, Zn, Ni, Mn, Pb, Cd, Al, etc.). Second: Magnetite and maghemite also are ferrimagnetic minerals, and among all common minerals found in soils, they are the ones usually atracted by a magnet. This mineralogical attribute is easily determined in field conditions by using mass specific magnetic susceptibility measurements. This technique is very simple and a magnet with a balance can be easily assembled in any laboratory. Dual frequency equipments are more sophisticated apparatus and are able to not only identify the presence of these minerals but also distinguish the presence of magnetic multidomain magnetite in the coarse fractions (silt+sand) from the single domain maghemite usually concentrated in the clay fraction of soils. Measurements of Mass Specific Magnetic Susceptibility (X_{BF}) and metals content in the iron oxides fractions from soils all over Southern region in Brazil were positively correlated with the presence of maghemite and magnetite and the presence of micronutrients. Therefore, We suggest that the Ferrimagnetic minerals Magnetite and Maghemite be incorporated into the Brazilian System of Classification as Weatherable Minerals, i.e., as a source of nutrients to plants and animals.

Keywords: Ferrimagnetic minerals; reserve of nutrients; sink and source of elements.
Financial support: CNPq. Projects 485221/2012 e 312033/2013-3. PRONEX. Fundação Araucária. Protocol 24732.

(8509 - 2401) Physical and Mineralogical Identification of an Ultisol in Coastal Lowered in the State of Rio de Janeiro – Brazil

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Bruno Nogueira Batista Souza[2]; Daniel Luiz Da Silva Machado Cunha[2]; Brenno Silveira Thourler De Carvalho[2]; Samara Moraes Cunha De Mesquita[2]

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These waters saturate the soil and begin to flow, so the understanding of these factors is of fundamental interest for the degree of resistance. In this way it is essential to know these factors for the understanding of the relief modeling and for the type of material that constitutes the substrate that composes the local landscape. Soil is defined as a collection of natural bodies occurring on the surface of the earth, containing living matter and supporting or being able to support plants. This thin layer is composed of rock particles at different stages of disintegration, content of water and dissolved substances, air, living organisms and organic matter in different stages of decomposition. For the pedological analyzes of the area of the Golden Realty and Quartier Companies in Iguaba Grande, region of the lakes of the state of Rio de Janeiro, four soil profiles were opened, according to the representativeness of the local topography. In these profiles the identifications and the description regarding the structure, texture and delimitation of the horizons were carried out. Deformed specimens were collected to follow the laboratory to perform granulometric analysis to obtain textural classification and specific mass. With the obtaining of these values through the analyzes of the collected samples, it was possible to characterize the soils of the area. In the granulometric analysis the presence of free sand was observed in the first horizon of the four profiles, later clay, phyllite and compacted clay. Only profile two did not present the clay horizon. In relation to the mineralogical identification by the specific mass method, based on the NBR 6457 spreadsheet, a concentration of biotite, Ilite and quartz is observed in profile 1. Materials with very low density in profile 2, not identifiable to the test. Quartz and Feldspar being identified in Profile 3 and Quartz, Feldspar, Biotite and Muscovite in Profile 4. Thus materials of several stages of the intemperic processes make up the set of horizons identified in the profiles. In the mineral identification through the leica binocular loupe, the presence of the following minerals was observed: Profile 1: Quartz, Quartz with Iron Oxide, Feldspar of Granada. Profile 2: Quartz, Biotite, Muscovite and Feldspar. Profile 3: Quartz, Quartz with Iron Oxide, Amphibolite Biotite, Muscovite and Feldspar Profile 4: Quartz, Amphibolite Biotite, Muscovite and Feldspar.

Keywords: Mineralogy, Soil Profile and Specific Mass
Financial support:

(5247 - 1777) Short-range-ordered (SRO) iron minerals are dynamic, emergent representations of recent environmental conditions in soils

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Ferric Iron (Fe) minerals that lack long-range crystal order or are highly substituted with ions or organic matter are critically important for a range of sorption and electron transfer reactions in soils. These short-range-ordered (SRO) Fe mineral phases are extremely dynamic in terms of reactivity, structure and function in soils. In fact, these particles are more susceptible to alteration of their mineral structure than any other solid phase constituents commonly present in environmental systems. The dynamics of iron cycling are critically dependent on changes in the oxygen content or redox state of the soil, which in turn depends largely on the availability of labile, reduced carbon (organic matter). This talk will review some of our recent findings from laboratory and field experiments from a variety of settings, including the Luquillo and Calhoun Critical Zone Observatories, long-term rice paddy experiments, and model mineral-microbe systems. We find that the SRO Fe phases are extremely plastic in terms of atomic structure, undergoing rapid (hrs to days) atom exchange with aqueous Fe^{2+}(aq) when present under anoxic conditions, but can exhibit relative high-stability in terms of mineral composition when co-precipitated with stabilizing ions or organic matter as long of physico-chemical conditions are maintained. Exposure to dynamic redox fluctuations does not appear to confer a singular influence on iron mineral composition (i.e., it does not by itself promote either increases or decreases in iron crystallinity), but rather increases the likelihood for changes in iron mineral structure that are determined by biogeochemical and physico-chemical conditions of system, such as precipitation/dissolution rates, the presence of foreign ions or organic compounds that can sorb or co-precipitate with the iron phases, or microbial community composition/activity. Understanding of these interactions is a critical aspect necessary to predict the fate of a range of elements in soils, in particular under conditions of changing external forcings (i.e., climate).

Keywords: redox, iron, critical zone, soils
Financial support: US-NSF

(9694 - 2941) soil characterization, classification and formation on sedimentary lithology in Gravatai municipality, Rio Grande do Sul state.

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UFRGS[1]; EMATER[2]; IFPR[3]

Metropolitan region of Porto Alegre, although great urbanization process, has some localities that can be defined like rural towns, being Gravatai one of the municipalities with bigger expression of this issue. Natural resources knowledgement is an important aspect for sustainable agricultural production systems. With the aim to characterize, classify and evaluate soil – environment relationships, morphologic description and sample colect were made in four representative soil profiles of sedimentary regions, to chemical, physical and mineralogical analysis. Results showed, with exception of P1, profiles with great pedologic development, expressed by subsurface horizons with higher clay content and hydromorphic features in P2. Organic carbon contents were relatively low, due to sandy texture, with acid pH. Ki index and Fed/Fes relationship showed high weathering degree. Soil distribution in landscape seems to show relief and hidrology as major influences. Soil characteristics indicated Lessivage as the major processes, showed by lower floculation degree in transitional horizons, and increase fine clay:total clay relationship values in subsurface horizons. Ferrolysis and Gleization seems to contribute, specially in P2, as indicated by higher Feo/Fed relationship in E horizon.

Keywords: soil-environment; soil classification, pedogenetic processes
Financial support:

(3262 - 2498) The transformation of clay minerals in the particle size fractions of two soils from different latitudes in China

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The behavior of clay minerals in different size fractions of soil colloids are very particular, mostly in the nanoparticle (25-100 nm) fractions, where clay minerals are very reactive and have a significant role in the transport of nutrients. In this work, the characterizations of clay minerals in the particle fractions of an Oxisol and an Alfisol were studied to better understand the transformations of clay minerals and their crystalline structures within the size particles. The particle size fractions (< 2000, 450-2000, 100-450, and 25-100 nm) of the two soils were investigated using inductively coupled plasma-optical emission spectroscopy (ICP-OES), conventional and synchrotron X-ray

diffraction (XRD), fourier-transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TG). Kaolinite dominated in all the particle size fractions. The moderate amount of HIV and illite present only in the larger size particles (< 2000, 450-2000 and 100-450 nm) weathered gradually to give kaolinite in nanoparticles of Oxisol. Kaolinite dominated in the bulk samples (< 2000 nm), vermiculite prevailed in the 450-2000 nm fraction; illite, kaolinite and vermiculite were equally common in the 100-450 nm fractions, and illite dominated in the nanoparticles of Alfisol. In the Alfisol, the dissolution of kaolinite and the transformation of illite into vermiculite occurred along the particle size fractions. The dissorder increased in the crystaline structure of clay minerals from nanoparticle size of Alfisol than Oxisol. Many others soil formation factors may have probably influenced these transformations. However, climate and vegetation actions are more visible in the Oxisol while climate and parent material act in the Alfisol.

Keywords: Keyword: Alfisol, clay minerals, nanoparticles, Oxisol, particle fractions, transformation.
Financial support: National Natural Science Foundation of People's Republic of China (Grant No. 41271252) for financing this research.

(3538 - 404) Soil Mineralogy of Forest Island and adjacent Farmland in West Africa

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Dominant perspectives in scientific literature assume that people only degrade natural soils but local knowledge and practices observed in West Africa suggest otherwise. In this region, anthropogenic activities seem to have transformed some inherently infertile soils to productive soils, with enhanced vegetative cover typical of forests often observed around villages in otherwise open savanna landscapes. To help understand the geochemical mechanisms underlying the formation of such forest islands, the types and distribution of Fe and Al oxides and the soil mineralogical diversity were compared for forest islands and agricultural land at 11 sites across Burkina Faso, Ghana, and Nigeria. Overall, we found that, irrespective of vegetation type, quartz and kaolinite to be dominating the clay fraction, but significant quantities of 2:1 silicate minerals were also present. There were Fe rich minerals in most of the locations irrespective of the ecosystem type with this being confirmed by the wet chemistry of the different forms of iron and aluminum oxides of the soils. Irrespective of vegetation type there was a gradual increase in the distribution of Fe and Al oxides with increasing soil depth and in most cases, the crystalline forms of the oxides were more prevalent than the amorphous form. Despite considerable variations between sites in the degree of oxide crystallinity, the soils of the forest islands were, generally speaking, less weathered with implicitly higher fertility. The deliberate and unintentional activities of the villagers may be germane to the soil transformation processes.

Keywords: ecosystem type, iron oxide, savanna, soil weathering
Financial support: Soils of forest island in Africa (SOFIIA) project sponsored by Royal Society UK DFID Africa capacity building initiative.

C2.4.2 -New techniques for advanced mineral studies

(3351 - 311) Advances in the Use of Small Spatial and Temporal Scale Synchrotron-Based Techniques to Elucidate Soil Mineral Reactivity

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The use of state-of-the-art, *in-situ* synchrotron-based spectroscopic techniques has greatly advanced our understanding of biogeochemical reactivity and speciation of contaminants in natural, heterogeneous systems such as soils. These techniques enable one to make measurements at small spatial and rapid temporal scales and simulate natural environmental conditions. Undoubtedly, the molecular and nano- scale characterization of microenvironments and interfacial reactions will become increasingly significant in understanding the interactions between chemistry, physics, and biology in natural environments. There are a number of areas dealing with soil and environmental biogeochemistry where the application of small scale synchrotron-based spectroscopic methods are resulting in major frontiers. Several of these research frontiers will be presented including the use of nano-scale carbon near edge X-ray absorption fine structure spectroscopy (CNEXAFS) coupled with scanning transmission X-ray microscopy (STXM) to determine carbon-mineral reactivity and sequestration under varying environmental conditions, quick X-ray absorption spectroscopy (Q-XAS) to study metal and metal(loid) sorption and redox reactivity at the mineral/water interface, and metal speciation of contaminated soils.

Keywords: Synchrotron Science, Soil Minerals, Mineral/Water Interface, Kinetics
Financial support:

(6545 - 2183) Differential X-ray diffraction in traceability of *Cannabaceae* family plants.

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Studies in forensic soil science are presented as an emergent area to aid the traceability of Cannabis sativa L. in brazilian territory, especially when there are seizures of whole plants with soil adhered to the roots. In these cases, with scarce amount of soil, the use of mineralogical techniques has been explored to define the geographical origin of these samples. Among the various techniques, X-ray diffraction (XRD) is considered the most reliable, fast and low-cost tool, generating qualitative and quantitative parameters for forensic soil science. The aim of this research was to verify the use of the differential X-ray diffraction (DXRD) technique for the traceability of plants of the Cannabaceae family. For this purpose, were selected 2 Latosols (05 and 11) and 2 Argisoils (06 and 14) from brazilian states and samples were collected under natural vegetation conditions in the superficial layer (0-0,20 m). An experiment was lead for eight months in a greenhouse, where seedlings of Humulus lupulus L., from the Cannabaceae family, were planted in triplicate in pots. After the experiment, soil retained in the roots was collected and called rhizospheric soil (RS). Also in triplicate, samples of the uncultivated soils, denominated standard soil (SS), were kept under the same conditions. Samples of 700 mg of the air-dried fine earth (ADFE) of SS and RS of the four soils were analyzed by XRD (powder method) in Bruker D2 Phaser equipment (Ni-Cu Cu-tube) in the angular range of 4 to 50 ° 2θ to the step of 0.01 ° 2θ and time of 1s per step (4545 effective total steps). The XRD were adjusted based on quartz reflection. DDRX was obtained by subtracting the intensity values obtained for RS (Irs) from the intensity values obtained for SS (Iss) (DXRD = Iss-Irs). The identification of minerals was performed with the EVA/3.0 program and according to Brindley and Brown (1980). The mineral composition by XRD of ADFE of SS and RS indicated kaolinite, gibbsite and quartz (Soil 05 and 06); kaolinite and quartz (Soil 11); and mica, kaolinite, quartz and rutile (Soil 14). In the four soils, DXRD indicated similarity between SS and RS samples, without seeing mineralogical changes. Also, resulted in diffractograms with almost no reflection, except for the quartz reflections due to variations in the intensities of this mineral. In this sense, the technique of differential

X-ray diffraction showed an expressive potential of use in the traceability of Cannabaceae family plants.
Keywords: *Cannabis sativa*; rhizospheric soil; mineralogy.
Financial support: CAPES/Pró-Forenses Project nº25/2014; INCT Forense.

(1359 - 872) High-throughput full pattern fitting of soil X-ray powder diffraction data

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Quantifying soil mineral concentrations is a powerful approach for understanding mineral contributions to soil properties, soil functions, and associated ecosystem services. The presence of poorly ordered clay constituents, however, makes quantitative soil mineralogy a challenging undertaking. X-ray powder diffraction (XRPD) has consistently proven to be an accurate and reliable method for quantitative mineralogy, and of the computational approaches currently available, full pattern fitting of prior measured patterns is well suited to the complexities of soil. Consequently, full pattern fitting programs such as FULLPAT and ROCKJOCK have been widely applied to quantify soil mineral concentrations. Despite their accuracy, the functionality of these Excel-based programs is not suited to high-throughput datasets. This limitation relates to the time and labour intensive step of selecting the reference patterns to include for each sample, i.e. mineral identification, which often requires expert input. Precision sample preparation methods in combination with high-throughput XRPD has recently facilitated reproducible analysis of several thousand soils from the United Kingdom, Africa and Scandinavia. High throughput full pattern fitting has potential to extract a wealth of quantitative information from this data. To facilitate high-throughput full pattern fitting of soil XRPD data, the "powdR" R package has been developed. When provided with a comprehensive and carefully prepared library of soil mineral reference patterns, the novel functionality of powdR automatically selects the most appropriate mineral phases for each fit. Further, powdR uses full patterns to estimate lower limits of detection of the selected minerals and objectively omits phases that are at or below detection limits. Tests on samples designed to replicate the complexity of soil mineral mixtures show powdR to select appropriate phases even from large libraries containing ~200 reference patterns. When compared to a similar Excel-based analysis (after manual mineral selection), the powdR computation is 10 times faster with only slight compromise on accuracy. Thus powdR bypasses the requirement of phase selection by a trained user, facilitating application of this approach to national scale soil datasets where mineralogy may vary considerably from one soil to another. This will ultimately allow quantitative soil mineralogy to be applied at spatial resolutions that are currently unattainable.
Keywords: Soil mineralogy, full pattern fitting, R
Financial support: Macaulay Development Trust

(1018 - 1578) Microfluidic Investigation of the Surface-Controlled Properties of Soil Constituents

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Soils represent highly heterogeneous and strongly surface-dominated mixtures. A quantitative study of the surface properties of individual inorganic constituents of the soil is hampered by the difficulty in characterizing these heterogeneities. The active surface area of each constituent, a key quantity in the study of surface-controlled properties such as ion exchange capacity and nutrient release rates, is difficult to determine with great accuracy. In bulk samples, this determination requires knowledge of the particle size distribution and average shape of each phase; quantities which themselves require thorough investigation and are subject to sampling bias. In this work, we describe a novel method to deconvolute the behavior of soil phases by using image analysis software in concert with soil thin sections and microfluidic devices. Electron micrographs of thin sections are analyzed with a custom image analysis routine that identifies the phases present and calculates the total exposed surface area of each phase. Solution of interest (e.g., Morgan's Solution and Mehelich-3) are then contacted with the studied thin–section area within microfluidic channels. The use of micro-channels allows the technique to better approximate the relevant length scales of the soil environment and to target specific features of interest identified in the imaging procedure. By measuring the change in the sample and fluid properties as a function of the studied mineralogy and inlet fluid properties, it is possible to quantify the contribution of each of the constituents to the overall properties of the soil. Here we present the results of the technique applied to quantify the behavior of each phase in a multicomponent fertilizer.
Keywords: Microfluidics, image analysis, ion exchange
Financial support: Advanced Potash Technologies

(3105 - 1737) Nano-scale secondary ion mass spectrometry (nano-SIMS) images can differentiate organo-mineral complexes and associated carbon preservation in a Chinese red soil

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The submicron information about *in situ* mechanisms of fertilization practices affecting organo-mineral complexes and associated carbon (C) preservation is limited. Recently, a novel imaging facility, nano-scale secondary ion mass spectrometry (Nano-SIMS), is capable of the concurrently quantitatively high spatial resolution imaging of five stable isotopes (e.g., $^{1}H/^{2}H$, $^{12}C/^{13}C$, $^{14}N/^{15}N$, $^{16}O/^{18}O$, $^{31}S/^{34}S$, etc.) with high sensitivity at ≥50 nm metric and ppm atom scales. Nano-SIMS analyses are particularly powerful when combining with ^{13}C- and ^{15}N-labelled amino acids, which can bound to their amino, carboxyl or both groups depending on their size. The quantitative of molecular and isotopic patterns of inorganic and/or organic C and N source could be hence imaged and detected. We applied Nano-SIMS, X-ray photoelectron spectroscopy and X-ray absorption fine structure spectroscopy to examine submicron effects of 24-year long-term inorganic (NPK: nitrogen, phosphorus & potassium) vs. organic (M: manure; and NPKM) fertilization on associations of organic and mineral components in a red soil in south China. Results showed that organic amendments had significantly increased the mineral availability, particularly in the short-range-ordered (SRO) phases. Nano-SIMS images provided direct evidence that citric acid, a major component of root exudates, promoted the formation of SRO minerals, which acted as "nuclei" for C retention, and that the submicron elemental distribution and spatial heterogeneity in the soil colloids and the ratios of $^{12}C^{-}/^{27}Al^{16}O^{-}$ and $^{12}C^{-}/^{56}Fe^{16}O^{-}$ were greater under NPKM or M than under NPK. The C-binding loadings of Al and Fe minerals in colloids at submicron scales, and the concentrations of highly reactive Al and Fe minerals, were greatly enhanced under NPKM or M than under NPK. Our submicron-scale findings suggest that both the reactive mineral species and their associations with C are differentially affected by 24-year inorganic and organic fertilization. References Xiao JA, et al. 2015. *In situ* visualisation and characterisation of the capacity of highly reactive minerals to preserve soil organic matter (SOM) in colloids at submicron scale. Chemosphere 138: 225-232. Xiao JA, et al. 2016. New strategies for submicron characterization the carbon binding of reactive minerals in long-term contrasting fertilized soils: Implications

for soil carbon storage. Biogeosciences 13: 3607-18.

Keywords: Soil colloids, spatial heterogeneity, submicron distribution, X-ray photoelectron spectroscopy, X-ray absorption fine structure spectroscopy

Financial support: National Natural Science Foundation of China (41371248 and 41371299) and Natural Science Foundation of Jiangsu Province of China (BK20131321).

(3076 - 560) Scanning Transmission Electron Microscopy (STEM) Analysis of Arsenic on Soil Particles

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Spectroscopic analyses of well-defined model systems such as synthesized metal-oxide minerals provide important knowledge about mechanisms of trace-element binding on minerals. However, directly translating this mechanistic information to soils is limited by the heterogeneous, multi-component nature of soil particles and a lack of molecular-scale spatial resolution of many spectroscopic techniques. Our objective was to characterize the nanoscale compositional diversity of As-treated soil particles to gain insights on trace-element binding. Clay particles isolated from a kaolinitic Ultisol were reacted with 300 mmol As(V)/kg at pH 5, and analyzed for particle morphology, crystallinity, and elemental composition using aberration-corrected scanning transmission electron microscopy (STEM) imaging (with 0.8-angstrom spatial resolution) and energy dispersive X-ray spectroscopy. Synthesized goethite and Al-substituted goethite samples were also analyzed for reference. The soil clay had diverse particles differing in crystallinity and elemental composition, as expected. Atomic structure was directly imaged on highly crystalline nanoparticles (probably hematite), which are soil particles that best reflect a model system. Most soil nanoparticles contained mixtures of Si, Fe, and Al; either as coatings or complex assemblages of varying crystallinity, with variable accumulation of As. In some cases, only minor amounts of As were accumulated with minimal co-localization with Fe or Al-enriched regions. Other particles showed co-localization of As with Fe and Al that appeared to be in (hydr)oxides. The greatest As accumulation tended to be in compositionally diverse particles containing Fe, Al, and Ca, with more As co-localization with Ca than with Fe- or Al. Atomic images of synthesized goethite particles showed a well-defined atomic structure, whereas the Al-substituted goethite (22% Al) had a poorly defined atomic structure with a non-uniform spatial distribution of Fe and Al. In essence, STEM analysis showed soil particles with well-defined atomic structures, similar to those in synthesized model analogues. However, the association of As with poorly structured, compositionally diverse soil particles indicates the challenge of defining molecular bonding mechanisms of trace elements directly in soils. Nevertheless, these STEM results show great potential for defining spatial associations of trace elements with soil from sub-micron to atomic length scales.

Keywords: nanoscale, minerals, soil complexity, trace elements

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(9690 - 1941) Transformations in mineralogy of alkaline-sodic soils in the Northern Pantanal

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Clay minerals in fine clay fraction (< 0.2 µm) have a great potential to record environmental changes. However, the distinction between inherited and neogenic clay mineral is not easy to detect by usual technics, such as simple XRD analysis. The combination of XRD modelling of oriented patterns, deconvolution of non-basal reflections and microscopic investigations enable a detailed characterization of clay minerals, helping on the interpretations of pedogenesis pathways. In Northern Brazilian Pantanal, there are no saline lakes at current conditions, but alkaline-sodic soils enriched in 2:1 clay minerals are very common. The annual flooding and absence of saline lakes arises the question about the stability of these minerals at current environmental conditions. This study aims to understand how floodwaters affect the mineralogical transformations in alkaline-sodic soils of Northern Pantanal. In order to do so, the apparent electrical conductivity (EC_a) of the area was assessed with an EM38 apparatus. After verification, the trench that comprises the abrupt variation of EC_a (6 m length, and 2 m deep) was opened in the transition between periodically and non-flooded area. For the mineralogical analyses, a sample of the horizon of maximum pedogenetic expression of the both areas was taken. The fine clay fraction (< 0.2 µm) was obtained and analyzed by X-ray diffraction (XRD) and transmission electron microscopy (TEM-EDS). The XRD patterns were modelled in order to observe the presence of mixed-layered phases. The 060 reflection peaks were decomposed to observe the octahedral composition of phyllosilicates. The modeling of the XRD patterns allowed the detection of K-S (kaolinite-smectite) minerals at different stages of kaolinization in both horizons, which are strongly associated to the transformation of Mg-rich trioctahedral smectite (from the non-floodable alkaline environment) into dioctahedral smectite and kaolinite-smectite (from the floodable, more acidic, environment). The current climatic and hydropedological conditions in the northern Pantanal favor the dissolution of carbonates, acidification of the soil, and transformations in the clay minerals assemblage. These results show how the detailed clay mineral characterization is helpful on providing clues for identification of pedogenic pathways related to climate change.

Keywords: XRD modeling Interlayered minerals Wetlands Hydropedology

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(3520 - 599) Unraveling soil clay mineralogy with X-ray diffraction: Advances and perspectives

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Soil fine fraction is commonly dominated by clay minerals that record soil pedogenetic history and control to a large extent important soil chemical and physical properties such as cation exchange capacity and specific surface area. An accurate determination of clay mineralogy and of its evolution along the soil profile or as a function of time is thus key for both purposes. Two main factors impede such a precise identification: first, soil clay parageneses are most often mixtures of clay species with sizes spanning from a few nm to 5-10 µm and variable crystal-chemistry; second, soil clay minerals are often mixed layers of variable compositions. For decades X-ray diffraction (XRD) has been the standard method to describe soil clay mineralogy. For both pure clays and mixed layers, usual XRD identification methods rely on the position of diffraction maxima and on the shift of these positions as the result of the possible expansion/collapse of elementary layers. Over the last two decades, decomposition of XRD data combined with simulation of diffraction effects from pure and mixed layer clays allowed revealing phase heterogeneity of soil samples and streamlining compositional description within a series of samples, e.g. a soil profile. This dual procedure allows only an approximate characterization of the mixed layers, however, as identification relies essentially on peak position without fitting reflection profiles as performed with the whole-pattern fitting approach. With this approach, complete XRD patterns are calculated

for a structure model optimized for each clay species present, thus overcoming the intrinsic limitations of the previous identification methods. Additional constraints are provided by fitting with a unique structure model all XRD patterns obtained for a given sample following different treatments, such as saturation by different interlayer cations, ethylene glycol solvation, heating, etc. This approach allows also quantitative phase analysis of complex clay parageneses. Improvements brought by whole-pattern fitting to the description of soil clay mineralogy will be exemplified with results obtained on bulk <2µm fractions and sub-fractions of natural samples from cultivated and/or forest soils, as well as from experimentally altered samples in an effort to unravel mineral reaction mechanisms.

Keywords: Soil clay mineralogy; Clay minerals; X-ray diffraction; whole-pattern fitting

Financial support: EC2CO/BioHefect

C2.5 - Soil chemical, physical and biological interfacial reactions

C2.5.1 - Soil interfacial reactions and their control of biogeochemical cycles

Organic matter in Brazilian tropical and subtropical soils: Contribution of minerals and organic interactions to its stabilization

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The soil-based ecosystems services are unequivocally linked to the soil organic matter and, therefore, for the well comprehension and sustainable maintenance, even optimization, of these services delivered by the soil, it is most necessary to identify the factors and mechanism for the stabilization of soil organic matter (SOM). In the specific case of Brazil, this issue is extremely relevant considering that the agribusiness is one of the main responsible of the country's economics. As a matter of fact, the estimated grain production of the 2017/2018 harvest should reach 230 million tons, being the second largest harvest of the Brazilian history. On the other hand, around 66% of Brazilian territory is still under native vegetation and its eventual occupation or use should be taken with extremely care. For instance, around 85 % of the area of Acre State, Southwestern Amazon, is still under native vegetation and therefore considered the “Green State” in Brazil. In this context the main purpose of this paper is to discuss results obtained with Brazilian soils from tropical and subtropical areas in the light of stabilization factors and to highlight relevant aspects related to environmental conditions and mineralogy. A study of 6 representatives Brazilian Oxisols under native vegetation from different regions (Amazon, Cerrado and South Brazil), verified by means of ^{13}C NMR spectroscopy that SOM of A horizons was composed by a considerable amount of O-alkyl C (29-38%), followed by alkyl (24-30%) and aromatic structures (10-14%). The organic nitrogen occurred mainly as amide, as indicated by the ^{15}N-NMR analysis. A similar pattern was exhibited by the SOM of lower horizons. The C recovery after HF treatment was around 47% and 66% at the surface horizons and decreased gradually with depth. SOM solubility after HF treatment and the considerable proportion of carbohydrate-like structures was related to organo-mineral associations that stabilized hydrophilic and biochemically labile SOM through interactions with Fe-oxides, Kaolinite and Gibbsite. The additional effect of climate on the SOM dynamics was proven in a toposequence of Oxisols under native pasture in Southern Brazil (28°S, 50° to 54°W). SOM content increased from the lowest to the highest sites (440 to 950 m altitude, 350 km of distance) due to increasing humidity and decreasing temperature. This influence was more pronounced in the heavy clayey Oxisols, indicating that organo-mineral interactions enhanced SOM accumulation. SOM aromatic C content increased with depth at the expense of O alkyl C, regardless of the site's altitude and climate, suggesting either a migration of carboxylated aromatic structures or a different SOM source. It follows that environmental conditions play also an important role on SOM amount in the surface horizons. With increasing soil depth the climatic influence decreased, and organo-mineral interactions take on a more important role. The importance of iron oxides in the stabilization of SOM via surface interactions was also observed in other types of subtropical soils in more detailed studies. A positive correlation was observed between Feo/Fed ratio with O-alkyl C groups of SOM from high altitude Entisols (28°S, 50°W) (Potes et al., 2010), highlighting the importance of poorly crystalline Fe-oxides on the stabilization mechanism. However, SOM-Fe-oxides surface interactions may also exert a synergic effect as observed by Hanke et al (2015) in a group of soils (Ferralsols and Mollisols) from a toposequence in Paraná State (22-23°S, 50-51°W). In this study, an inverse correlation was obtained between crystal mean diameter of iron oxides and of kaolinite with SOM O-alkyl C and carboxyl groups. Therefore, the surface reaction may not only stabilize SOM but also hinder the further crystallization of variable charge minerals. In highland soils of subtropical climate (28-29°S, 50-52 °W) where average temperatures (14.4°C) are low and rainfall can be high (2940 mm y-1) but concentrated in winter and springs, SOM of A-horizons, regardless the soil type (Inceptisols, Entisols) presented a proportion of O alkyl C structures (52 to 59 %) comparable or higher to that of subtropical and tropical well aerated Oxisols. Furthermore, exchangeable Al correlated with organic C. In this case, it seems that both environmental conditions as complexation contributed to SOM stabilization. The role of pedogenesis on the composition and content of SOM was further investigated by Hanke et al. (2017a and 2017b) in a toposequence in Paraná State (22-23°S, 50-51°W). In the upper part of the landscape (Brown Oxisol), organo-mineral interactions between SOM and clay minerals promoted SOM stabilization and preservation of carbohydrate-like structures. Nevertheless, on the slope (Inceptisol) and on the lower part (Histosol) of the toposequence, colder climate associated to the water table fluctuation contributed to SOM accumulation and to the enrichment of alkyl C structures. The occurrence of SOM hydrophobic sites lead to the preservation of encapsulated carbohydrate-like structures, which may or may not be adsorbed to iron oxides. This assemblage, once formed seems to confer a certain resistance against microbial decomposition, since the samples (surface and subsurface) showed a very slow decomposition rate when exposed to a respirometry experiment. On the other hand, in sandy soils with clay content ≤ 10 %, SOM accumulation and composition are likely to be much dependent of local environmental conditions. In a study on SOM content and chemical composition of a profile of a sandy Entisol in Southwestern Amazon, Brazil, (9° S, 67 °W) the impact of forest burning on increasing C content was detectable after 1 year of burning (1Y) but disappeared within 3 years after burning (3Y) (data not published).The unburned forest site (PF) showed a bi-modal pattern of n-alkanes, indicating contribution of both microbial products and higher plants to SOM lipids. On the burned forest site (BF) a uni-modal *n*-alkanes distribution profile was observed as well a shift towards smaller chains, with maximum at C16, C17 and C18. This pattern indicates SOM lipids mainly from microbial origin. PAH’s of high molecular weight were detected in this site at 1Y. Nevertheless, both differences disappeared within 3Y. Another interesting feature of this region was the lower amount of humin fraction (NaOH insoluble humic substances). Most probably the intense tropical climate conditions, i.e. high rainfall and temperature, caused the rapid humification and efficient mineralization of organic residues. Regarding the humin fraction, the same result was observed in a sandy Entisol from South Brazil (30°S, 51° W) in an area of high rainfall, but lower temperature (data not published), corroborating the role of clay fraction in stabilizing SOM via organomineral interactions. Nevertheless, in this subtropical site, the removal of forest residues decreased in half the soil C content within 7 years in comparison to the site where residues were maintained. From the above presented data and discussion we can synthetize that SOM

stabilization in tropical and subtropical soils is strongly influenced by organo-mineral interactions where the Fe-oxides are the main adsorbents. Nevertheless, in poorly drained subtropical, where the ultimate decomposition of vegetation residues to CO2 is slowed down by the reductive soil environment, the enrichment in hydrophobic moieties, e.g. aliphatic chains, leads to the formation of hydrophobic sites which in turn promotes the self-assemblage of humic matter, turning SOM more resistant to microbial degradation when exposed.

Key words: organo-mineral interactions, hydrophobicity, chemical composition

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(1916 - 2722) Affirmation of the Existence of Humic Substances and Humin and their Importance in the Interfacial Reactions of Soil Organic Matter

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The validity of the term and the very existence Humic Substances has been questioned and a 'Soil Continuum Model' (SCM) proposed to describe the decomposition of soil organic matter (SOM)[a)]. We fundamentally disagree with these concepts. The SCM focuses on the ability of decomposer organisms to access organic debris and SOM, and on the protection against decomposition afforded by soil minerals. In effect the SCM regards SOM as a continuum spanning the full range from intact plant material to highly oxidized carbon in 'carboxylic acids'. The authors also state that there are no components of SOM that are inherently resistant or acquire resistance to decomposition. We demonstrate that nothing could be further from the truth. It is inappropriate to refer to SOM components and their transformations as a 'continuum' because it is a heterogeneous mixture of a wide range of discrete materials with different compositions with different pathways and rates of decomposition. We will present a number of reasons why the SCM is a flawed concept and cannot be used to describe the known behaviour and composition of SOM. Compelling evidence regarding the existence of components of SOM (including humic substances), obtained using a variety of extraction and fractionation procedures, which exhibit widely different chemical properties and decomposition behaviour. Evidence from Spectroscopy and modelling will be presented to illustrate these major compositional difference and the impossibility of considering them to be part of a 'continuum' concept which fails to identify the different components of SOM and recognise their importance in many interfacial reactions in soil.

a) Lehmann, J. & Kleber, M. The contentious nature of soil organic matter. Nature 528 60-68 (2015)

Keywords: Soil Organic Matter, Humic Substances, Humin, Composition, Decomposition

Financial support:

(9005 - 690) An Investigation of Organic Matter Quality and Quantity in Acid Soils as Influenced by Soil Type and Land Use

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Knowledge of the molecular composition of soil organic matter (OM) and the interaction of OM with soil minerals is needed to fundamentally understand the persistence of OM as affected by land use. We investigated organic carbon (C) fractions, content of reactive surfaces (i.e., aluminium and iron oxy-hydroxides) and OM chemistry of 45 top soils across a range of soil orders and land uses in New Zealand, with the objective of understanding the influence of main soil properties, with especial attention to the abundance of short-range order (SRO) constituents, on the quality and quantity of soil OM under different land uses. The results showed that the largest C contents were found under pasture and, among soil orders, in Andisols, which had the largest unprotected and protected C contents. Yet compared to non-Andisols, Andisols were those more susceptible to loss C when used for cropping. The relative contribution of microbial- vs. plant-derived OM was influenced by soil order and land use: microbial-derived OM tended to increase as the presence of soil reactive minerals increased, which was more abundant in Andisols; soils under ungrazed grasslands had the largest contribution of fresh plant-derived molecules to OM (and that of unprotected C to total C) while cropping had a negative impact on the contribution of plant-derived OM, consistent with a decrease in the unprotected C content. Yet cropping did not have any impact on the C most closely bound to minerals. Overall, the results showed that the ability of soils to store C and their vulnerability to lose it when under specific land use is closely related to their abundance in short-range ordered constituents, and this, in turn, influences the contribution of plant-derived vs. microbial derived OM.

Keywords: soil organic matter, Andisols, land use, pyrolysis-GC/MS

Financial support: Massey University Research Fund and New Zealand Agricultural Greenhouse Gas Research Centre

(6597 - 718) Microbial community composition structured by pyrogenic organic matter regulates the soil carbon and nitrogen transformation processes

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Pyrogenic organic matter (PyOM) has been artificially applied to soils in agricultural ecosystems or is widely distributed in natural ecosystems after wildfire. PyOM can affect soil biogeochemical cycling (e.g. carbon sequestration, N_2O emission mitigation etc.) and soil productivity (e.g. pathogen control and nutrient provision) by changing soil microbial abundance, diversity and community composition. The effects of the interactions between microoganisms and PyOM in soil ecosystems are very crucial but also depend on PyOM properties, escpecially the different C component in PyOM. To investigate the effects of PyOM components (i.e. relatively-aliphatic C and relatively-aromatic C) on soil microbial community composition, we produced a variety of PyOMs and categorized them into two groups, i.e. PyOMs with relative enrichment and depletion of aliphatic C compared to fused aromatic C. We found that aliphatic-dominated PyOM had higher total microbial biomass and respiration rates than those of aromatic-dominated PyOM. The phylum of *Actinobacteria* was the dorminant taxa in aliphatic-dominated PyOM. More bacterial OTUs preferentially thrived on the aliphatic-dominated PyOM rather than aromatic-dominated PyOM. Aliphatic-dominated PyOM can also increase the abundance of denitrification genes, i.e. *nirK*, *nirS* and *nosZ* and consequently increased N_2O emission, which may be offset the effects from carbon sequestration. We attributed it to the high content of aliphatic C, which preferentially acts as an electron donor for NO_3^- reduction rather than an electron acceptor. The aliphatic-dominated PyOMs also induced greater changes in fungal community composition compared to the aromatic-dominated PyOMs. The

aliphatic-dominated PyOMs significantly decreased the relative abundance of *Basidiomycota*, most of which were not from saprotroph. The aliphatic-dominated PyOM was further supported to promote saprotroph growth and lead to the overall fungal diversity decrease and the suppression of plant pathogens. Our study highlighted the important interactions between microorganisms and PyOM in soil ecosystems, and the key roles of PyOM components in microbial community modification, and consequent soil biogeochemical cycling and productivity.

Keywords: Aliphatic C, bacteria, fungi, electron donor, saprotroph
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(5270 - 2324) Precipitation and soil moisture: drivers of redox potential, iron reduction, and carbon decomposition in a tropical forest soil in Puerto Rico

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Soils from tropical rainforests can undergo spatial and temporal variations in moisture and oxygen content because of rainfall events, leading to changes in redox potential, iron (Fe) reduction rates, and carbon (C) decomposition and/or accumulation. We hypothesized that rainfall variation (periods of drought vs. high rainfall) may: (a) generate redox fluctuations that affect Fe reduction rates and dissolved organic carbon (DOC) release in forest soils, and (b) have different impact in Fe and C biogeochemistry across topographic positions. To test these hypotheses, we measured soil Fe and C pools in 3 catenas at valley, slope, and ridge positions approximately every 2 days for a 2-month-period in a montane forest in Puerto Rico (USA). Measurements included soil extractions of Fe(II), total Fe, pH, DOC, and total C. Sensors were installed in the field to measure redox potential (Eh) using platinum electrodes, O_2, soil moisture, and CO_2 flux. We found that rainfall and soil moisture were the main drivers for changes in Fe reduction (detected as changes in ferrous iron [Fe(II)] concentration), pH, Eh, and DOC. Comparing topographic positions, the valleys were the most responsive in terms of shifting redox potential and Fe(II) concentrations. During a 270-mm-precipitation event over 6 days, soil moisture increased from 0.34 to 0.50 m^3 m^{-3} (θv), affecting the soil Fe and C biogeochemistry as follows. Most of the ridges and slopes increased Fe(II) content from 3 to 9 mmol kg^{-1}, and in one of the valleys from 50 to 126 mmol kg^{-1}. In two of the valleys, the redox potential dropped from 524 to 3 mV and 256 to -344 mV within the 6 days, indicating a change from oxic to nearly anoxic conditions. After this rainfall event, the soil slowly dried over 12 days. During this drying event, the Fe(II) content decreased from 8 to 1 mmol kg^{-1} in some of the ridges and slopes, and from 101 to 56 in one of the valleys. Redox potential in two of the valleys increased again (up to 550 mV) during this 12-day-soil-drying, indicating a return to predominately oxic conditions. DOC across most of the sites remained near constant in the intense rainfall, and decrease during the following drier days, for example, in one of the slopes, DOC changed from 254 to 114 mg kg^{-1}. We have found similar patterns of Fe and C dynamics in responses to redox fluctuations during laboratory incubations with likely implications for climate change and soil management.

Keywords: *Iron, carbon, tropical forest soil, redox oscillations*
Financial support: National Science Foundation (USA)

(2866 - 586) Role of bacterial biomass in the development of soil water repellency

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Soil particle wettability has an impact on basically all soil processes where water is involved. Beside its effect on infiltration and water availability it affects the water phase distribution and continuity in the soil matrix which is crucial for diffusion of organic substrates, nutrients and enzymes, and hence, the overall conditions for microbial life. Pure soil minerals are usually wettable, but under environmental conditions they become easily covered by organic compounds, modifying their surface properties and potentially inducing water repellency. Besides organic compounds typically identified to cause water repellency such as waxes, alkanes, fatty acids and free lipids, recent research also points to a direct impact of bacterial cell envelopes on water repellency. In addition, it has been shown that the chemical composition of the cell envelope and the surface properties of bacteria may vary with respect to water and salt stress, potentially causing a feedback between cell surface modification and microbe-induced water repellency. To investigate the factors and conditions that contribute to the occurrence of bacterial surface hydrophobicity we conducted a series of water stress experiments on different Gram-negative and Gram-positive bacterial strains. The results showed that increasing stress leads to pronounced changes in cell surface properties. With increasing stress level we found an increase in water repellency (sessile drop contact angle) in *Pseudomonas fluorescence* and *Bacillus subtilis* strains which turned out to be associated with distinct changes in surface elemental composition as proved by X-ray photoelectron spectroscopy. The results further showed that mineral coverage by bacterial cells leads to marked changes in contact angle and may render originally wettable material strongly water repellent. To explore the conditions under which bacteria with water repellent surface properties are enriched and how soil moisture history affects the activity and surface properties of soil bacteria we conduct an incubation experiment with soils from two mature beech sites with contrasting wettability and hydroclimatic conditions. The soils are incubated at different water potentials and part of them subjected to wetting-drying cycles. In our contribution we will present results on shifts in microbial composition and associated changes in soil wettability.

Keywords: Bacteria Interfacial properties Microbial biomass Soil organic matter Wettability
Financial support: German Research Foundation (DFG) (GO 2329/2, DI 1907/2, MI 598/4)

(1173 - 868) Soil carbon dynamics affected by changes in soil water repellency

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Soil carbon (C) dynamics is strongly dependent on accessibility and distribution of moisture in soil pores, which in turn can be modified by reduced wettability. Many soils around the world are affected by soil water repellency (SWR), which reduces water infiltration causing diverse moisture distribution, increased preferential flow and enhanced overland flow. Despite a few studies investigating how water repellency affects soil C dynamics, the relationship is still poorly understood. Given that predicted climatic changes are likely to increase the severity and spread of SWR, it is important to understand how reduced wettability alters soil C dynamics. In this contribution,

we will report on results from several studies conducted under laboratory and field conditions to understand the effect of reduced wettability on CO_2 fluxes. The studies were conducted on soils under temperate humid climate in the UK and the Netherlands, and under Mediterranean climate in Portugal, combining water repellent conditions induced by natural seasonal variability, drought/warming simulation and fire. The results show that the effects of water repellency can be very variable depending not only on severity of SWR, but also distribution of water-repellent patches. Microbial respiration in severely and uniformly affected water repellent soils is very low, and remains low even upon intensive rainfall, because of very low infiltration rates. Patchy distribution of SWR, on the other hand, result in enhanced microbial activity in the 'hot-spots' leading to much higher overall CO_2 fluxes. The main conclusion from the study is that SWR clearly has an important effect on soil respiration, but its impact is more complex than previously assumed, with its spatial variability likely to be the most influential factor.

Keywords: soil carbon, soil water repellency, CO2 flux, hydrophobicity, preferential flow
Financial support: not required

(2458 - 2086) Soil organic matter decomposition under anaerobic-abiotic conditions

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Iron (Fe) reduction potentially releases protected carbon (C), providing a mechanism for C destabilization under anaerobic-abiotic conditions. Soil organic matter (SOM) degradation is catalyzed by peroxidase enzymes that decompose hydrogen peroxide into O_2(g) and H_2O, the same substrate is used by Fenton reaction to catalyze the conversion into •OH, that is a strong non-selective oxidant of SOM in presence of Fe. Biotic and abiotic coupled degradation of SOM can explain the high rate of decomposition in temperate rain forest soils of southern Chile, under redox fluctuations conditions. Ultisols in south Chile present high iron oxide content, with a mean annual precipitation >5000 mm and mean annual temperature of 9 °C and, a quick redox fluctuation. In the present study, we hypothesized that anaerobic-abiotic process involving Fenton accounts for significant proportion of recalcitrant SOM oxidation in temperate rainforest in soil. The objective was to study the C release by Fenton and biotic (enzymes activities) mechanisms in a microcosm experiment. Top mineral Ah horizons were sampled (5-15 cm) and incubated at 20ºC in dark under under anaerobic conditions. Fenton was evaluated by adding different H_2O_2:Fe (II) ratios 5:1; 10:1; 20:1 at different pH (2.5, 3.0, 4.0 and 4.5 natural pH) to sterilized soil in presence of lignin peroxidase (LiP) and manganese peroxidase (MnP) enzymes. The release of CO_2, H_2O_2 consumption and presence of Fe(II) were measured. Hydroxyl radical ($^{\bullet}OH$) production was estimated using a fluorescence probe (confocal microscope). Peroxidase enzymes activities were also measured. About 13.8% of total CO_2 was released by purely abiotic C mineralization in soil, while LiP and MnP contributed to 78.6 % when coupled with Fenton and 52.1% when enzymes react alone. The ratio H_2O_2:Fe (II) 10:1 produced the highest C mineralization, > 43 % over the control soil at pH 3. Fenton enhanced the presence of $^{\bullet}OH$ from 521.9 to 1505.7 a.u. (fluorescence intensity). Biotic mineralization through LiP activity coupled to Fenton increased when the soil pH increased and decreased when the peroxide is consumed, while manganese peroxidase activity increased when Fe (II) and redox potential decreased. Our results indicated that iron abiotic oxidation coupled to biotic organic matter decomposition contributes to explain the rapid turnover time of soil C under anaerobic conditions in temperate rainforests soils ecosystems.

Keywords: Carbon cycle, Fe reduction and oxidation , Peroxidase enzyme, SOM oxidation, Reactive oxygen species
Financial support: The authors want to thank Postdoctoral FONDECYT project N 3160513 and regular FONDECYT project N 1170119 for financial support.

(3678 - 524) Succession and resource partitioning of bacterial and fungal communities at different biogeochemical interfaces

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Studies of microbial biogeography can often provide key insights into the physiologies, environmental tolerances, and ecological strategies of soil microorganisms that dominate in natural environments. In comparison with aquatic systems, soils are particularly heterogeneous. Soil heterogeneity results from the interaction of a hierarchical series of interrelated variables that fluctuate at many different spatial and temporal scales. Whereas spatial dependence of chemical and physical soil properties is well known at scales ranging from decimetres to several hundred metres, the spatial structure of microbial communities is less clear. Previous work has primarily focused on spatial heterogeneity at a single analytical scale using the distribution of individual cells, specific types of organisms or collective parameters such as bacterial abundance or total microbial biomass. There are fewer studies that have considered variations in community function (e.g. resource partitioning into bacteria and fungi) and soil enzyme activities at different biogeochemical interfaces. This presentation will give an overview about our recent studies focusing on spatial pattern of microbial communities and their feeding behaviour in different micro-habitats. Whereas zymography allows the visualization of enzyme pattern in the close vicinity of roots, micro-sampling strategies followed by MUF analyses clarify micro-scale pattern of enzymes associated to specific microhabitats (micro-aggregates, organo-mineral complexes, subsoil compartments). Isotopic as well as geostatistical approaches allowed disentangling the importance of abiotic and biotic properties for biodiversity of soil microbial communities and their carbon use efficiency.

Keywords: detritusphere, rhizosphere, soil mcroorganisms, nutrient cycling, resource partitioning
Financial support: Financial supported is provided by DFG (KA 1590, 8-3, 11-1, 12-2, 17-1)

C2.5.2 - Advances in techniques to investigate soil interfaces to understand interfacial reactions

Laser Induced Breakdown Spectroscopy (LIBS): novel methods for soil analysis

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Laser-induced breakdown spectroscopy (LIBS) is a technique for elemental analysis based on the lasergenerated plasma. In this technique, laser pulses are applied for ablation of the sample, resulting in the vaporization and ionization of sample in hot plasma which is finally analyzed by a spectrometer. The unique spectral signatures identify each element in the sample. The advantages of this technique are the almost no sample preparation and the low cost of the analysis. However, the challenge is to deal with matrix effects for different kinds of materials. The soil is a complex matrix, with many elements distributed in amorphous and crystalline chemical structures. Thus, to develop quantitative models for soils is a challenging task. Nevertheless, its potential for field application and/or large-scale measurements with low cost (mapping) make this technique a promising tool for soil analysis, including determination of carbon, and macro and micronutrients. Also, the use of all the spectral information makes possible to determine other soil parameters, like texture and pH. So some recent results using LIBS in soils will be presented, as quantification of soil C in areas under different soil and crop tillage systems, as no-tillage, pasturelands, and

sugar-cane; determination of some macro and micronutrients; identification of pollutants, as Hg and Cd, in soils; soil texture determination and others. It was used a commercial and homemade LIBS systems in configuration single pulse and double pulse. Optimal experimental conditions were evaluated for improving the sensitivity of developed LIBS system through parametric dependence study. The LIBS results were compared with the results obtained using standard analytical techniques such as inductively coupled plasma emission spectroscopy (ICP) and elemental analyzer CHN. For both, nutrients and contaminants, the developed models had accuracy higher than 80%. The limits of detection (LOD) were estimated for all the studied elements, and for many, the results demonstrate that LIBS could be highly appropriate for quick soil analysis, including generation of digital nutrients soil maps to precision farming. In this context, an innovative automated rover system with a LIBS system embedded for soil analysis is under development, and it will permit real-time measurements in field conditions.

(2592 - 260) Assessing impact of near-surface wind speed conditions on horizontal pore gas velocity profiles in wind-exposed porous media

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Several past studies, have shown that near-surface wind action is a potentially important mechanism affecting the exchange of gaseous compounds (including water vapor, greenhouse gases and volatile contaminants) between near-surface soil and atmosphere. Until recently, vertical, high-frequency gas velocity fluctuations inside the soil, caused by wind-induced pressure fluctuations at the soil surface, have been regarded as the mechanism behind wind-induced soil-atmosphere gas exchange. Very recent research, however, suggests that horizontal gas movement and development of steady subsurface pore gas flow patterns under windy conditions, may play an important role in controlling gas exchange. The primary purpose of this study was therefore, to assess experimentally, if, and to which extent, horizontal pore gas movement occurs in wind-exposed porous media, and how pore gas movement is related to near-surface wind speed. A simple method for measuring wind-induced, near-surface pore gas velocity profiles in porous media, was initially developed. This method is based on traditional tracer tracking, but was designed for conditions where tracer gas mass loss from the experimental domain is unknown (as is the case under wind induced gas transport in near-surface porous media), making traditional inverse determination of gas velocities inapplicable. Instead the method tracks the tracer gas plume center of mass. Experiments were conducted under controlled (wind tunnel) conditions at wind speeds (25 cm above the surface) up to 5.6 ms^{-1}, using a dry, granular porous medium (crushed basalt 2 – 4 mm grain size), and CO_2 as tracer gas. Near-surface, horizontal pore gas velocity profiles in the top 15 cm of the porous medium, were measured as function of wind speed. Results indicate, that the experimental method developed here generates consistent, reproducible, and accurate results, and that it can handle the very low porous media pore gas velocities typically generated by wind action. Results further showed that steady horizontal pore gas velocities do indeed develop in wind exposed porous media, with gas velocities being highest near the wind-exposed surface. Pore gas velocities were further strongly dependent on and directly proportional to the average, near-surface wind speed, suggesting that transfer of momentum across the surface rather than pressure fluctuations, plays an important role in controlling pore gas velocities under windy conditions.

Keywords: Near-surface wind speed, soil-atmosphere interface, pore gas velocity profiles, granular porous media, experimental method development.

Financial support:

(3853 - 274) Enhanced Hydroxyl Radical Formation Induced by Smectite Clays and Polyphenols Interactions

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Smectite clays and polyphenols are naturally occurring in subsurface soils, sediments and waters. However, their interactions and the possibilities of hydroxyl radical (·OH) formation are rarely studied. In this study, smectite clays with varied structural Fe contents and polyphenols with different functional groups were selected to investigate the ·OH formation in the presence of hydrogen peroxide (H_2O_2) under anoxic conditions. The results show that the presence of smectite clays and polyphenols can significantly promote ·OH formation. The formed semiquinone radicals ($SQ\cdot^-$) of polyphenols and structural Fe(II) in clay are the main active species to induce ·OH formation. The types and positions of functional groups of polyphenols greatly influence the interaction pathways to smecetite clays, which furtherly affected the ·OH formation. Structure Fe in tetrahedral layers are more active than Fe in octahedral layers in interacting with polyphenols and then produce more ·OH. Our findings presents on the overlooked role of smectite clays and polyphenols in enhancing ·OH formation and provide useful information for further study of attenuating organic contaminants in subsurface environments.

Keywords: Electron Transfer, Hydroxyl Radical, Smectite Clay, Polyphenol, Semiquinone Radical

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(9518 - 226) Interaction of organic molecules with reactive soil interfaces – molecular modeling and simulation

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The filter and buffer properties of soils contribute significantly to important ecosystems functions guaranteeing healthy water, food and feed. The highly divers molecular properties of organic contaminants contained in agrochemicals and pharmaceuticals complicate the prediction of their possible environmental behaviour. Molecular modelling and simulation – methods not directly based on experimental results but on basic laws of physics and chemistry - offer the opportunity to investigate interactions on a molecular level and to characterize various details of these interactions, which can be then used to explain experimental findings. Here we give an overview of our investigations of the molecular interactions of organic contaminants with selected soil components. The methods used involve both the *ab initio* level, as well as force field calculations and coarse grained models. We developed representative structural models of important soil minerals such as clay minerals or iron-oxyhydroxides. We also focussed on models for soil organic matter (SOM), starting with smaller moieties frequently found in SOM and ending up with the Vienna Soil Organic Matter Modeller, enabling us to simulate supramolecular structures of SOM in their full complexity and their interactions with small organic compounds. We showed that water as well as cations increase the rigidity of SOM. Furthermore, we characterized hydrophobic domains potentially entrapping nonpolar substances like PAHs as well as interactions of functional groups with polar species like phenoxyacetic acid derivatives. In an investigation of interactions of PAHs with iron-oxyhydroxide surfaces we showed

specific binding of the linearly shaped PAHs such as anthracene with goethite. Structural parameters derived from *ab initio* molecular dynamics calculations on inner and outer surface complexes of MCPA with goethite were successfully used as input parameters for modelling of adsorption isotherms with CD-MUSIC. From our studies of surface complexations including clay minerals like kaolinite and montmorillonite we generally found that in case of polar species, hydrogen bonds, cation bridges and electrostatic interactions play an important role in the formation of the surface complexes. In case of nonpolar PAHs, dispersion forces dominate in the planar stacking of the PAHs molecules on mineral surfaces. The next level of complexity concerns the formation of organo-mineral complexes their impact on adsorption processes.

Keywords: molecular modeling, organic contaminants, soil organic matter, soil minerals
Financial support:

(7551 - 744) Long-term continuous phosphate fertilization on phosphorus speciation in an Oxisol under no-till evaluated by P-XANES

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The increase of no-till system (NT) in tropical agro-systems contributes to the buildup and conservation of soil organic matter (OM) and affects phosphorus (P) phytoavailability. With the long-term P application in highly weathered soils, NT also impacts the P species present in the soil and the crystallinity of Fe and Al oxides associated with P. Therefore, we evaluated the effects of a long-term NT in conjunction with continuous P application on the solid speciation of P in a tropical soil by combining P *K-edge* X-ray absorption near edge structure (XANES), Micro X-ray fluorescence (μ-XRF), X-ray fluorescence (XRF) and P chemical analyses. Soil samples were collected in October 2015 from a Rhodic Hapludox developed on a basalt spill submitted to continuous P application for 26 years under NT. The annual P application rates for the double-cropping system were 0, 50, 95 and 110 kg ha^{-1} of P_2O_5. The P availability assessed by Mehlich 1 and exchange resin increased as the rates of P increased. Consequently, the proportions of P adsorbed to Goethite, hematite and kaolinite changed as P availability changed overtime. Such changes were identified by the intensities collected at 2158 eV and at 2169 eV of XANES. Increasing crystallinities of oxide minerals overtime were also observed. The phosphorus application rates under NT contributed to more crystalline Fe oxides being the most responsible for P adsorption. The long-term no-till production increased soil OM and maintained adequate phytoavailable P with appropriate P fertilization. Phosphorous application also contributed to Fe oxide crystallinity.

Keywords: P K-edge XANES; Fe oxides changes; long-term P fertilization; P sorption in clay minerals
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(8129 - 1313) Nanoscale distribution and speciation of organic carbon in temperate and permafrost soils

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We have examined soil microaggregate structures of temperate and permafrost soils with scanning transmission X-ray microscopy (STXM) to elucidate the fine-scale heterogeneity of soil organic C (SOC) which is critical to understanding its lability. Samples and standards were prepared as fine-grained suspensions deposited on Formvar-coated Cu grids. Small C-XANES image stacks from 279 eV to 315 eV, with an energy resolution of 0.1 eV between 282 eV and 290 eV, were acquired from areas shown to contain significant carbon. The distribution of SOC in the temperate soil is locally concentrated in chemically distinct forms. The C XANES spectra reveal two broad regions within microaggregates showing different OC compositions. The first region shows significant peaks corresponding to the L_{III} and L_{II} edges of K as well as distinct peaks at 287.0 eV (aliphatic C) and 289.0 eV (carboxylic C) with a minor peak at 285.5 eV (aromatic C). The second region, in contrast, does not show any significant K presence but is instead dominated by peaks at 285.5 eV (aromatic C), 287.0 eV (aliphatic C) and 289.0 eV (carboxylic C). The source of the K, possibly mica, is evidently associated with reduced amounts of aromatic C. A third region, of limited extent, displays an intermediate SOC composition as it does not show the L_{III} and L_{II} edges of K, nor does it show enriched aromatic C as observed for the K-free region. The C XANES spectra of the permafrost soil microaggregates were generally weaker in intensity than those for the temperate soil because the SOC in the former was more diffuse. The permafrost SOC peaks are dominated by resonance from aromatic C (285.5 eV). However, as we observed for the temperate soil, aromatic C abundance correlates negatively with K presence. Thus, for spectra which are dominated by intense peaks at 297 and 300 eV arising from K, the aromatic C peak is largely absent. All spectra from the permafrost soil show the presence of aliphatic C (287.5 eV) and carboxylic C (288.0 eV) although these peaks are less intense than that for aromatic C. Interestingly, significant quinonic peaks (283.7 eV) are present in all permafrost spectra. As the ambient temperatures of these soils are too low to facilitate quininic C formation via microbe mediated humification of SOC, this quinonic C may be due to the presence of pyrogenic C. The strong aromatic C peaks further support a pyrogenic origin for much of this SOC.

Keywords: STXM, microaggregate, organic carbon
Financial support:

(5096 - 2187) Soil Chip-XPS integrated technique to study formation of soil biogeochemical interfaces

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Many soil functions are modulated by processes at soil biogeochemical interfaces (BGIs). However, characterizing the elemental dynamics at BGIs is hampered by the heterogeneity of soil microenvironments. In order to investigate the dynamic processes at BGI, we developed a SoilChip method by assembling dispersed soil particles onto homogeneous 800-mm-diameter microarray chips and then submerging them in a solution that contained dissolved organic matter (OM) extracted from one of the two soils. Dynamics of individual elements at the Mollisol and Oxisol BGIs were quantitatively determined using X-ray photoelectron spectroscopy (XPS). In addition, we found that N fertilizer enhanced carbon (C) coating and modified the biochemical components of the Oxisol BGI. Composition through the vertical structure of the BGIs were further profiled by combining Ar+ cluster sputtering technique (removing substrate layer-by-layer) with X-ray photoelectric spectrum. Therefore, the SoilChip method is

a promising tool for investigating micro-ecological processes in soil.
Keywords: Soil biogeochemical interface Soil C, N, P dynamic Lab on a chip SoilChip X-ray photoelectron spectroscopy Soil C, N, P dynamic
Financial support: funded by the National Natural Science Foundation of China (Grant No. 41430860)

(4075 - 2474) Synchrotron-Based Techniques for Determining Phosphorus Speciation in Soils

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Phosphorus (P) is an essential element for crop growth and a widely-applied fertilizer to agricultural soils, but can act as a pollutant when excess P erodes or leaches into water sources. A fundamental understanding of soil P speciation is essential to assess P retention and transport in soils. Current methods for soil P speciation often rely on sequential chemical extractions, which are *ex situ* and can introduce artifacts during analysis. To overcome limitations of current methods, non-invasive spectroscopic techniques can be used to analyze soils *in situ*. This study evaluates synchrotron-based micro-focused X-ray fluorescence (μ-XRF) and X-ray absorption near-edge spectroscopy (μ-XANES) techniques to assess soil P speciation. Soils with varying chemical and physical properties were collected from the Mid-Atlantic region of the United States for μ-XRF and μ-XANES analyses. Micro-XRF maps were collected at high (12,000 eV) and tender (2240 eV) energies to evaluate co-location of P with Fe, Al, Ca, and Si; μ-XANES spectra were collected at the P K-edge for P hotspots. Iron (Fe) extended x-ray absorption fine structure (EXAFS) spectroscopy and macroscopic batch desorption studies complimented these analyses to further elucidate P speciation. Results indicate that μ-XRF and μ-XANES are useful for identifying Ca phosphate, Fe phosphate, Al-sorbed P, and Fe-sorbed P species. Calcium phosphates were distinguished from other species by a slight downward shift in the position of the primary fluorescence peak and the presence of a post-edge shoulder, and the presence of a pre-edge feature was key in determining the presence of oxidized Fe associated with P. Features of secondary peaks were used to further identify P mineral species. X-ray fluorescence maps were useful to distinguish Al-oxide sorbed P from Fe-oxide sorbed P species. This study is the first to combine μ-XRF maps at high and tender energies with P K-edge μ-XANES and demonstrates the value in combining these analyses to narrow the number of possible P species identified. A low signal-to-noise ratio often limited μ-XANES data collection in regions with diffuse, low-concentrations of P. Therefore, some forms of P, such as organic P species, were likely not detected during analysis. This study highlights the potential of μ-XRF and μ-XANES analysis to speciate mineral and sorbed P forms in agricultural and environmental studies.
Keywords: Phosphorus, speciation, XANES,
Financial support: Delaware Environmental Institute

(4153 - 1156) Travelling across scales - application of hyperspectral imaging and NanoSIMS to investigate nutrient distribution in soil

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Organic carbon and nutrient storage in soils is spatially highly heterogeneous, both vertically and horizontally. Localised hotspots of C and nutrient storage can occur throughout the profile, in particular in non-mixed soil horizons. Traditional methods for e.g. C budgets involve sampling discrete depth intervals or horizons and subsequent mixing of the samples. This masks the presence of hotspots for C storage in the profile, only enabling overall trends in the depth distribution to be investigated. Hyperspectral imagery of soils is a simple but powerful tool which can overcome this limitation, providing information on the distribution of C in the soil profile at the micron spatial resolutions (pixel size ~60 μm), while NanoSIMS analyses can provide insights at the submicron scale (typically 100 nm). We applied a hyperspectral technique to spatially characterise the soil organic carbon down the soil profile at the microscale. Soil cores of length 1 m and diameter 6 cm sliced in half vertically and air-dried prior to hyperspectral imaging in the spectral region 400-1000 nm. 'Regions-of-interest' were visually identified based on characteristic features (structure, colour) within the soil profiles and sampled for C analysis. C content was then predicted down the entire soil cores using randomForest models trained on the spectral features of these regions of interest. The models performed very well at predicting profile C content (R^2>0.9). The mapped distribution of C down the continuous soil profiles showed that the ploughed topsoil was more homogeneous than the undisturbed subsoil. Although the C content decreased overall from the surface to the deeper subsoil, several C-enriched subsoil biopores were detected in the cores , including the one with highest C content in any sample. To further characterise the chemical properties of these biopores, we used light microscopy of cross-sections of the soil cores to visually identify transitional zones from biopore to bulk soil, which exhibited notable colour changes. These transitional zones between biopores and bulk soil were then analysed using NanoSIMS, allowing us to investigate the nutrient distribution in C hotspots and the spatial extent and influence of the rhizosphere. Combining hyperspectral imagery with NanoSIMS analyses therefore helps us to links the information contained within soils from the submicron, across the micron to the profile scale.
Keywords: soil organic carbon, mapping, vertical distribution, spectroscopy
Financial support:

C3.1 - Soil Use and Management

C3.1.1 - Recent advances in terroir zoning, functioning and sustainability

(1550 - 315) A new dynamic viticultural zoning approach to explore the resilience of terroir concept under climate change: the case study of Aglianico grapevine in southern Italy.

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Climate change directly influences agricultural sectors, presenting the need to identify mitigating actions that can make local farming communities and crop production more resilient. In this context, the viticultural sector is one of those most challenged by climate change (CC) due to its great impact on grapevine cultivar adaptation, also generating a high degree of uncertainty about expected grape quality and, therefore, farmers' future incomes. Therefore, understanding how suitability for viticulture is changing under CC is of primary interest in the development of adaptation strategies in traditional wine-growing regions. Within this framework, the planning and managing of vineyards that aim at high quality wine is carried out by means of viticultural zoning procedures which are mostly based on empirical approaches. Considering that climate is an essential part of the terroir system, the expected variability in climate change could have a marked influence on terroir resilience with important effects on local farming communities in viticultural regions. From this perspective, the aim of this paper is to define a new dynamic viticultural zoning procedure (DVZ) that is able to integrate the effects of CC on grape quality responses and evaluate terroir resilience, providing a support tool for stakeholders involved in viticultural planning (winegrowers, winegrower consortiums, policy makers etc.). To achieve these aims, a Hybrid Land Evaluation System (HLES), combining qualitative (standard Land Evaluation system) and quantitative (simulation model) approaches, was applied within a traditional region devoted to high quality wine production in Southern Italy (Valle Telesina, BN), for a specific grapevine cultivar (Aglianico), considering high resolution climate projections that were derived under two different IPCC scenarios, namely RCP 4.5 and RCP8.5. The results obtained indicate that: (i) only 2% of the suitable area of Valle Telesina expresses the concept of terroir resilience oriented towards Aglianico ultra quality grape (UQG) production; (ii) within 2010-2040, it is expected that 41% of the area suitable for Aglianico cultivation will need irrigation to achieve quality grape production; (iii) by 2100, climate change benefits for the cultivation of Aglianico will decrease, as well as the suitable area.

Keywords: Dynamic Viticultural zoning, Terroir resilience, SWAP, Grapes quality, Climate change
Financial support:

(7762 - 348) Effect of long-term application of inorganic fertilizers and organic manure on yield and soil organic carbon dynamics in a crop rotation system

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Cultivation practices and nutrients management have a profound influence on soil productivity and the sequestration of soil organic carbon (SOC). However, there have been few integrated studies on yields and SOC dynamics following application of organic amendments in long-term multiple-crop-rotation systems. The aim of this study was to assess the effects of nutrient management on yield and SOC sequestration potential over a 33-year field experiment (rice – wheat/broad bean – maize/cotton – barley, each cycle of rotation taking 3 years). The treatments were (1) control, with neither fertilizers nor manure, (2) nitrogen and phosphorus but no potassium (NP), (3) nitrogen, phosphorus, and potassium (NPK), (4) pig manure alone (M), (5) pig manure combined with NP (MNP), and (6) pig manure combined with NPK (MNPK). MNPK increased yields by 15.2%–65.8% and C sequestration by 27.0%–64.4%. The rice–wheat rotation gave the highest yield and biomass C (5.27–12.59 t ha^{-1} yr^{-1}), whereas the lowest biomass C was recorded in the board bean – maize rotation (3.40–7.72 t ha^{-1} yr^{-1}). The crop rotation at the site served as a C sink with a significantly higher SOC sequestration potential in the manure treatments. The observed SOC sequestration rates were lower than those commonly reported for flooded rice paddies, which is probably because of lower inputs of C especially in the broad bean – maize rotation and also in the cotton–barley rotation.

Keywords: Multiple crops rotation, Organic amendment, Long-term application of fertilizers, Carbon sequestration
Financial support: The study was financially supported by the National Department Public Benefit Research Foundation of China (grant No. 201203030) and the Jiangsu Agricultural Independent Innovation Fund (program Name. CX (17)-1001)

(3545 - 395) Effects of soil erosion on agro-ecosystem services: a multidisciplinary study in nineteen organically farmed European and Turkish vineyards

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Excessive soil water erosion in vineyards, or improper earthworks before plantation, may produce degraded areas, where farmers complain an excessive reduction of grape yield. This multidisciplinary research work evaluated the effects of soil erosion on different agro-ecosystem services besides grape yield, namely grape quality, carbon storage, soil biodiversity, water and nutrient supply, and enzymatic activity, with the aim to work out a proper strategy of soil remediation. Degraded areas in nineteen organically farmed European and Turkish vineyards resulted in significantly lower amounts of grapes and excessive concentrations of sugar. Plants suffered from limited water nutrition, due to shallow rooting depth and reduced available water capacity, low levels of total nitrogen and cation exchange capacity, and high concentrations of carbonates. Carbon storage was depressed in degraded areas, but biological diversity and activity, monitored by different proxies, did not show any clear and significant difference between degraded and non-degraded soils. No clear difference in overall microbial diversity indices and diversity evenness were observed. All indices were relatively high and indicative of rich occurrence of many and rare microbial species, high diversity and low abundance of individual species and high species evenness. Dice cluster analyses indicated slight qualitative differences in Eubacterial and fungal community compositions in rhizosphere soil and roots from degraded and non-degraded areas. Fingerprint clustering suggested that soil erosion might have an influence on certain functional taxonomic units. The general trend of soil enzyme activity mainly followed organic matter stock however, variations in specific enzymatic activities in eroded soils suggested that, alongside a general slowdown in organic matter cycling, there was a relative greater reduction in decomposition capacity of the most recalcitrant forms. This multidisciplinary study indicates that organic farming is capable of coping with surface biodiversity, but not the other soil agro-ecosystem services. Then the loss of soil fertility caused by excessive earth movement before planting and or accelerated erosion is difficult to recover through the

ordinary biological management, but it requires site-specific and more intensive treatments, including accurately chosen organic matrices for fertilization, privileging the most easily decomposable.
Keywords: Soil enzymes; soil biodiversity; soil carbon stock; soil fertility; yield components
Financial support:

(5657 - 1697) Evaluation of the effect of the incorporation of two types of plastics (biodegradable and conventional) and the activity of earthworms in sandy soils in wheat (*Triticum aestivum* L.)

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Plastic films such as low density polyethylene (LDPE) and biodegradable in agriculture arise as an alternative for soil, crop and water protection. The knowledge of both plastics in the terrestrial ecosystem is scarce. The objectives were to evaluate in the development of wheat plants: i. The effect of the incorporation of biodegradable and conventional plastic in sandy soils, ii. The effect of the size of macro and micro plastics and iii. The effect of earthworms (*Lumbricus terrestris*). The study was conducted in a climate-chamber at Wageningen University, The Netherlands. Two plastic films, two particle sizes (5 – 10 mm and <1 mm), presence and absence of earthworms, were used in a DCA design and five replicates ($P \leq 0.05$). Leaf height and number of leaves were evaluated weekly. At the end of the experiment, stem diameter, aerial and root biomass, live and dead leaves, leaf area, tillering, soil pH and conductivity and earthworm mortality and weight were evaluated. The incorporation of biodegradable plastic at a concentration of 1% w / w in soil delays the development of wheat, lowers the electrical conductivity in soil and does not affect pH, whereas LDPE in the soil does not cause an effect on its growth, but generates greater leaf area. Micro plastics lower wheat growth. The earthworms lowered the pH in the soil, increased the biomass, number of leaves, tillering and leaf area but did not affect the height and stem diameter of wheat. Its mortality increases in the presence of biodegradable plastic.
Keywords: Biodegradability, coverage, mulch, soil moisture.
Financial support:

(9408 - 852) Farm-scale soil mapping protocols for New Zealand

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Farm Environment Management Plans and nutrient budgeting is now a compulsory regulatory requirement in a number of regions across New Zealand, and are reliant on quality soil information as a key input. The soil mapping protocol presented here provides standards and guidance to be used nationally for collecting and presenting soil map information. This Envirolink tools project was initiated by Regional Councils to address the need to provide: a framework for consistent soil mapping, identification of appropriate methods, a process to determine if the work has met minimum standards, and guidance on the level of detail required for different land use applications. This was to overcome the variety of soil maps and differing standards of work that could otherwise be generated and provided. The generic approach used to prepare the soil mapping protocols is based on a quality assurance / quality control process that is applicable at a range of scales and land use applications, allowing the document to be a New Zealand Soil Mapping Protocol. Standards for different land use applications (these can be expanded as required) are established for 6 procedures (site density, site distribution, soil characterisation, soil variation, provider, and review) that are necessary components of soil mapping. Each of these procedures has 3 levels of detail (low, medium, and high) that are defined along with accompanying guidance information. This provides a framework to determine what is expected to be conducted to construct a soil map for applying to a particularly land use application. Following on from this, the work outputs can be inspected using a listing of what is expected to be provided. Finally, a self-assessment matrix allows for a summary of the level of work detail to be evaluated. The entire protocol is contained in 4 tables, with the remaining text providing detailed guidance, rationale and explanation.
Keywords: framework maps land use
Financial support:

(9275 - 1655) Fertilizer sources and application methods of zinc in citrus orchard

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In order to prevent or correct zinc (Zn) deficiency in citrus orchards, the micronutrient is supplied either via leaf sprays or soil application. This study aimed to evaluate the effects of Zn fertilizer sources and application methods on the nutritional status and fruit yield of citrus trees. Two experiments were carried out with three-year-old sweet orange trees orchard during the first years of fruit production for four seasons. In the first experiment, three sources of Zn (nitrate, sulfate or EDTA) were applied via fertigation, whereas in the second one, the same sources were applied via foliar sprays. A control treatment, common to both experiments, consisted of nil application of Zn. Concentration of Zn extracted by DTPA in the soil increased with the nutrient application either by fertigation or via foliar sprays. Moreover, when Zn was applied via fertigation, Zn-EDTA promoted higher levels when compared to the control. On the other hand, when Zn was sprayed to the leaf, the increment of the nutrient concentration in the soil was observed mainly when applied as nitrate form. Application of Zn via fertigation increased the nutrient levels in the leaves only after the third year of fertilization, mainly when applied as EDTA, whereas nitrate and sulfate promoted intermediate levels of the nutrient. The application of Zn via foliar sprays increased the nutrient level in the leaves up to 120 mg kg^{-1} when applied as nitrate. When Zn-fertilizers were applied via fertigation, the accumulated fruit yield, was higher in trees fertilized with Zn-EDTA when compared to control ones. When the nutrient was sprayed in the leaves, the fruit yield was higher in trees fertilized with nitrate or sulfate than those sprayed with Zn-EDTA or not (control treatment). After Zn fertilizers application either via leaf sprays or fertigation, the trees exhibited lower H_2O_2 content than the control ones. In addition, trees fertigated with Zn-EDTA or leaf sprayed with nitrate or sulfate sources exhibited higher CAT activity, in both experiments when compared to the control. Furthermore, we verified a positive correlation between the increment of CAT activity and accumulated fruit yield. In conclusion, the balanced nutritional status of plants related to Zn supply improved the nutrient levels in the plant, reduced the effects of abiotic stress and increased the fruit yield, mainly when the trees were supplied with Zn-EDTA via fertigation or with nitrate or sulfate via leaf sprays.
Keywords: micronutrient, nutritional status, fertigation, foliar application, reactive oxygen species
Financial support: São Paulo Research Foundation (FAPESP, grant #2010/17589-9)

(5197 - 2089) Influence of soil characteristics on the composition of winter wines (Syrah cv.) from commercial vineyards of southeastern Brazil

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A novel management approach called double pruning made feasible the opening of a new frontier of fine wines production in southeast of Brazil. Such management changes the harvesting of wine grape from wet summer to dry winter by means of two pruning carried out during the year, decreasing disease incidence and improving the grape quality. Since the wine consumption in Brazil has increased, along with the demand for such wines worldwide, the better understand of factors influencing the terroir is strategic to figure out the potential of local wines uniqueness. Studies that describe or explain how soil properties affect the characteristics of wine are very important. This work aimed to investigate the influence of soil characteristics on a wine composition produced from grapes from vineyards in 2016 harvest of Syrah. The study areas are located in the municipalities of Cordislândia, Andradas, Três Pontas, São Sebastião do Paraíso in Minas Gerais State, and Espírito Santo do Pinhal (ES Pinhal) and Itobí in São Paulo State. The average variation between day and night temperatures is 15 °C and altitude is 900 m. The following physical and chemical analyzes were performed on soil horizons: soil texture, gravel, effective cation exchange capacity (CEC) and K+. Grapes from each vineyard were harvested for winemaking. The wines had their chemical composition analyzed to determine anthocyanins (Anth), total soluble solids (TSS) and sugars since that these parameters express wine quality. The canonical correlation analysis was performed in R 3.3.3 software to evaluate the existence and the strength of linear association between soil characteristics. Three canonical pairs were generated. The correlation between the original variables and the canonical variables was significant for the first ($p<0.001$, test F) and second canonical pair ($p<0.05$, test F). The first pair presented canonical correlation of 0.95. This pair was given by: X=-1.20sand–0.43silt+0.07clay+0.02gravel–0.23K+ +0.90CEC and Y= -1.57TSS–1.01Anth– 0.44sugar. The relationship between soil and wine characteristics is mainly explained by the association between the highest coefficient of sand and the coefficients of content of TSS and Anth. The soils of Andradas and ES Pinhal presented the highest levels of sand and wines with higher content of anthocyanins and TSS, respectively. Thus, the higher content of sand, the lower retention of water, causes greater accumulation of these compounds in the grapes.
Keywords: soil texture, wine's quality, canonical correlation
Financial support: CNPq, CAPES, FAPEMIG

(8620 - 2949) Land suitability of the Legal Amazon deforested areas

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This paper presents the results of the land suitability of the Legal Amazon deforested areas, excluding permanent protection areas and indigenous reserves. The methodology used corresponds to the one recommended by the Sistema de Avaliação da Aptidão Agrícola das Terras (Ramalho Filho & Beek, 1995), with small adaptations. Soil information provides the Soil Map of the Legal Amazon developed by IBGE. Since it is a large extension area, according to PRODES (2008), 2,170,992 km^2 and, consequently, a great diversity of soils, it has become necessary to organize the legend of the soil map in a spreadsheet and establish search procedures and automatic data processing. It was established an automatic procedure that allowed for all the components of the mapping units, both the assignment of limitation degrees and their submission to the guiding framework, recommended for the humid tropical region, which led to the determination of the fitness class for the various uses. It was observed that 611,789 km^2, about 28.2% of the Legal Amazon deforested areas, present Good land suitability for Crops at the high technological level, indicated for farmers with intensive use of financial resource and technologies, while 329,449 km^2, equivalent to 15.2% of the deforested area, present Good or Regular land suitability for crops at the medium technological level, indicated for farmers with little use of inputs and technologies. The indication for planted pasture presents the largest area, 37% of the total, while the indication for conservation reforestation is done in 155 thousand km^2. Of the deforested area, 188 thousand km^2, or 8.7%, do not have land suitability and are indicated for the preservation and conservation of fauna and flora. In general, the limitation to the use is mainly due to the strong soil fertility deficiency of the region and limitations to the use of mechanization and susceptibility to erosion, when they appear in rough relief. References EMBRAPA, 2013. Sistema Brasileiro de Classificação de Solos. 3.ed. rev. ampl. Brasilia DF. 2013. 353p. RAMALHO FILHO, A. & BEEK, K. J. Sistema de avaliação da aptidão agrícola das terras. 3.ed. rev. Rio de Janeiro - RJ. 1995. 65p. PRODES (2008). Áreas desmatadas da Amazônia Legal n. Available at: <http://www.dpi.inpe.br/prodesdigital/prodes.php>. Accessed on Nov 10. 2014 Solos da Amazônia Legal. Available at: <http://www.visualizador.inde.gov.br>. Accessed on Nov 10. 2014.
Keywords: Agricultural potential, Amazonian biome, Environmental protection.
Financial support: Work executed with resources from the Project "Uniformização dos Zoneamentos Ecológico-Econômicos da Amazônia Legal", coordinated by Embrapa Amazônia Oriental and financed by FINEP.

(6830 - 2384) Modeling hydrological processes for improved soil, water and land management for high quality wine production under Mediterranean semiarid climate condirions

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Soil hydrological processes may be the main critical factors affecting the quantity and quality of grapes and wine production, both under dry-land and irrigated conditions. This is specially true in areas under the present and previewed future changing Mediterranean semiarid climate conditions, where high quality wines are frequently produced. The variable soil properties and land characteristics, mainly the ones affecting the soil moisture regime in the root zone, are a further factor to be considered. Recently adopted changes in the traditional crop and land management systems, directed to increase production and to permit mechanization of most of the agricultural operations, are also affecting those hydrological processes and their effects. Therefore, following the "terroir" approach, looking for the best combination of site specific conditions leading to high quality wine production, there is proposed a non-empirical modeling system to evaluate and preview the effects of the combination of climate, of soils and of land management on the hydrological processes affecting the soil moisture regime and water supply in the different growing periods of vines. There are presented examples and results of the application of such approach, in three wine producing regions of Catalonia (NE Spain), under variable rainfall, soils and crop and land management conditions. The tested land management practices include different cropping plantation patterns and densities, dryland and irrigation production systems, tillage practices, use of cover crops, land leveling and terracing.
Keywords: Keywords: Modeling; hydrological processes; wine; climate change
Financial support:

(1201 - 1887) Modeling soil organic carbon stock after 10 years of cover crops in Mediterranean vineyards: improving ANN prediction by digital terrain analysis

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Estimate changes in soil organic carbon (SOC) stock after Agro Environment Measures adoption in Europe are strategically for national and regional scales. Uncertainty in estimates also represents a very important parameter in terms of evaluation of the exact costs and agro-environment payments to farmers. In this study we modeled the variation of SOC stock after 10-year cover crop adoption in a vine growing area of South-Eastern Sicily. A paired-site approach was chosen to study the difference in SOC stocks. A total 100 paired sites (i.e. two adjacent plots) were chosen and three soil samples (Ap soil horizons, circa 0-30 cm depth) were collected in each plot to obtain a mean value of organic carbon content for each plot. The variation of soil organic carbon (SOC_V) for each plot was calculated by differences between contents of the plot subjected to cover crops (SOC_{10}) and the relative plot subjected to traditional agronomic practices (SOC_0). The feasibility of using artificial neural networks (ANN) as method to predict soil organic carbon stock variation and the contribution of digital terrain analysis to improve the prediction were tested. We randomly subdivided the experimental values of SOC-stock difference in 70 learning samples and 30 test samples for model validation. SOC_V was strongly correlated to the SOC_0 content. Model validation using only SOC_V as unique covariate showed a training and test perfection of 0.632 and 0.771 respectively. We hypothesized that terrain-driven hydrological flow patterns, mass-movement and local micro-climatic factors could be responsible processes contributing for SOC redistributions, thus affecting soil carbon stock over time. Terrain attributes were derived by digital terrain analysis from the 10 m DEM of the study area. A total of 37 terrain attributes were calculated and submitted to statistical feature selection. The Chi-square ranking indicated only 4 significant covariates among the terrain attributes (slope height, valley depth, protection index, surface area). Model validation using SOC_V and the selected terrain attributes as predictors showed a training and test perfection of 0.889 and 0.921 respectively. Results confirmed that after 10 years of cover crop practices the SOC contents generally increased in the topsoil horizon and this increment is affected by the initial SOC content and terrain-driven factors.

Keywords: SOC stock modeling, vineyards, cover crops, digital terrain analysis, artificial neural network
Financial support:

(9666 - 1845) Pedotechnique application in intensive viticulture: links between economic assessment and soil security

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Since ancient times Man and Soil have experienced interwoven links. Nowadays soil scientists continue to stress such links highlighting the importance of soil to provide man's growing demand for food, water and energy, and also the soil's importance in providing ecosystem services that affect climate change, human health and biodiversity. In soil management for agricultural purposes, pedotechniques to tailor soils suitable for table grapes cultivation in large-scale farming are used to get substantial financial returns. However, farmers in tailoring soils for high income crops, frequently do not take into account the fundamental objective of the pedotechnique, i. e. to meet the needs of man, avoiding any undesirable environmental consequences that may occur during handling of earthy materials. Indeed, we should consider that any human intervention on the environment, could originate new soilscapes and new soils whose security should be verified. In this note, we report on an emblematic case study of pedotechniques application in Sicily (Italy). After stressing the threats to soil security derived by the presence of anthropogenically tailored soils for table grapes cultivation, we assess their economic sustainability, taking into consideration only the internal factors and excluding the external economic contributions that are allocated to social sustainability. To evaluate the effectiveness of the financial investment, results have been compared with profitability data related to traditional crops without pedotechniques application. Results highlight that the transformation of the soilscape, from one hand, allows for considerable investment costs, on the other hand, the highest productivity and the consequent higher profitability of the cultivation, compared to the conventional crops, allow to amortize the startup costs. We cannot ignore that this transformation could trigger potentially a considerable decrease in quality of the environment and in pedodiversity.

Keywords: pedotechniques, anthropogenic soils, soil security, land use change
Financial support:

(1841 - 1853) Potential areas identified for cocoa cultivation in honduras

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International demand has aroused interest in producing cocoa. Honduras is the second largest producer of cocoa in Central America, with recognized high quality. Cocoa production is affected by climatological and soil factors. The objectives of this study were to determine the potential areas for cocoa cultivation in Honduras and to propose fertilization programs according to the soil fertility levels. The study was conducted in 38,364 samples for soil fertility assessments, practically covering the entire country. The analyses were performed in the Honduran Foundation of Agricultural Research (FHIA by is initials in Spanish). Climatological and soil information of the country were used, according to geographical location. The areas of the country suitable for cocoa cultivation were divided according to their climatic and soil properties. The Country was divided in five districts. The data analyzed were soil chemical characteristics, classified by its chemical characteristic; pH, organic matter content, phosphorus, calcium, magnesium, potassium and exchange soil acidity. The climatological factors assessed were temperature and precipitation. Soil effective depth and elevation above sea level were used as physical conditions on these characterization. Descriptive statistics were performed. Forty-eight percent of the samples analyzed had a soil reaction less than 5.5, organic matter content fluctuated between 2.4 and 5.4%. Phosphorus was highly deficient. The contents of Ca, Mg and K are in directly related with soil pH. The main limitation of soils were low natural fertility, soil acidity and low natural fertility levels. Soil fertility should be amended for cocoa cultivation. Honduras has a climatic and edaphic conditions favorable to produce cocoa in 10.30% of its extension. The selection of planting sites should be done based on a soil studies and climate analyses.

Keywords: cocoa, climatic and soils condition, soil suitability
Financial support: Zamorano University and FHIA (Honduran Fundation for Agriculture Research), Honduras.

(7739 - 1576) Proximal Soil Sensing and Multispectral Imaging for Site-specific Nutrient Management in Tropical Soils

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Evaluating nutrient uptake and site-specific nutrient management zones in rice in Costa Rica from plant tissue and soil sampling is expensive because of the time and labor involved. In this project, a range of measurement techniques were implemented at different

vintage points (soil, plant and UAVs) in order to generate and compare nutrient management information. More precisely, delineation of site-specific nutrient management zones were determined using 1) georeferenced soil/tissue sampling, 2) proximal soil sensing (soil pH, Electrical Conductivity ECa, and dual-wavelength optical measurements) and 3) multispectral (blue, green, red, red edge, near IR narrowband wavelengths) and thermal images (0.1 ^{O}C temperature resolution) generated from UAV platforms. New nutrient management plans were designed and applied based on site-specific soil/plant deficiencies and nutrient uptake at commercial scale. Two treatments were implemented to evaluate the benefits of site-specific nutrient management, namely i) Business-as-usual (control) where the conventional fertilization was maintained and ii) Optimized fertilization using nutrient deficiency maps (soil and plant) and variable rate applications. The zoning maps were used to apply macro and microelements according to soil deficiencies and crop needs. Delineation maps have shown to be a useful approach to guide fertilization operations. The precision agriculture practices resulted in a production yield increase of up to 18.9% for some of crops. The yield of the optimized fertilization was 42.6% higher than the Costa Rican average for rice production. A cost-benefit analysis was carried out indicating that the optimized site-specific fertilization resulted in gains of USD $188/ha per rice cycle compared to conventional fertilization practices. This study indicates that this new multi-sensor and data fusion approach is a useful technique to improve yield, generate gains (after cost of data generation), and to optimize rice production.

Keywords: Site-specific Nutrient Management, Optimized Fertilization, Proximal Soil Sensing, Hyperspectral Imaging, Precision Agriculture, Rice

Financial support: Sistema de Banca para el Desarrollo de Costa Rica. Award No. AG-1475-185-2016

(2775 - 3200) The potential of alfisols developed from different parent materials in two agro ecological zones for oil palm production

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Land suitability evaluation is a tool in the assessment of the actual and potential capability or suitability of soil resources for specific use. Soils in two agro ecological zones of dry upland rainforest (Ado-Ekiti) and southern guinea savanna (Kabba) of Nigeria were mapped, characterized and classified for their potential to support the cultivation of oil palm. Seven mapping units were delineated at Ado-Ekiti (labelled AA to AG) and nine units at Kabba (labelled KA to KI). Based on the principle of matching land qualities and climate requirements of crop to the characteristics of the land, the suitability classification of the soils mapping units was developed. Mapping units KA, KD, KG, KH, KI, AA, AB, AD, AE AND AF have index of actual productivity (IPC) lower than 50%, therefore were rated as currently marginally suitable (S3) for oil palm production. KB, KC, KE, KF and AC were currently not suitable (N1) while AG was permanently not suitable. The major limitations to oil palm production at both sites were rainfall, poor soil drainage condition in some portion and soil fertility. Fertility is a limitation that can be improved with appropriate post-harvest crop residue management and mulching, use of organic manure and biosolids, legumes in crop rotations; judicious use of inorganic fertilizer and integration of fertilizer with manures. These soil fertility management techniques will raise the productivity of mapping units KB, KF, KG, KH and AA, AB, AC, AD and AF to Class S2; moderately suitable for oil palm production.

Keywords: Classification, land, oil palm, potential and soil.

Financial support:

(4865 - 2585) Zoning of productive areas for the establishment of plantations of acacia in Colombia

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Forest zoning is an important instrument for identifying, grouping and ordering the territory, to promote better management of resources and contribute to sustainable forest development. The management of forest plantations is the object of several researches worldwide, with the purpose of understanding their dynamics as an ecosystem, achieving an increase in productivity and efficiently satisfying market requirements. *Acacia mangium* is considered a potential species in commercial reforestation programs in the region of the Colombian Orinoquía, due to its easy adaptability, rapid growth and the stable growth rates that have been reported (27 m^3 ha^{-1}). The objective of the present investigation was to evaluate a zoning methodology, with the purpose of establishing productive zones for future forest plantations of Acacia in the Altillanura plana. Based on an first-order autoregressive statistical model (AR1), the calculation of prediction intervals (R Project Vr 3.2.2) and the analytical and geographical information of soil mapping units (SMU), four productive zones were obtained, differentiated by the future yields (wood volume) of the stands and the presence and intensity of edaphic limitations such as moisture deficit for three (3) months or more, poor natural drainage and low effective depth due to the presence of gravel, abrupt textural change, ground, water level or petroferric layers. The SMU were grouped into new areas that would have similar yields, wich are nor individual or homogeneous soils, but groupings that can have significant variations or contrasting characteristics. The areas obtained were outlined in a semaphore type map: *highly productive zones* - green (> 50 m^3 ha^{-1}), *productive zones* (40 - 50 m^3 ha^{-1}) - yellow, *moderately productive zones - orange* (20 - 40 m^3 ha^{-1}) and *marginally productive zones - red* (<20 m^3 ha^{-1}), thus providing a general visual of the spatial distribution of the identified zones for the establishment of commercial stands of Acacia. It was found that despite the inherent limiting soil and climatic conditions of Altillanura plana (high acidity and naturally compacted soils), *A. mangium* is an alternative for forest development in the region, under conditions of strict silvicultural and edaphic management and adapted to the needs of each established productive area. The production ranges and the areas defined in the present investigation contribute to forest management with productive purposes in the Colombian Orinoquía.

Keywords: *Acacia mangium;* wood volume, productivity; soils; altillanura plana.

Financial support: Corporación Colombiana de Investigación Agropecuaria (CORPOICA). International Plant Nutrition Institute (IPNI).

C3.1.2 - Multi-scale and multi-domain approaches to develop smart farming

(1571 - 906) Development of a collaborative Soil Fertility and Crop Nutrition Management platform to formulate site-specific fertilizer recommendations in sub-Saharan Africa

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OCP S.A. is a major global company specialised in phosphate mining and the development and commercialisation of phosphate-based complex fertilisers adapted to the soils and crops in regions around the world. OCP AFRICA is a subsidiary of OCP committed to the sustainable development of agriculture in Africa. To extend and sustain its work and as part of its R&D program on soil fertility, OCP AFRICA initiated a long term collaborative agreement with Wageningen University & Research (WUR) and ISRIC – World Soil Information. This consortium is developing a soil fertility and crop nutrient management platform to develop site- and crop-specific fertilizer formulations, including macro- and micronutrients, for important agro-ecosystems throughout Africa. The engine of this platform is formed by well established agronomic crop models of (semi-) mechanistic nature in a first tier, and machine learning techniques in a second tier, integrated with a geospatial database of detailed maps of the continent, such as the ISRIC SoilGrids for Africa, and fertilizer trial data. This engine is generically applicable and valid for the whole of Africa whereas local accuracy and precision is obtained by target-specific model calibration using additionally collected local data on soil and crops. To fully design and evaluate this platform, a pilot project for proof of concept has been started to develop and test targeted fertilizer formulations for irrigated rice in the Niger river inland delta in Mali and the delta and valley of the Senegal River in Senegal. The consortium collaborates herein with international partners (Nutrient Management Institute, AfricaRice and World Agroforestry Centre) and national R&D partners in Mali and Senegal. Yield gap analysis is at the basis of the approach wherein the nutrients required by the rice crop are compared with the nutrients available from the soil and wherein the fertilizer use efficiency is modelled as a function of the size of this gap. For this purpose, we modelled crop growth and soil fertility with the ORYZA and QUEFTS models in which we integrated the behavior of micronutrients (Cu, Zn, B, S), calibrated with local trial data. We took samples from the soil rootable depth in the targeted areas of interest and used the analytical results to produce area-specific updates of SoilGrids, followed by recalibrated calculations of site-specific fertilizer formulations. The recommended fertilizers will be validated by onfarm trials.

Keywords: soil fertility; site-specific fertilisers; micronutrients; Africa; digital soil mapping

Financial support: OCP AFRICA S.A.

(4967 - 3120) Kinetica: web-based application for determining nutrient uptake kinetic parameter values in plants

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The estimation of kinetic nutrient uptake parameter values has been a commonly used approach to estimate the ion acquisition capacity by plants. The values of the Michaelis-Menten constant (K_m), maximum absorption rate (v_{max}) and minimum uptake concentration (C_{min}) can be employed, for example, in the development of fertilizer management strategies, and for selection of plants and agricultural systems models with enhanced nutrient use efficiency. The values of v_{max}, K_m and C_{min} can be estimated based on the ion depletion from a solution where volume, concentration, and time and sampling instants are known. Claassen and Barber (1974) proposed a technique in which the concentration of each sample is multiplied by the solution volume at the sampling instant, obtaining the nutrient amount (q) as a function of the sampling time (t). The kinetic uptake parameters v_{max} and K_m are then calculated from the q(t) derivative function ($\delta q/\delta t$). In order to simplify these calculations, Ruiz (1985) proposed the graphical-mathematical model, which divides the function q(t) into two segments: linear and asymptotic. With aid of computational resources, it is possible to adjust several models to the asymptotic segment, testing for the best fit. Therefore, the aim of this work was to develop a web-based computational tool that facilitates the determination of kinetic nutrient uptake parameter values (K_m, v_{max} and C_{min}) in plants. For this purpose, an application was built with Python programming language. In order to estimate the parameters values, users will be required to go to https://kinetica.ufv.br and upload a spreadsheet containing the data obtained from the depletion experiment: ion instant concentrations, the initial volume of nutrient solution, the sampled volume, the duration of the sampling period, the final volume and the root mass or volume (fresh or dry). Based on these data, the algorithm will test several models and select those with the highest coefficients of determination (R^2) for the two segments of the function q (t) simultaneously. The value of C_{min} can be estimated from the ion concentration at the point where q(t) reaches the lowest value. Values of K_m and v_{max} will be estimated by applying the graphical-mathematical method to the adjusted regression equations. The results will be available for visualization on the web browser or compiled into a spreadsheet and downloaded back to the user's device.

Keywords: soil fertility; plant mineral nutrition; nutrient uptake; kinect parameters; web-based application.

Financial support: Project funding by Minas Gerais Research Support Foundation (FAPEMIG)

(1553 - 330) Mid-infrared Technologies Based Proximal Sensing of Selected Soil Properties: Diffuse Reflectance Spectroscopy, Attenuated Total Reflectance Spectroscopy and Photoacoustic Spectroscopy

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Diffuse reflected spectroscopy (DRF), the attenuated total reflectance spectroscopy (ATR) and Fourier transform infrared photoacoustic spectroscopy (PAS) are useful techniques which are widely utilized to characterize soil properties. In this study, the techniques were employed to evaluate the soil properties with 1456 paddy soil samples located in Nanjing from China to explore their differences in the region of 4000-500 cm^{-1}. DRF spectra showed broad and shoulder peaks ranged from 4000-500 cm^{-1}. ATR spectra displayed a strong peak around 1000 cm^{-1} in fingerprint region. PAS spectra demonstrated several moderate intensity peaks in the regions of 4000-2600 cm^{-1} and 2500-500 cm^{-1}. Then effective variables were selected based on uninformative variable elimination (UVE) algorithm for quantitative estimation of pH, soil organic matter (SOM), total nitrogen (TN) and available phosphorus (AP) contents according to a self-adaptive partial least squares model (SAM-PLS). The results showed that selected variables could improve prediction accuracies considerably comparing to full spectrum. For pH value prediction, ATR spectra showed slight higher performance (RMSEP, R^2 and RPIQ were 0.29, 0.90 and 3.31, respectively) with the selected variables of 550. The DRF spectra performed better (RMSEP = 2.24 g kg^{-1}, R^2 = 0.91 and RPIQ = 3.49 for SOM, and RMSEP = 0.18 g kg^{-1}, R^2 = 0.86 and RPIQ = 3.23) than others with 538 and 599 variables, respectively in SOM and TN prediction. The predictions of AP values were poor. IR incident light paths, absorption modes, contact between the sensor and soil samples, as well as the peak interference and the perdition model were the main factors that affected the assessment of soil properties.

Keywords: Diffuse reflected spectroscopy (DRF), the attenuated total reflectance spectroscopy (ATR) and Fourier transform infrared photoacoustic spectroscopy (PAS), soil properties

Financial support: The work was supported by the National Natural Science Foundation of China (41401256), the National Key Basic

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(2022 - 964) New frontiers in soil conservation and landscape management: Geospatial Cyberinfrastructure applied to Decision Support System

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This work aims to present results from the use of Geospatial Decision Support (DSS) tools (LANDSUPPORT H2020 project) aiming to both the best multiscale soil conservation and land management and also to an easy landscape implementation of some important agro-environmental regulation (e.g. EU directives). The background behind these applications refers to the evidence that some agriculture and environmental directives/regulation have an intrinsic complexity because they apply to soils and landscapes which have the well recognized “multiple functions” and dynamic behavior as a fundamental features. Then these DSS tools requires, as fundamental feature, to include and mix many different high qualities both static and dynamic digital information, engine and processing in order to be successfully applied. The presented tool has been developed in the framework of a “Web-based Spatial Decision Supporting System” and it will consider soil and landscape. Decision makers (individuals, groups of interests and public bodies) can have real-time (or near real-time) access to critical, accurate, complete and up-to-date spatial data held in multiple data stores. The system produces detailed spatial documents, report and maps on a series of questions including agriculture, environment and climate change. The tool is available to and it will also allow to integrate classical top-down decision with bottom-up contributions to landscape planning and managing. The tool, as prototype, is under development in Italy, Hungary, Austria and in an additional case study in Tunisia but its development will enable future applications in other areas. Among the several topics having a different level of complexity and already implemented in the DSS, we will show those concerning soil sealing and viticulture zoning (terroir). Emphasis will be on how combining digital soil databases, advanced digital soil mapping procedures (e.g. neural network analysis), physical-based modelling (i.e. soil-vegetation-atmosphere water balance to calculate crop water stress indexes) and land assessment. Finally, the high qualified tools (still under construction) and their main technical/scientific constraints, as those referring to the near real-time management of typical crops, will be discussed. We believe that this work shows that web based Spatial Decision Supporting System must become a priority in future research to make soil science playing a larger role in landscape management and conservation.

Keywords: Decision Support Systems Land management

Financial support:

(1048 - 1816) Review and update of the program AGROZAM digital platform v1.0 to capture information of agricultural land, Zamorano, Honduras

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The Panamerican Agricultural School, Zamorano one of the leading college in Latin-American agriculture. In order to improve its resource management and decision making in agriculture fields, the program and platform AGROZAM v1.0 were revised and updated. Production lot were updated and assigned responsibility for each production zone and lots. Areas for the registration of inputs (fertilizers, pest control, diseases and weeds) were created and additional soil information was integrated (soil analysis and fertilization programs). Change of nomenclature was made once the land boundaries in Google Earth were defined. Information was compiled and integrated in Excel 2013 of soil analysis (2007-2016) and fertilization programs (2015-2016) of characterized lots. The platform was updated with SQL SERVER 2012 (database), Visual Studio 2015 (structure) and DotNetNuke (design) programs. This database contains information of conservation, analysis and use of soils, crops, use of inputs from production lots of the Panamerican Agricultural School, Zamorano. Information is displayed from the Zamorano employee portal through tables, windows and reports. It allows the creation of new log sheets and history in date ranges. The source of information were documents of graduation projects, field records provided by the learning and production units, Land and Water Management, Department of Science and Agricultural Production. AGROZAM v1.1 facilitates the storage and recording of information for decision-making.

Keywords: Database, inputs, resource management, software, soils.

Financial support:

(2265 - 2181) Soil quality evaluation in the land-use agroecological monitoring systems for smart farming development at the Central Region of Russia

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Russia is one of boreal regions in the world with Global Climate changes’ benefit from temperature warming due to an increasing of growing season length and generally more mild climate conditions, including predicted enhancement of precipitation. Characteristic for the RF southern taiga zone in first decades of XXI century accelerated annual temperature growth is almost in 3 times higher than mean planetary one. Together with essentially increased precipitation values this resulted in 2 record years for grain crops total harvest in 2016 and 2017. Grain export growth and more favorable agro-climate conditions gradually improve RF farming profitability and sustainability. Growing RF agricultural potential strengthens due to arable land area increasing by using the previously abandoned farms – especially in the Central Russia with increased population density. However, despite these favorable circumstances the further sustainable development of Russian agriculture will be possible only with urgent improvement of its modern scientific basics including soil quality evaluation in the land-use agroecological monitoring systems for smart farming development. Climate-smart agricultural land-use design takes into attention the traditional and new crop varieties, intensive and organic farming systems with flexible agro-technologies application – best adapted to local soil cover agroecological conditions. Actively developed for land-use at the Central Region of Russia the Regional automated system of land agroecological evaluation RASLAE: (i) reflects soil zonal and provincial features and functional; (ii) allows evaluate soil integral functional and environmental quality even in case of heterogeneous plots; (iii)identifies and quantifies the limiting agroecological factors and their principal parameters in case of concrete soil cover patterns and farms; (iv) conducts agroecological computer simulation, search and target prediction of soil quality changes and agroecological problems solution; (v) improves the effectiveness of land-use decision making – by agroecological system analysis and comparison of the various scenarios of their inputs, outcomes and consequences. After RASLAE localization in the concrete region conditions, it’s application in the local land-use agroecological monitoring system with crops production simulation and land-use efficiency assessment allows essentially improve the current agriculture through the implementation of best farming practices.

Keywords: Soil quality; land agroecological evaluation; agroecological monitoring systems; smart farming; Central Russia.

Financial support: This research has been done with particular support by the RF President grants for the leading scientific school # NSh-10347.2016.11.

(3035 - 1346) What key parameters should we access in agrosoil to increase crop productivity?

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To tackle the increasing challenges of agricultural production, the agricultural ecosystems need to become smarter and improving their productivity. Several issues fascinating on this way include i) soil variability within fields; ii) complexity of soil quality indicators, and iii) big data analyzing. The plausible way to solve at least part of this problems is to provide large-scale and replicated ecological experiments. The pilot study was conducted at the European part of Russia (Kursk region) and the crucial indicators of soil quality which are influenced on crop productivity have been investigated. The field experiment includes 3 cropping systems (winter wheat, wheat, beet). Variety properties in soil samples such as porosity, water retention, organic matter content, pH, soil nutrients availability, microbial community structure and soil enzymes activity were measured. For analysis of relationships between key soil parameters and crop yields, we utilize modern clustering methods and reinforcement learning techniques. Our results revealed substantial spatial heterogeneity among basic soil chemical properties within the fields. Notwithstanding, only several factors provide marked influence on yields among all tested parameters, and they were connected mainly with soil physical properties. It's interesting to note, that soil microbial community structure was mainly associated with cropping system than with chemical or physical soil parameters. Finally, we identifying a set of soil properties, which are relevant for hot-spot monitoring for these agro-important ecosystems.
Keywords: Big data analysis, Agriculture, Soil quality
Financial support:

C3.2 - Soil and Water Conservation

C3.2.1 - Managing and remediating floodplain and wetland soils

(6167 - 2872) Application of microwave and optical remote sensing data for monitoring wetland agriculture

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This paper presents case studies related to remote sensing (RS) applications for monitoring agricultural activities in different types of wetlands located in Hungary, Rwanda and Afghanistan using Sentinel-1 Synthetic Aperture Radar (SAR), Sentinel-2 and Landsat 8 optical RS data. The objective of the Hungarian case study is the monitoring of the presence and crop growth affecting effect of perched water on agricultural fields in one of the wetlands of the Danube valley. The study focuses on the delineation of agricultural plots affected by the regular presence of excess water, on the morphological characteristics of the hydromorphic soils and on the temporal pattern of crop growth on the studied sites. The results serve the base of a perched water monitoring system, and contribute to the development of more effective crop planning scenarios in order to avoid crop failure due to the excess water and the often related drought. The Rwandan case study focuses on the retrieval of phenological indicators related to paddy rice management and rice plant development from the series of SAR data. Based on time-series analysis the start, middle, end, length of season and the seasonal backscatter amplitude was determined for four paddy rice growing sites in the Southern Province. The results show that there is a considerable difference in the temporal and spatial distribution of investigated phenological indicators which reflect the need of harmonization of agricultural activities in order to achieve a more effective and sustainable irrigation water and labor force management in the already endangered marshlands. The Afghanistan case study aims the monitoring of the patterns of agricultural activities on the arable fields surrounding Mazari Sharif, Balh Province. Multi-year time series analysis was applied to extract information on the temporal and spatial patterns of crop rotations and irrigation water management. Based on the results indicating considerable spatial heterogeneity in cropping patterns, following a more conscious planning procedure might avoid the often reported crop failure due to water shortage, and the overexploitation of natural resources. These case studies confirm that remote sensing techniques can contribute to the more effective and sustainable wetland management and conservation.
Keywords: Wetlands, Remote Sensing, Time-series analysis, Rwanda, Afghanistan, Hungary
Financial support: ESA TigerBridge Africa; EFOP-3.6.1-16-2016-0016 (Evaluations of Human Development Programmes)

(6675 - 1606) Biodegradation of hydrocarbons under methanogenic conditions in different oil sands tailings

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Vast oil sands activities in northern Alberta, Canada, generate huge volumes of fluid tailings during bitumen extraction from oil sands ores. Tailings are deposited in tailings ponds that presently contain >1 billion m^3 of fluid fine tailings and cover a total area of ~185 km^2. The established tailings ponds emit greenhouse gases (methane; CH_4 and carbon dioxide; CO_2) produced during methanogenesis. The hydrocarbons, components of the unrecovered extraction solvent such as naphtha in tailings, sustain methanogenesis in tailings ponds. We investigated biodegradation of naphtha (complex mixture of *n*-, *iso*- and *cyclo*-alkanes and monoaromatics, primarily in the range of C_6-C_{10}) used by different operators by conducting a long-term experiment (~1600 days) simulating oil sands tailings pond conditions. Mature fine tailings (MFT) retrieved from tailings ponds of two different oil sands operators were amended with naphtha (0.2% similar to the concentration present in tailings ponds) to examine the ability of indigenous microbial communities to biodegrade hydrocarbons in naphtha under methanogenic conditions. Gas chromatographic analyses were performed to monitor hydrocarbon biodegradation and CH_4 production in the microcosms during incubation. MFT samples were retrieved from the microcosms periodically to perform pyrosequencing of 16S rRNA genes for microbial characterization. Indigenous microorganisms in MFT started biodegrading naphtha to CH_4 after a lag phse of 100 d and preferentially biodegrade *n*-alkanes over *iso*-alkanes. Complete biodegradation of all *n*-alkanes, several *iso*-alkanes (2-methylpentane, 3-methylhexane, 2-, and 4-methylheptane, *iso*-octanes, *iso*-nonanes and 2-methylnonane) and a few *cyclo*-alkanes was observed during the incubation. 16S rRNA gene pyrosequencing showed dominance of *Anaerolineaceae* and *Methanosaetaceae* during initial stage and *Peptococcaceae* and "*Candidatus* Methanoregula" during later stage of naphtha biodegradation. The results advance our knowledge and extend known range of hydrocarbons susceptible to methanogenic biodegradation in petroleum impacted anaerobic environments.The results are important for refining existing kinetic model to predict greenhouse gas emissions from tailings ponds.
Keywords: Hydrocarbons, oil sands tailings, methanogenesis, GHG emissions, tailings ponds, microbial communities
Financial support:

(8955 - 1501) Preliminary screening of the affected riparian areas of the *Gualaxo do Norte* river by the Samarco's mine dam burst using pXRF

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On November 5, 2015, the *Fundão* tailings dam collapsed and released more than 50 million m^3 of iron mine waste into the *Rio Doce* basin system in Southeast Brazil. *Gualaxo do Norte*, *Carmo* and *Doce* were, in this sequence, the most impacted rivers. The mud was spread across approximately 15 km^2 of the flood plain of these rivers. This study aimed to provide a preliminary evaluation of the impacts of the mud deposition on soils of the *Gualaxo do Norte* floodplain, which was the first and most affected area. We collected soil samples in 23 locations across the entire affected section of this river. At each point, samples were collected at 0-20 cm soil depth in different locations as follows: affected areas that have received an emergency intervention; affected areas without any intervention; and unaffected areas that were used as reference. An initial screening of these samples was performed with a portable X-ray Fluorescence spectrometer (pXRF). We used principal components analysis (PCA) to assess pXRF data and visualize differences between samples. Iron (Fe) was the most abundant element observed in samples. Overall, Fe concentrations were around 1.6-fold higher in affected samples than in the reference. Manganese (Mn) was also higher (2.3-fold) in affected samples. On the other hand, reference samples presented ~ 3-fold higher Aluminum (Al) concentration than the affected ones. Some other potentially toxic elements presented lower magnitude variations between impacted and unimpacted samples. PCA results demonstrated a clear separation from affect and unaffected samples. Fe and Al (mainly Fe) were the elements that driven most this separation, explaining about 37 % of the variation among samples. Affected samples with and without emergency intervention did not present an expressive variation in the concentration of the elements detected neither could be distinguished through PCA. This study provides preliminary information for the long-term monitoring that should be performed in the impacted areas. The observed variations and the clear separation of impacted and unimpacted samples suggest the need for further risk assessment using standard methods and a complete survey through the impacted areas in the *Rio Doce* basin.

Keywords: Mariana mining disaster; Portable X-ray Fluorescence spectrometry; Soil contamination.

Financial support: FAPEMIG; CAPES

(9415 - 373) Release of trace elements from a serpentine soil controlled by oxidation-reduction cycles with a microcosm system

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Serpentine soils are characterized with high concentrations of geogenic trace elements (TE). Although the TEs are mainly bound in the mineral frameworks, they could be released into liquid phases through oxidation-reduction cycles and further pose potential risks to the environment and human health. The objectives of this study were to measure dissolved Cr, Ni, and Co under a continuous range of pre-defined redox conditions as well as how major soil properties regulate the dynamics of the TEs, and to provide critical information on potential risk of TEs released from serpentine soil. An automated biogeochemical microcosm (MC) system was used to simulate flooding condition in the soil, which equipped with an automatic-valve gas regulation system control of Eh by adding nitrogen or oxygen gas. The MC was filled with 300 g soil sample from Taiwan mixed with 6 g straw powder and ultrapure water in 1:8 for incubation with 4 weeks. To simulate the alternative wet/dry cycles of paddy soils during rice growth, the Eh of slurry was set from 200 mV to -200 mV, and then returned to 250 mV. TEs and dissolved organic carbon (DOC) were measured in the supernatant from slurry. The experimental results indicated that the temporal course of Eh and pH in the MCs revealed converse trends in the soil. DOC increased along with straw breakdown and further complexed with Fe, Mn, Cr, Ni, and Co, and thus the soluble TEs became higher. Cr mainly existed as Cr(III) oxides in the soil and thus the concentration of soluble Cr was very low and dependent on redox change. Soluble Co increased with Ni, indicating that Co and Ni were both controlled by redox process because of their similar ionic diameters and the same adsorptive sites on soil colloid surfaces. The release of Cr was very low, but it increased with DOC as well as Ni and Co. These findings were important to control the soil quality and paddy rice production at serpentine sites in the world.

Keywords: paddy rice; trace element; serpentine soil; wetland

Financial support: Ministry of Science and Technology, Taiwan under Contract No. MOST 105-2313-B-002-009-MY3.

C3.2.2 - Soil management in organic production and agroecology

(9793 - 2000) Biomarkers in *Allium cepa L.* for the assessment of soil toxicity under organic and conventional management

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Organic production has rapidly increased as a sustainable alternative for food security and soil conservation. Organic farming systems reduce soil pollutants such as heavy metals and agrochemicals, which usually occur in conventional agriculture. Nevertheless, there are few indicators to evaluate soil toxicity and agricultural management. *Allium cepa* L. is a sensitive model used in toxicological research. Chromosomal aberrations, DNA damages, micronucleus and disturbances in mitotic cycle are common endpoints to evaluate mutagenicity, genotoxicity and cytotoxicity in environmental samples. The aim of this research was to assess the cellular biomarkers in *Allium cepa* L. cultivated in both organic and conventional management in an intensive agricultural region of Colombia. The mitotic index and different types of chromosomal abnormalities were compared through microscopic analysis of root tips. The mitotic index of the *Allium cepa* L. grown in conventional management (3.96±0.88%) was statistically lower than those observed in organic (12.36±2.25%) and transition sites (14.97±2.97%). Chromosomal aberrations and nuclear abnormalities were not observed in the samples from the organic crop. Conventional and transitional cultures presented chromosomal aberrations in frequencies of 0.078±0.07% and 0.11±0.08%, respectively. Nuclear abnormalities were higher in the samples of conventional management (0.079±0.01%) in comparison to samples from transition cultures (0.021±0.02%). The microscopic evaluation of root tips of *Allium cepa* L. allows the identification of cellular alterations associated with the type of crop, offering potential biomarkers for soil health monitoring and agricultural management.

Keywords: Organic agriculture, biomarkers, soil toxicity, *Allium cepa L.*

Financial support: This research was supported by the National Fund for Science, Technology and Innovation "Francisco Jose de Caldas" of Colombia, the National Program for Doctoral Formation (COLCIENCIAS, 727-2015) and University of Cartagena.

(8236 - 2970) Managing indigenous arbuscular mycorrhizal fungi to benefit field crops in sustainable production systems.

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Arbuscular mycorrhizal fungi (AMF) provide macro and micronutrients to their host plants, protect them from biotic and abiotic stresses, improve the quality of soil for their root systems and influence biodiversity of plants in the same ecosystem. Maximum benefit is associated with rapid colonisation of the host, which is most readily achieved if extraradical mycelium (ERM) is the dominant propagule. Minimizing soil disturbance can help maintain ERM intact. However, our knowledge of functional diversity within ERM is limited, so ensuring that the most effective strains of AMF will be those colonizing a new crop is essential. Experiments investigating Mn toxicity and Fusarium oxysporum f.sp. radicis-lycopersici as stressors suggest ways to determine the assemblage of strains that will colonize new host plants and provide the necessary protection. Under manganese (Mn) toxicity, the presence of intact ERM enhanced arbuscular colonization 21 days after planting (DAP) by 1.8 and 3.3 times in wheat and subclover, respectively, relative to other type of AMF propagule. Shoot growth of both crops more than doubled and was significantly correlated with a reduction in the Mn concentration of shoots of wheat and in the roots of sub-clover. If the plant establishing the intact ERM was a member of the Fabeacea shoot growth was almost double that of a plant colonized by ERM formed by a host from the Poaceae, although there were no differences in AMF colonization or in plant manganese concentrations. The AMF assemblage selected in association with the first plant colonised the roots of the second plant in the succession when the ERM was kept intact, whatever the combination of plant families and despite host-AMF preferences. In the field, barley was used to develop intact ERM and tomato plugs were planted into soil, which contained F. oxysporum that had reduced yields by 20 tha-1 in the previous season. Compared with the crop that did not have the agronomy directed towards optimizing AMF protection, yields were 30% greater and plant mortality was 17% less. The presence of an intact ERM also induced better growth of tomato plants (3.2 times at 21 DAP) after infection with Fusarium oxysporum (109 conidia/plant). The key parts of any strategy to manage AMF diversity in a field is to maintain high levels of inoculum through crop sequences, either in a rotation or with cover crops, and to minimise soil disturbance so that ERM can be maintained from one crop to another.

Keywords: Biodiversity, biotic and abiotic stresses, soil disturbance, reduced tillage, preferential parterships

Financial support: Foundation for Science and Technology (FCT), Project nº FCOMP-01-0124-FEDER-014139 (FCT-PTDC/AGR-PRO/111896/2009), and InAlentejo Project ALENT-07-0262-FEDER-001871.

(4029 - 1124) Monitoring of long-term (8 years) effect of composted sewage sludge application on zinc in agricultural soil and evaluation of the plant availability of zinc in the applied compost

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In Japan, some regions use compost made by dehydrated sewage sludge and straw (composted sewage sludge, CSS) to maintain soil nutrients and organic matter amounts. From 1997, in Abashiri City, Hokkaido (N 44°, E 144°), some farmers use typically about 30-40 Mg ha^{-1} of compost which contain 10-50% of CSS every three years, which contain remarkable amount of Zn (65-740 mg Zn kg^{-1}). Therefore, the application of CSS on soil Zn and its availability to plants have been monitored. Five different upland fields (One Cambisol and four Andosols) were selected as monitoring fields. From 2010 to 2017, 0-80 cm depth of soil had been sampled for every 20cm of depth from each field. In these field, typical crops are wheat, barley, potato, and sugar beet, in the monitoring period, 30-40 Mg/ha of compost with CSS have been applied 2-3 times. Soil general chemical properties, total Zn (T-Zn) and 0.1 N HCl extractable Zn (HCl-Zn) had been measured. For these soils, pH ranged between 5.3-6.8, T-Zn ranged between 50-140 mg Zn, and HCl-Zn ranged between 1-12 mg Zn. Add to this, the plant availability of Zn in the CSS was evaluated by pot cultivation experiment. Komatsuna plant (*Brassica rapa var. perviridis*) have been cultivated for one month with 250 g of soil (Cambisol; pH 5.7; 39 mg T-Zn/kg; 0.05 mg HCl-Zn/kg) mixed with 0, 6.8, and 11.3 g of CSS (correspond to 30 or 50 Mg CS /ha). The CSS fermented for one week (755 mg Zn/kg) or 6 months (735 mg Zn/kg) were used. Then the Zn content and uptake of the plants, soil total and 0.1 N HCl extractable Zn have been measured after cultivation. As a result, for all observed fields, soil total Zn content remarkably increased immediately after the compost application from 60-100 mg Zn/kg to 80-140 mg Zn. The increased Zn level was sometimes beyond the index value of contamination (120 mg Zn/kg) of Japan. However the increased Zn value tended to be decreased to be below the index value after 1-2 years of application. The results of pot study showed clear increase of 0.1 N HCl extractable Zn and plant Zn uptake with the application rate of CSS but soil total Zn did not changed with CSS application clearly. Thus the 0.1 N HCl extractable Zn should be the good indicator for Zn availability. Although their Zn contents were mostly the same, the Zn uptake by plant was higher for six months fermented CSS than one week fermented one. It should be due to the decomposition rate of these composts.

Keywords: Compost; Zinc; Sewage sludge; Availability

Financial support: Waste Management Center, Abashiri City

(1991 - 1145) Reduced tillage practices decrease soil erosion in organic farming systems

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Soil erosion is of major concern in many parts of the world, impairing plant productivity and leading to soil degradation. Several long-term field trials showed that the use of low input strategies such as organic farming instead of conventional farming leads to considerable changes in soil characteristics. Organic farming increases top soil organic matter content compared to conventional farming. Soil surfaces are protected more efficiently against particle detachment and overland flow due to a continuous surface cover and a well-developed root system increases soil structure stability. Stability and aggregation are further improved by conservation tillage systems, which likewise provide a protecting cover from previous year's residue. While it is widely acknowledged that conservation tillage can reduce soil erosion, it is still unclear how conservation tillage under conventional conditions compares to tilled organic systems. Thus, in-situ research with different tillage treatments is important to evaluate and potentially improve soil erosion control in organic farming. This study investigated rainfall induced soil losses in the Swiss FArming System and Tillage experiment (FAST, Agroscope) with four different production systems: (1) organic farming-intensive tillage, (2) organic farming-reduced tillage, (3) conventional farming-intensive tillage and (4) conventional farming-no tillage. A rainfall simulator was used with micro-scale runoff plots in a randomised and replicated field experiment in 2014 (no cover crop) and 2017 (maize). Organic farming decreased soil losses compared to conventional farming by 54 %. In 2014, the combination of organic farming and reduced tillage showed lowest sediment delivery, whereas intensively tilled conventional plots showed highest rates. Intensively tilled organic and no tillage

conventional treatments had similar soil losses. In 2017, no tillage conventional treatments showed lowest sediment delivery, but comparable rates to 2014, whereas sediment delivery in organic farming with reduced tillage was slightly higher. This difference is mostly due to weed infestation in organic treatments in 2014 attributed to the absence of herbicides. Both intensively tilled treatments showed highest soil losses. Soil surface cover and soil aggregation were the best predictors for reduced soil erosion rates. In conclusion, this study showed that the combination of organic farming with reduced tillage drastically reduces soil erosion.

Keywords: Soil erosion, organic farming, tillage system, rainfall simulation, runoff plots

Financial support:

(1441 - 1152) Soil Basal Respiration of soils cultivated with Agroforestries and Horticulture in Atlantic Forest Biome

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Soil basal respiration (BR) is a biological indicator to assess changes in soil quality. It is defined as the steady rate of respiration in soil, which originates from the mineralization of organic matter and may be estimated on the basis of CO_2 evolution. Therefore, this study aimed to assess basal respiration of soils cultivated with agroforestries and horticulture in relation to native vegetation. Soils were sampled from late December 2017 to early January 2018 in an ecosystem inside the Atlantic Forest biome located on the coast of the Brazilian state of Paraná. Soils of the study sites are Cambisols and were sampled at 0.00 – 0.25 m depth. Four areas were sampled: 11 and 7 years old agroforestries, horticultural field of *Solanum melongena* and Atlantic Forest (native vegetation). Both agroforestries were agroecological farming with rows composed of a range of fruit and timber trees and horticultural crops between trees rows. Samples were taken on both tree rows and between rows plots. The horticultural field was conventionally farming. BR was determined by incubating the soil in the dark at 25 ^{o}C within sealed incubation vessels along with 10 mL of 0.5 M NaOH. The C-CO_2 evolved was measured at 168 h by adding $BaCl_2$ and subsequently titrating with 0.1 M HCl. The average BR for the 11 and 7 years old agroforestries were 0.256 and 0.438 mg C-CO_2 kg^{-1} soil h^{-1}, respectively. BRs were higher in tree rows than between rows (horticultural beds) for both fields. The horticultural crops grown between rows in agroforestries are often tilled, which may expose more carbon to oxidation and reduce the carbon source to microbes, resulting in lower respiration rates. Horticultural and Atlantic Forestry BRs were 0.309 and 0.442 mg C-CO_2 kg^{-1} soil h^{-1}, respectively. These results confirm the significant contribution of long-term agroforestry farming, as the BR in the 11 years old agroforestry was closer to the native vegetation than to conventional farming. Higher plant biodiversity and litter inputs in the 11 years old agroforestry have probably contributed to a broader carbon source, which stimulated the soil microbial activity and led to higher basal respiration in relation to conventional horticulture farming. This work strengthened the advantages of agroecological farming through agroforestries as it promotes soil biology development of Brazilian Cambisols.

Keywords: ecology indicator, agroecology, soil microbes.

Financial support: National Council for Scientific and Technological Development (CNPq).

(6614 - 2164) Use of recycled paper mulch in letucce production

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Use of organic mulches is one of the suitable methods used to keep soil temperature and humidity, besides reducing the incidence of weeds and consequently herbicide application. Among the organic material to cover the soil such formerly living material, has the possibility the use of recycled paper mulch that is more environmentally friendly to polyethylene, which can cause environmental impact. This study aimed to evaluate the potential use of recycled paper mulch in weed control, soil temperature, water consumption and efficiency of water use and lettuce yield (*Lactuca sativa L.).*, The field experiment was conducted in the city of Viçosa, state of Minas Gerais, Brazil (20º45' S; 42º50' O; altitude 640 m) during January and February, 2017. The experiment was conducted in a completely randomized design with four treatments and five repetitions. The treatments were the soil covered with recycled paper (131 g/m^2), black polyethylene, and the uncovered soil with weed control and no weed control. Soil temperature was measured at 5 cm depth during the crop cycle. The density and dry matter of weeds were evaluated at 18 and 30 days after transplanting, lettuce yield and water consumption and efficiency (liters of water per kg of lettuce). The data were submitted to analysis of variance and the averages were compared by the tukey test at 5% probability. The recycled paper and polyethylene were equally efficient in weed control. Higher lettuce yield was verified in the treatment with recycled paper an increase of 15 and 28% in relation to the polyethylene film and the treatment uncovered soil with weed control, and also reduced the soil temperature in 8.2 and 2.1 ºC respectively. The recycled papers reduced water consumption in 27% and improve the efficiency of water use in relation to the other treatments. We concluded that recycled paper mulch is an efficient strategy in weed control, reduction soil temperature and water consumption, and increase the efficiency of water use in lettuce production, in an environmentally correct form, and can be used in organic production systems.

Keywords: organic mulch; water save; weed control; temperature range; Lactuca Sativa L.

Financial support: Universidade Federal de Viçosa

(4247 - 483) Evaluation of bio-intensive complimentary cropping systems under different planting methods and recycling of crop residues under rainfed organic agriculture

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Globally, there is growing awareness of the adverse impact of chemical inputs on soil environment and human health. This has prompted both developed and developing countries to shift towards organic agriculture and organic food production. In India, farmers are adopting different crops and cropping systems in rainfed and irrigated ecosystems. Selection of suitable crops and cropping systems in rain-fed organic agriculture (OA) with appropriate method of planting and recycling of crop residues (RCR) for increased and sustainable crop yields and good soil health is assuming greater importance in present day agriculture. In this context, a long term field experiment in fixed site was conducted to evaluate bio-intensive complimentary cropping

systems under rainfed organic production system during three consecutive years (2013-14, 2014-15 and 2015-16). In the present study, performance of soybean-wheat sequence (S-WSC), groundnut + cotton (2:1) inter (G+CIC), mungbean-sorghum sequence (M-SSC) and soybean + pigeonpea (2:1) inter (S+PIC)-cropping systems under different planting methods [Broad bed and furrow (BBF) and flat bed (FB)] with or without RCR were studied. Experimental plots received organic amendments with respect to nutrients (farmyard manure, enriched compost, vermicompost in 1/3 rd proportion equivalent to 100 % N and 100 % P_2O_5 for cereals and legumes, respectively) since 2004. Lopping of gliricidia, and leucaena; and crop residues from different component crops in the cropping systems were used as mulch/recycling. Bio-fertilizers (*Rhizobium*, *Azospirilium* and phosphate solubilizing bacteria), foliar spray of cow urine and vermi-wash @ 5 % were also used. Neem cake, bio-insecticide and bio-fungicide/bactericides were used for insect-pest and diseases management. Rainfall received during the total crop growth periods of S-WSC, G+CIC, M-SSC and S+PIC in 2013-14, 2014-15 and 2015-16 was 539.8, 537.6, 543.0 and 534.6 mm; 658.0, 763.0, 658.0 and 658.0 mm, and 368.2, 347.0, 347.0 and 367.8 mm, respectively. Results indicated that BBF and FB with RCR found beneficial over BBF and FB without RCR. RCR of component crops as a mulch and recycling of component crops residues of preceding year to succeeding season found beneficial in improving soil properties with decreased bulk density; and increased soil moisture holding capacity and increased available N, P and S. Among the different complimentary cropping systems, G+CIC system found more sustainable in OA.

Keywords: Keywords: Bio-intensive complimentary cropping; organic agriculture; intercropping; sequence cropping, broad bed and furrow (BBF); flat bed (FB); recycling of crop residues (RCR).

Financial support: Financial Support: ICAR-Network Project on Organic Farming, ICAR-Indian Institute of Farming System Research (IIFSR), Modipuram, Meerut 250 110 (Uttar Pradesh), India.

C3.2.3 - Artificial drainage systems: maintaining soil functions and protecting water resources

(1565 - 1013) Efficiency of surface drainage systems in the reduction of water erosion on graveled forest roads

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Forest roads are infrastructure works that cause high environmental impacts in areas of forest production, especially those related to soil erosion. Such impacts can be mitigated by the appropriate design of the surface drainage system. The objective of this work was to evaluate the efficiency of three surface drainage systems in the control of water and sediment losses due to water erosion, in sections of graveled forest roads, located in the Planalto Sul Catarinense, during a period of one year. The forest road has the main use as a feature, with seven meters of medium width and bed covered with 10 cm layer of compacted sedimentary gravel. The drainage systems (treatments) evaluated were: water outlets 30 m equidistant with a ridge in the center of the plot associated with a “bigode” (S30 + CB) (ii) 20 m equidistant water outlets associated with a “bigode” 60 m equidistant (S20 + B); and, iii) system without drainage works (TEST). For each treatment were installed plots with a dimensions of 70 m in length towards the slope and half the width of the road. To evaluate the losses of sediment (LS) and water (WL), a collection system was implanted at the lower end of each plot, composed of three tanks with a 500 L capacity each, the first and the second provided with a spillway with 13 windows. The accumulated rainfall during the evaluation period was 1,892 mm. The results showed that the most efficient treatment in the control of Water Loss was S20 + B followed by S30 + CB, with efficiency of 98.5% (10.5 mm year^{-1}) and 98% (13.9 mm year^{-1}). The system that presented the highest Water Loss was the system without drainage infrastructure (TEST) as expected, with an accumulation of 687 mm year^{-1}. In the same way, the drainage system without infrastructure (TEST) presented the highest Sediment Loss, with an accumulation of 17,424.84 kg km^{-1} year^{-1}. The treatment with runoff capture systems (S30 + CB and S20 + B systems) controlled the Sediment Loss in 98.7% and 99.7%, when compared to the system without infrastructures (TEST). These systems presented total Sediment Loss of 225 kg km^{-1} year^{-1} and 57 kg km^{-1} year^{-1}, respectively, proving to be efficient in the control of water erosion. The results of this work demonstrate the importance of using drainage infrastructures to reduce water erosion on forest roads.

Keywords: sediment production; water losses; main road.

Financial support: Klabin S.A.; CAPES.

C3.2.4 - Nutrient and contaminant transport in drained soils

(6061 - 1052) Effect of organic matter amendments on nitrate leaching losses from livestock urine

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We tested the hypothesis that incorporation of Carbon-Rich Organic Matter Amendments (CROMA) into bare soil after winter forage grazing would immobilise urinary-nitrogen (N) and thus reduce nitrate (NO_3^-) leaching losses, in Canterbury, New Zealand. In mid-winter (July 2016), 32 intact soil monolith lysimeters (500 mm diameter and 700 mm deep) received cow urine at the equivalent rate of 300 kg N ha^{-1}, and one of the following CROMA treatments: (i) no CROMA (control), (ii) three rates of barley straw [2, 4 or 8 t carbon (C) ha^{-1}; C/N ratio of 66:1], (iii) two rates of separated dairy effluent solids (2 or 4 t C ha^{-1} C/N ratio of 31:1) or (iv) two rates of spent woodchip bedding material (2 or 4 t C ha^{-1}; C/N ratio of 29:1). Leaching was measured for a period of 99 days after treatment (250 mm of leachate collected). Across all treatments, 98–99% of the N leached was in the form of NO_3^--N. Barley straw was most effective in reducing NO_3^--N leaching losses (up to 25% reduction compared to the control treatment). Incorporation of effluent solids resulted in a small, but significant, immobilisation of urine N, while spent woodchip bedding was ineffective at reducing NO_3^- leaching losses. These findings provide proof of concept that CROMA materials could be incorporated to reduce the impact of winter grazing on water quality outcomes.

Keywords: Nitrogen immobilisation; nitrate leaching; winter grazing; *Beta vulgaris* L.; cow urine

Financial support:

(4606 - 1569) Evaluation of total and soluble phosphorus concentrations in the Arroio Lajeado Ferreira catchment during a rainfall event

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The increase in population results in the attenuation of pressure exerted on the environment, consequently leading to intensive agriculture that results in inadequate soil management and use of

techniques involving the application of fertilizers at large scale, thus contributing to degradation and soil erosion. The essential elements for the growth and development of plants, such as phosphorus, when in excess in view of unsustainable management, are leached together with surface runoff, reaching bodies of water and hindering their quality, which consequently accelerates eutrophication of the area by allowing an excessive growth of the aquatic biota. Therefore, it is pivotal to identify the areas impacted by erosion in order to monitor and plan sustainable techniques. The present study had the aim of verifying the amount of total and soluble phosphorus present in the water of a small rural catchment during a pluviometric event of 97 mm. With an area of 1.24 km², the Arroio Lajeado Ferreira catchment is located in the municipality of Arvorezinha - RS. It is an area with steep slopes and predominance of intensive agricultural crops. By means of the results obtained, it was possible to observe an increase in phosphorus with peaks of flow and suspended sediment concentration (SSC). The SSC during the event ranged from 29.1 mg/l to 3.791.2 mg/l, while total phosphorus concentrations varied from 0 to 2.85 mg/l and soluble phosphorus from 0 to 0.05 mg/l. Total phosphorus concentration during the event in the catchment had a mean of 0.59 mg/l above 0.15 mg/l, which is the maximum value allowed by CONAMA Resolution No. 357 for Class 3 surface waters for lotic environments. These results indicate the contribution of high sediment concentration in the course of the water during the event, reflecting the condition of high susceptibility to erosion due to inadequate soil use and management conditions in the studied area. Thus, the present study alerts to the need for monitoring allied to sustainable soil practices while avoiding excessive entry of nutrients, such as phosphorus, that impact water quality and limit its uses.

Keywords: total and soluble phosphorus, erosion, intensive agriculture
Financial support:

(7840 - 1748) Increase of land slope or pig slurry rate rises phosphorus losses by runoff

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Phosphorus (P) losses from agricultural areas to the environment can lead to the eutrophication of water bodies, but little is known about this process in the steepness regions of Santa Catarina state. The effect of land slope and pig slurry rates in the P losses by runoff were determined. Two field experiments were carried out, on a Nitisol with 64% of clay content (Middle West Region), and on a Cambisol with 22% of clay content (Itajaí Valley Region). Treatments included three land slope percentages (10, 20 and 30% on the Nitssol and 15, 25 and 35% on the Cambisol) and four rates of P_2O_5 (0, 110, 220 and 440 kg ha^{-1} $year^{-1}$) applied as pig slurry. Both experiments were taken in bermudagrass pastures. The experimental design was randomized blocks, arranged on slopes strips. The surface runoff samples were taken from January 2016 to August 2017, and surface runoff volume, total P, and sediments lost determined. Surface runoff, total P, and sediments losses increase with the land slope on the Nitisol, been higher under 30% than 10% of land slope, otherwise, no difference was observed throughout the slopes on the Cambisol. Substantial increases in the P loss (in grams) occurred in response to P rate, more expressively on the Nitisol (P loss = 181.423 + 3.640 * P_2O_5; R^2: 0.963) than on the Cambisol (P loss = 327.324 + 0.005 * $P_2O_5^2$; R^2: 0.715). These data indicated that markedly more P was lost through surface runoff on the Nitisol, even this soil been more adsorpitive than the Cambisol, likely because of its smaller infiltration rate. However, other paths of P loss, like leaching, were not considered in this study and may be important in the faster-drained soil. Spearman correlations between total P loss, land slope, and pig slurry rates (r: 0.354; r: 0.758; and r: 0.440; r: 0.282 to Nitisol and Cambisol, respectively) show that pig slurry rate is much more important for Cambisol than Nitisol. Else, the land slope presents similar importance between both soils. These results indicate that intrinsic characteristics of soils, like clay content, infiltration rate, and adsorption capacity may interfere with the P transfer from agricultural lands to the environment. Thus, the land slope and pig slurry rate must be taken into account in novel approaches to avoid environmental phosphorus enrichment in Santa Catarina state.

Keywords: steepness, superficial flow, animal waste, eutrophication
Financial support: CNPq 448699/2014-1 and CAPES 88887.113973/2015-00

(1716 - 1415) Phosphorus runoff losses from two land uses in the Santa Lucia River Basin, Uruguay.

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In recent years there has been in a surge of cyanobacteria blooms in Uruguayan surface waters, which was associated with an increase in nitrogen and phosphorus (P) concentrations in these water bodies. One of the most affected areas is the Santa Lucía River Basin (SLRB), the water supply source for more than 50% of the country's population. Part of this watershed is under intensive farming, and the current agricultural management practices, no-till and surface P fertilization, has led to the accumulation of labile P in the first few soil centimeters. The aim of this research was to quantify P runoff losses from two predominant land uses within the SLRB, natural grassland (NG) and cultivated pastures (CP), and how these losses change with the soluble phosphate fertilizer application rate. Runoff plots were installed in 2014 in a field under both NG and CP, and P losses were monitored under natural rainfall. In CP, several P_2O_5 rates (0, 50, 100 and 200 $kg.ha^{-1}$) were applied on the soil surface; while in NG, P was not applied. Water runoff samples were collected from 16 rainfall events; in some events soil samples were also collected at two depths (0-7.5 and 7.5-15 cm). Total P (TP) and dissolved P (DP) were determined in runoff water; Bray1-P and water-extractable P (WEP) were analyzed in soils samples. Mean DP concentrations in runoff water were higher in the CP control than in NG (0.317 vs 0.125 $mg.L^{-1}$), and the same pattern was observed in TP (0.567 vs 0.259 mgL^{-1}). In the CP fertilized treatments, DP concentrations peaked in the first two rains after P application, starting from 0.220 $mg.L^{-1}$ in the control, to a maximum of 1.615 $mg.L^{-1}$ (increase rate: 0.016 $mg.L^{-1}$ per kg of P). After these events, DP concentrations sharply decreased. Soil Bray1-P and WEP from the 0-7,5 cm layer showed a similar tendency. In CP, the cumulative DP loss from the unfertilized treatment was 0.82 kg $P.ha^{-1}$. Approximately 2% of the applied fertilizer-P was lost as DP in water runoff, reaching a maximum of 2.4 $kg.ha^{-1}$. Meanwhile, the cumulative loss of particulate P was 0.7 $kg.ha^{-1}$ and did not change with the P rate, which would be expected if the P concentration of the soil sediment did not increase with P-fertilization. These results agree with international reports that observed an association between soil surface labile-P buildup and DP increase in surface waters, which could in turn led to a surge of algal blooms, because this P form is highly bioavailable.

Keywords: Soil P, water extraction phosphorus, water quality
Financial support: Agencia Nacional de Investigación e Innovación (ANII), Uruguay; Instituto Nacional de Investigaciones Agropecuarias (INIA).

(6270 - 2057) Solid Cattle Manure Less Prone to Phosphorus Loss in Tile Drainage Water

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Forms (e.g. liquid and solid) of manure influence the risk of phosphorus (P) loss after land application. The objective of this study was to investigate the effects of P-based application of various forms of cattle manure (liquid, LCM; or solid, SCM) or inorganic P as triple superphosphate (IP) on soil P losses in tile drainage water. A four-year field experiment was conducted in a clay loam soil with a corn-soybean rotation in the Lake Erie basin. Over the four years, the dissolved reactive P (DRP) flow-weighted mean concentration (FWMC) in tile drainage water was greater under SCM fertilization than either IP or LCM fertilization. Notwithstanding its lower value on an annual basis, DRP FWMC rose dramatically immediately after LCM application. However, the differences in DRP FWMC did not result in detectable differences in DRP loads. Regarding particulate P and total P losses over the four years, they were 68 and 47%, respectively, lower in the soils amended with SCM than those with IP, whereas both values were similar between IP and LCM treatments. Overall, the P contained in solid cattle manure was less prone to P loss after land application. Accordingly, the present results can provide basis for manure storage and application best management practices designed to reduce P losses and improve crop growth.

Keywords: Phosphorus, tile drainage, aimal manure, water quality, Great Lakes, Lake Erie
Financial support: Agriculture and Agri-Food Canada

(6219 - 1213) The impact of water erosion on the organic carbon export from agricultural soil

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A declining trend in soil organic matter on Finnish agricultural lands has been discovered within the past few decades. Organic carbon (OC) is transported from soil by discharge as dissolved organic carbon (DOC) and as OC attached onto eroded soil material. The loss of OC weakens soil structure and further increases the risk of erosion. Soil tillage e.g. ploughing increases the amount of eroded material and OC in the discharge. Further, soil managements that increase the topsoil OC content may increase the annual DOC load in the discharge, but the relation between soil OC% and the annual erosion-transported OC load is not clear. Global estimates suggest that 1.9 Pg of terrestrial carbon is transported into inland waters annually. Organic carbon is an important energy source for heterotrophs, and hence it may enhance eutrophication in the receiving waters. The aims of this research are to quantify OC load transported by water erosion from agricultural field, and to study the effects of soil management on OC loss. The discharge water samples were collected during autumn and spring flows in 2015-2017 on two experimental fields on clay soil in Southern Finland (Kotkanoja and Yöni). Surface runoff and subsurface drainage were collected separately from Kotkanoja field, but from Yöni the combined discharge of both routes was collected. At Kotkanoja field, the cultivated plots had conventional ploughing and no-till managements. Yöni field had both mineral fertilization (conventional farming) and manure fertilization (organic farming), in addition to permanent grassland. The preliminary results suggest that the average annual OC loads carried by erosion material from the studied clay soil fields were c. 2-30 kg ha^{-1}. At Kotkanoja field, the loads from ploughed soil were clearly higher compared to no-till plots, as they were in subsurface drainage compared to surface runoff. At Yöni field, there was no clear trend in the erosion-transported OC load between conventional and organic farming, but the loads from grassland were lower compared to these two managements. The OC content in the erosion material from all plots was on average 3% (range 1-8%). Topsoil (0-5 cm) OC% correlated negatively with the erosion-transported OC load in the discharges of both Kotkanoja and Yöni fields.

Keywords: Soil management, discharge, erosion, organic carbon
Financial support: Nessling Foundation (no. 201500181, 201600017, 201700122), Marjatta & Eino Kolli Foundation (no. 1093), Oiva Kuusisto Foundation (2016 and 2017).

(3333 - 1642) Typical degradation parameters of base-flow water quality

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The quality of a body of water is closely related to climatic dynamics with use and management of the soil. Morphological, geological, topographic and anthropogenic actions are responsible for the spatial-temporal variability of surface and groundwater quality. Intensive agriculture of tobacco cultivation in areas of high environmental fragility tends to heighten erosive processes, which reflect the degradation of water quality due to the high concentration of elements contributed by surface runoff and sediments. The objective of this study was to identify the main parameters responsible for variations in the base-flow water quality of and, through this, infer the main sources of pollution of the hydrological catchment. The study was conducted in a 1.19 km² rural catchment located in Rio Grande do Sul State, southern Brazil. The main use of the catchment is conventional agriculture of tobacco cultivation. Water samples were collected monthly in 8 points distributed in the catchment area for 12 months. Water quality parameters were analyzed according to the Standard Methods for Examination of Water and Wastewater (APHA, 2012). Principal component analysis (PCA) was applied in order to identify the relevance of each parameter in the quality of the water. Two components were able to explain 94.28% of the total variance, with the former accounting for 67.34% and the second representing 26.94% of the total variance. With this procedure, the number of variables capable of describing water quality was reduced from 20 to 12. The variables are pH, CE, T°, turbidity, total dissolved solids, soluble P, Cu, Mg, Ca, NH_3, total coliforms and *Escherichia coli.* The main source of pollution in the catchment is associated with surface sources, including animal waste and the absence of sanitation and treatment of residential sewage. In this natural environment, the PCA technique was efficient at determining the spatio-temporal variability of water quality, since it indicates a smaller number of parameters to represent the quality of water. This is because most studies that assess water quality cover a number of costly and time-consuming parameters, resulting in lengthy and difficult to interpret data sets. In this way, efforts can be directed in a more feasible way and reduce the effects of point or diffuse pollution.

Keywords: water pollution, principal component analysis, soil use
Financial support:

C3.2.5 - Soil erosion modelling: Global Alliance

(3044 - 1134) Current and future assessments of water erosion on the Tibetan Plateau

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Soil erosion by water is accelerated by a warming climate and negatively impacts food and water security and ecological conservation. The Tibetan Plateau (TP) has experienced warming at a rate approximately twice that observed globally, and heavy precipitation events lead to an increased risk of erosion. In this study,

we assessed current erosion on the TP and predicted potential soil erosion by water in 2050. The study was conducted in three steps. During the first step, we used the Revised Universal Soil Equation (RUSLE), publicly available data, and the most recent earth observations to derive estimates of annul erosion from 2002 to 2016 on the TP at 1 km resolution. During the second step, we used a multiple linear regression (MLR) model and a set of climatic covariates to predict rainfall erosivity on the TP in 2050. The MLR was used to establish the relationship between current rainfall erosivity data and a set of current climatic and other covariates. The coefficients of the MLR were generalised with climate covariates for 2050 derived from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) models to estimate rainfall erosivity in 2050. During the third step, soil erosion by water in 2050 was predicted using rainfall erosivity in 2050 and other erosion factors. The results show that the mean annual soil erosion rate on the TP under current conditions is 8.34 t ha^{-1} y^{-1}, which is equivalent to an annual soil loss of 1,604 × 10^6 tonnes. Our 2050 projections suggested that erosion on the TP will increase to 9.73 t ha^{-1} y^{-1} and 11.60 t ha^{-1} y^{-1} under conditions represented by RCP2.6 and RCP8.5, respectively. The current assessment and future prediction of soil erosion by water on the TP should be valuable for environment protection and soil conservation in this unique region and elsewhere.

Keywords: water erosion; Tibetan Plateau; modelling; climate change; earth observation

Financial support: This study is supported by National Natural Science Foundation of China (No. 41461063, 41571339, 41661061), and the Fundamental Research Funds for the Central Universities Zhejiang

(7093 - 2407) Estimating fractional cover for hillslope erosion modeling using Landsat-8 images

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In this study, we estimated three components of fractional cover including photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), and background (BS) using Landsat 8 images for selected rangeland study areas in Australia and China. Regular field campaigns were carried out at twelve sites in NSW, Australia, and on China's Loess Plateau (Wuqi County) to collect in situ measurements of fractional cover during the period 2013-2017. More than 50 Landsat-8 images were acquired near the same time as the ground measurements. The PV was calculated based on a modified transformed vegetation index from Landsat imagery. The estimates of non-photosynthetic vegetation were poor using these indices. A soil adjusted vegetation index, the Normalized Difference Senescent Vegetation Index derived from Landsat 8 produced a reasonable relationship with NPV ground cover. Estimation of BS consequently gave a similar reasonable relationship. The results showed that PV and NPV of mixed rangeland could be estimated using Landsat-derived vegetation indices. Such estimates of fractional cover could become a critical input to more comprehensive estimation of rangeland biomass. The C-factor was subsequently calculated as a product of soil loss ratio (SLR) weighted by rainfall erosivity ratio by RUSLE definition. The SLR ratio was related to fractional vegetation cover (PV and NPV) rather than traditionally green vegetation indices (e.g. NDVI). The R-factor was estimated based on a daily rainfall erosivity model on monthly and annual basis. Time series C-factor maps have been produced on monthly and annual basis and compared with that from MODIS (or Moderate Resolution Imaging Spectroradiometer) and field measurements. This study revealed that there is great spatial and seasonal variation in C-factor values ranging from 0.001–0.03 in Australian study area, but about 10 times higher on average in China's Loess Plateau. These spatiotemporal variations were consistent with the spatiotemporal distributions of SLR and rainfall erosivity across the study areas. The technology developed in this study can be readily applicable across a wide range of areas and useful for cost-effective erosion control.

Keywords: *Fractional cover, hillslope erosion,* remote sensing, RUSLE

Financial support: Special-fund of scientific research programs of State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau (A314021403-1703).

(6933 - 1272) Global impacts of 21st century land use change on soil loss by water erosion

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Human activity and related land use change are the primary cause of accelerated soil erosion. This has substantial implications for nutrient and carbon cycling, land productivity and thus the worldwide socio-economic conditions. In this study we provide quantitative, thorough estimates of soil erosion at the global scale by means of an unprecedentedly high-resolution (250 x 250m grid), spatially distributed, RUSLE-based modelling approach. Unlike previous studies which dealt with soil erosion as a static process, here we shed light on the impacts of 21st century global land use change on soil erosion (2001-2012). The proposed geo-statistical approach, allows for the first time, the thoroughly incorporation of land use types and their changes, the extent, types, spatial distribution of global croplands, the effects of the different regional cropping systems, as well as the mitigation effects of conservation agriculture into a global soil erosion model. Our baseline model predicts an annual average potential soil erosion amount of 35 (+5.5/-2.3) Pg yr^{-1} for 2001, with an area-specific soil erosion average of 28 (+0.44/-0.19) Mg ha^{-1} yr^{-1}. In 2012, we estimated an overall increase of 2.5% in soil erosion (35.9 (+5.6/-2.4) Pg yr^{-1}), driven by spatial changes of land use. The reduction of soil erosion considering croplands under soil conservation practices in 2012 is estimated at ca. 1 Pg yr^{-1}. Combining the global soil erosion with a recent SOC map, we estimated a gross SOC displacement by soil water erosion on the order of 2.5 (+0.5/-0.3) Pg C yr^{-1}. The preservation of the soil quality and the attainment of a land degradation neutral world belong to the recently approved UN Sustainable Development Goals (SDG). Notwithstanding the significant scientific contribution of the expert based global maps created in the early 1990s such as GLASOD, a soil erosion modelling framework, based on the latest technologies , opens up new scientific perspectives to dynamically simulate alternative conservation scenarios and design more effectively future land management programmes. References Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Van Oost, K., Montanarella, L. and Panagos, P. 2017. An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications* 8, 2013. DOI:10.1038/s41467-017-02142-7

Keywords: Soil degradation; Environmental impact; Carbon cycle; Sustainability; UN-SDG

Financial support:

(7862 - 1151) Modelling structural and functional hydrological connectivity in a Mediterranean catchment by using a new aggregated index

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Hydrological (runoff and sediment) connectivity (HC) within a catchment largely depends on its morphological complexity and climatic conditions, and it is strictly related to the anthropogenic (cropland, land abandonment, settlements, infrastructures) modification of the landscape (López-Vicente and Álvarez, 2018, DOI: 10.1002/esp.4321; Persichillo et al., 2018, DOI: 10.1016/j.catena.2017.09.025). The interaction between topography and processes occurring within catchments is key to understanding dynamics of HC, both at average-year and monthly scales. Structural HC is defined as the connectivity of surface conditions that are susceptible to overland flow generation and transport, it is a principal component used to describe the hydrologic response on fragmented landscapes. And functional HC reflects how these spatial patterns interact with catchment processes to produce runoff and water transfer. In this context, the present study evaluates the influence of anthropogenic features on the values and patterns of HC in a large catchment. We achieved this goal by means of running two HC indices: (i) an updated version of the Borselli's HC index (Borselli et al., 2008, DOI: 10.1016/j.catena.2008.07.006; López-Vicente et al., 2017, DOI: 10.1016/j.geomorph.2017.05.006), and (ii) an aggregated and new HC index developed to integrate soil and climatic data with topographic and land use information. The study area is the Vero river catchment (380 km2) that is located in the Southern Pyrenees and within the Ebro river basin (Huesca province, NE Spain). The northern part of the catchment is mountainous, humid and covered with forest, whereas the southern part has hilly and gentle topography, with alluvial terraces, sub-humid conditions, and it is mainly devoted to agriculture (vineyards – DO Somontano, winter cereal, olive and almond groves). Small villages and one town (Barbastro), and many roads and trails appear along the study area. All input (e.g., LiDAR-derived DEM) and output maps were generated at 5 x 5 m of cell size. A total of 12 weather stations were used to obtain the climatic maps (test period Sep'2009-Aug'2017; 8 years). Results of structural HC of both indices were compared between them and validated with field observations of soil erosion processes, whereas the values of functional connectivity obtained with the new aggregated index were correlated with the monthly values of the Vero river flow near the outlet.

Keywords: Hydrological connectivity; aggregated index; vineyard; cover crop; soil conservation
Financial support: Spanish Ministry of Economy and Competitiveness (project number CGL2014-54877-JIN). N.B.-S is beneficiary of an IAMZ-CIHEAM fellowship.

(7113 - 3058) Potential of phosphorus fractions to trace sediment sources in a rural catchment of Southern Brazil: comparison with conventional approach based on elemental geochemistry

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In areas with extensive soil erosion, there is a need to identify the sources supplying sediment to improve our understanding of erosion processes and to guide the implementation of management measures. Geochemical elements are often used as tracers. Although P-fractions can provide more detailed information than the total P content, their potential to distinguish between different potential sources of sediments has rarely been tested. The objective of the current research was to evaluate the contribution of sediment sources in a rural catchment (Arvorezinha, 1.19 km^2) of Southern Brazil, using different sets of tracers (i.e. P-fractions only, geochemical tracers only, and a combination of both tracers). Three potential sediment source types were identified in the catchment: (*i*) cropland, (*ii*) unpaved roads and (*iii*) stream channel banks. Thirty-one suspended sediment samples were collected in the river draining this catchment during 9 significant floods between 2009 and 2011. Estimates of P-fractions were obtained by Hedley fractionation using anion exchange resin membrane (P_{resin}); 0.5 mol L^{-1} $NaHCO_3$ (pH 8.5) (P_{bic}); 0.1 mol L^{-1} NaOH ($P_{NaOH0.1}$); 1.0 mol L^{-1} HCl (P_{HCl}); 0.5 mol L^{-1} NaOH ($P_{NaOH0.5}$); and residual P ($P_{residual}$). Total organic (P_{org}) and inorganic P ($_{inorg}$) were obtained by the ignition method. The P_{HCl}, $P_{NaOH0.5}$ and P_{inorg} fractions were not conservative. With exception of $P_{residual}$, all P-fractions passed the Kruskal-Wallis *H*-test and provided potential tracers of sediment sources. When the P-fractions were combined to geochemical tracers, the discrimination power was much higher than when using geochemical tracers only. The Mahalanobis distance was 9% higher than that observed in the geochemical approach. For the three approaches, cropland was the dominant source of sediment. The calculated contribution of sediment sources using the three approaches was very similar, and cropland was the predominant source of sediment, with calculated contributions of 56±19, 46±16 and 48±16% for geochemical, P-fraction, and geochemical+P-fractions, respectively. The results obtained in the current research demonstrate the great potential of some P-fractions to trace potential sediment sources in rural catchments, as they show a high discriminant power while remaining conservative during sediment transport in the catchment.

Keywords: Phosphorus fractionation, fingerprinting approach, sediment tracers.
Financial support: CNPq

(4026 - 2218) Runoff and soil erosion process-based modeling in different land uses in the Brazilian Cerrado

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Land use can influence runoff and soil erosion, threatening soil and water conservation in the Cerrado biome in Brazil. The adoption of a process-based model was necessary due to the lack of long-term observed data. We aimed to predict runoff and soil erosion for four different land uses: wooded Cerrado (Cerrado sensu stricto), tilled fallow without plant cover, pasture, and sugarcane, using a process-based model named WEPP (Water Erosion Prediction Project). We performed the model calibration using a 5-year dataset (2012-2016) of observed runoff and soil loss in four different land uses in experimental plots (5 m width and 20 m length) located in the central area of the State of São Paulo. Selected soil and management parameters within the WEPP model were calibrated for each land use with the existing field data. The simulations were conducted using the calibrated WEPP model components with a 100-year climate dataset created with CLIGEN (weather generator) based on regional climate statistics. The WEPP model had an acceptable performance for the

subtropical conditions. Land use can influence runoff and soil loss rates in a significant way. Finally, the runoff behavior was distinct for each land use, but for soil loss we found similarities between pasture and wooded Cerrado, suggesting that the soil may attain a sustainable level when the land management follows conservation principles.
Keywords: Overland flow; soil loss; WEPP model
Financial support: CNPq (grant numbers 201109/2015-8 and 142393/2015-0) and FAPESP (grant number 2015/03806-1)

(1673 - 1135) Soil Erosion in Woodlands: Effects of Tree Species, Tree Diversity and Biological Soil Crusts after Forest Disturbances

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It is widely accepted in erosion research that vegetation cover is a key factor to mitigate soil losses. Therefore, scientists have emphasised the importance of forests for erosion control for a long time. Afforestation is a common measure to protect soil surfaces, but mechanisms of soil erosion in early forest stages are not clear in detail and especially the roles of different tree species, tree diversity and biological soil crusts (biocrusts) are up for debate. Here, we present results from a Biodiversity and Ecosystem Functioning experiment (BEF China) in subtropical China, which investigated how tree species, tree species richness and different forest floor covers affect soil erosion control. For that purpose, rain splash and interrill erosion were measured with splash cups (T-cups) and micro-scale runoff plots under natural and simulated rainfall within a setup of 40 different native tree species in monocultures and various diversity mixtures. Building on that, a new experiment investigating the influence of biocrusts on soil erosion in temperate forest disturbances and the restoration of bryophytes in skid trails will be introduced. Results from subtropical China showed that initial soil erosion increased tremendously within early stage tree plantations compared to old-grown forests. At the same time, throughfall kinetic energy (TKE) as well as initial sediment delivery were strongly influenced by tree architecture and tree and leaf-specific functional traits. TKE decreased with low LAI, low tree height, simple pinnate leaves, dentate leaf margins, a high number of branches and a low crown base height. High crown cover and leaf area index reduced sediment delivery, whereas it slightly increased by increasing tree height. Thus, the appropriate choice of tree species plays a major role for soil erosion control in young forest plantations. Even if an erosion-reducing trend could be observed, tree species richness did not affect sediment delivery. At the same time, biocrusts strongly decreased soil erosion, being more effective than abiotic soil surface cover. Biocrusts developed from initial cyanobacteria-dominated to bryophyte-dominated crusts within only 3 years and their cover was still increasing after 6 years of tree growth. Based on these findings, a new project on biocrust cover and their restoration in zones of forest disturbance will be set up in a temperate European forest and first results will additionally be presented at the 21st WCSS.
Keywords: Soil erosion, forest, biological soil crusts, throughfall kinetic energy, interrill processes
Financial support: DFG FOR 891

(9195 - 995) The use of dendrogeomorphology as a tool for dating and reconstructing erosion dynamics in tropical regions.

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Water erosion is an important degradation process, which results in loss of soil, reduction in agricultural productivity, and causes severe environmental impact. Dendrogeomorphology is a method in which structure of the wood of the trunk and roots of tree and shrub species affected by sediment deposition or by root exposure is analysed, to establish the chronology of erosive events. The objective of the present work was to apply the methodology of dendrogeomorphology based on scars analysis to the roots of tropical trees, *Schizolobium parahyba* and *Esenbeckia leiocarpa,* exposed to the process of water erosion. The study area presents features arising from erosion, such as gullies, with the consequent exposure of tree roots. The growth rings and the scars formed by the flow of water and soil particles were analysed in transverse sections of exposed roots mainly to date the erosion processes and after to infer the mean rate of erosion. This paper demonstrates the potential of *Schizolobium parahyba* and *Esenbeckia leiocarpa* for dendrogeomorphological studies, validating the dendrogeomorphology as a research tool in tropical climate. Scars used for erosion dating in cross sections have been proven as good indicators of geomorphic processes. The relevance of this work is to become the first attempt in tropical regions to date and reconstruct erosion processes using dendrogeomorphological techniques on exposed roots.
Keywords: soil erosion, dendrogeomorphology, growth rings
Financial support: CNPq and FAPESP

(4596 - 2912) Use of tracer and digital filters for runoff separation: an aid to modeling soil erosion in catchments

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Modeling sediment production requires precise hydrological control to quantify erosion processes. Erosion processes occur mainly due to the high kinetic energy of surface hydrological processes. In catchments, the water outlet is recorded in a hydrograph and composed of surface and subsurface flows. Thus, a valuable strategy for hydrological control and understanding of the erosive processes by modeling is the separation of these components in relation to their trajectory. For this, the use of conservative elements or properties of the hydrological system have been widely used. Tracers are elements that are conserved in specific phases of the hydrological process, thus allowing, through mass balance, to quantify different components. Another widely used method for separating flow is recursive digital filters (RDF), which are computational routines applied over the flow that remove the large amplitudes of the hydrograph associated to surface flow. Recursive digital filters are empirical models and numerous studies have shown positive correlation between RDF and tracers. Additionally, the responses of RDF are calibrated and validated by tracer observations, which enables the separation of the entire series. The Lajeado Ferreira catchment area, which is located in the municipality of Arvorezinha-RS in southern Brazil, was the subject of different sediment modeling studies. In order to verify the participation of the different flows, sample collection of the dissolved silica (DSi) tracer was performed to verify the behavior of the plot of each component in the hydrograph. With the use of these observations, the parameterization of the RDF model, which is called the Eckhardt filter, allowed flow separation of the river catchment, in addition to being coupled to erosion prediction models. Separation of the flow facilitates interpretation by the model of hydrological processes, such as infiltration, resulting in greater quantitative control over the superficial processes responsible for the production of sediments.
Keywords: Superficial flow, Hydrology, Sediment Yeld.
Financial support: CAPES and CNPq

C3.2.6 - Agricultural management to protect soil resource to support a growing population

(8680 - 1660) A comprehensive tool for calculating Cover and Management Factor (C-Factor) of RUSLE for Brazilian managements systems of sugarcane

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The sugarcane crop plays not only a great economic role in the Brazilian economy but also it is the primary raw material used to produce biofuel. In tropical conditions, several management systems can be employed when cropping sugarcane. As a response to the national and international demand for bioenergy, sugarcane has been expanding rapidly to new areas. Often, this expansion takes place in less suitable lands associated with inadequate management systems. Therefore, this development may cause an increased risk of accelerated erosion, which in turn may lead to serious environmental and socio-economic impacts. For soil loss modeling purposes, the C-Factor needs to combine land cover and crop management characteristics to indicate the erosive potential of each use and management. However, the determination of sugarcane C-Factors using field experiments for the various management systems can be an arduous and expensive process. Here, we developed a tool (spreadsheet) to calculate the C-Factor based on the method described in RUSLE manuals, from the sub-factors: Soil Cover, Canopy Cover, Soil Roughness, Soil Moisture and Prior Land Use. The tool requires eight input variables, namely, local, planting date, preparation date, tillage system, crop rotation, straw management, productive cycle of sugarcane and management level. Further, the tool furnished with crop growth data obtained from scientific and technical literature. It allows more than 100 million combinations of management systems. The amplitude of C-Factor was from 0.0351 (min) to 0.5922 (max). Using this tool, we observed that C-Factor is mostly influenced by i) change in the number of harvests (productive cycle of sugarcane): up to 40%, ii) planting date: 23% and iii) the crop rotation: 16%. We made this tool freely available for download to researchers for modeling and education purposes.

Keywords: Modelling Soil Erosion C-factor Sugarcane RUSLE

Financial support: CAPES Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

(7833 - 221) Conservation agriculture for enhancing resource-use efficiency, carbon sequestration, soil health and crop productivity

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Conservation agriculture for enhancing resource-use efficiency, carbon sequestration, soil health and crop productivity U.K. Behera, Swarna Ronanki, Firehiwot Endale Mergya, Amit Kumar and A.R. Sharma *Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012* Email: ukb2008@gmail.com Abstract Conservation agriculture and resource conservation technologies have great relevance to restore the degraded ecologies of India, where low farm income and fatigue in yield have become a major concern. Field experiments were conducted in the Inceptisols of New Delhi during 2004–16 on various tillage, viz. zero tillage and conventional tillage; crop establishment, viz. flat and raised bed planting; and nutrient and crop residues management practices in different cropping systems. Rainy season crops, viz. soybean, greengram and maize performed better under raised-bed than flat-bed system. Conservation tillage (zero tillage + crop residue) proved superior to conventional tillage and helped in conserving of resources (water, nutrient and energy), and carbon sequestration. Performance of maize, soybean, cotton and pigeonpea was similar under conservation tillage and conventional tillage. Influence of residues of previous crops (cereal or legumes) was significant during the latter years. Carbon sequestration was higher under conservation tillage than conventional practice. Soil biological parameters, viz. dehydrogenase, acid phosphatase and alkaline phosphatase, soil microbial count and respiration were positively influenced due to tillage and residue management. Soil aggregation was better in zero and conservation tillage than conventional tillage, while bulk density was higher in former than latter. Zero tillage saved about 15-20% of the energy requirement of the system compared with conventional tillage. Conservation tillage resulted in higher profit than conventional tillage by enhancing resource-use efficiency and crop productivity.

Keywords: Carbon sequestration, conservation agriculture, cropping systems,energy, grain yield

Financial support: I have to pay from my pocket for registration fee, transport and accommodation. I shall be grateful if organiser provide me finacial support in the way of : waveing off of registration fee or airfare or accommodation.

(9675 - 730) Correlating Ecological Sites to Soil Surveys

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The NCSS Soil Survey program is near completion of their first-pass of a nationwide product. In addition, interpretations have been developed to accompany the survey, such as the Ecological Site Descriptions (ESDs), the primary tool for conservation planning required as a basis for important decisions. It is widely understood that, where conservation is a desired goal, ESDs are the context in which to effectively apply soils information. The monumental effort of conducting a nationwide soil survey was most easily achieved as a county-by-county process, slowly adding to national coverage like pieces to a jigsaw puzzle. Early versions of ESDs were mostly developed as an afterthought, playing catch-up to their published soil surveys. The simplicity of this methodology ignored the reality that dynamic ecological functions do not behave along political boundaries. To resolve this widespread error, soil surveys need to be recorrelated to ecological boundary concepts of Major Land Resource Areas (MLRA) and their subdivisions, Land Resource Units (LRU). The entire update effort will take many years to complete and national guidance on the process is still developing. Instead of focusing on one county at a time, update projects are managed by LRU, a division of the landscape by shared edaphic characteristics with biotic potential, introducing efficiency and consistency into the process. Additionally, dichotomous keys are produced for each MLRA and LRU so that regular errors in mapping (depicting earth systems on temporally fixed, 2-D media) and the challenges of on-site component validation can be overcome by non-soil-scientists. Though methodologies vary slightly region by region, logical steps in the process are being developed during update projects. The update process begins with testing the current soil and ESD tools for each LRU. Correlation discrepancies between the soil components and ESDs, with respect to the bounding concepts of their MLRA and LRU, are identified and targeted for update (this often results in additional new ESDs and soil series). Updated concepts are rigorously tested during the development process, iteratively refined, and then released to the public. Soil and ecosite products are harmonized through simultaneous development, adding integrity to the tools. Concurrently, inclusion of conservation partners in this process captures local knowledge so that tools are developed with a focus on usability and needs of the stakeholders.

Keywords: soil survey, ecological site descriptions, major land resource areas, land resource units, conservation

Financial support: USDA- Natural Resources Conservation Service

(1914 - 869) Crops and soils respond differently to residue cover

management in no-till systems from the pampas region

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The broad use of no-till systems in the pampas region helps to sustain productive soils by reducing soil erosion and maintaining its organic matter and related properties. However, the benefits of residue cover accumulation on crop yields can vary between crops that interact with the expected changes in soil fertility properties. Several studies suggest that residue cover could be partially removed impacting minimally on soil properties. Furthermore, under certain conditions, residue removal can improve wheat and other crops grain yields. Our objective was to determine the effects of residue cover removal or its accumulation on soil properties and grain production in a long-term (14 seasons) crop rotation with soybean, corn and wheat/double crop soybeans. The study, initiated in 2003, was performed in a Typic Haplustoll under no-till practices in the sandy pampas region of Argentina. The treatments compared 3 amounts of yearly chipped residue cover spread immediately before planting: *(i) control* leaving the field produced residues, *(ii) reduced* removing the coarse residues and *(iii) increased* duplicating the quantity of residues lying over the ground piling those removed in the second treatment. Grain production and crop yield components were yearly measured and soil properties were evaluated every 6 seasons. The experimental design was in randomized complete blocks with 3 replicates in 100 m^2 plots, and the grain production data was analyzed based on repeated (seasons) measurements. The total removal of residues limited the productivity of summer crops, reducing corn grain yields by 13% and soybean crops by 3%. In seasons with low wheat production, the grain yields were reduced 10% in presence of the regular residue cover or 15% when the quantity of residues was duplicated. No significant changes were observed in double crop soybean yields. The cumulative grain production in the sequence with above ground biomass removal was 5.3% less than when the residue cover at planting was duplicated. In treatments with the removal of residues the soil organic matter contents were reduced but soil extractable P and K values increased in response to low crop productivity and nutrient uptake. However, when the residue cover was duplicated the changes in soil properties were smaller suggesting major risks on crop production and soil productivity properties after residue removal practices take place in the sandy pampas region.

Keywords: Biomass removal; Crop production; Dryland agriculture; Soil organic matter

Financial support:

(2855 - 1022) Effects of sugarcane straw removal from soil surface in dissolved organic carbon and soil carbon stock

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Sugarcane has become very important in Brazil for the bioenergy production. However, the practices that aim to remove all crop residues from the soil surface to bioenergy production can be damaging to soil and atmosphere, by reducing soil carbon (C) inputs which disfavor the microbiota, changing nutrients cycle, decreasing C stock and labile fractions, and even C cycle is strongly affected, increasing the returns as CO_2 form. Thus, this work aimed to evaluate dissolved organic carbon (DOC) and C stock in soil under sugarcane straw removal levels (SRL) on soil surface. The study was conducted in Piracicaba-SP, Brazil from November 2016 to May 2017, in the rainy period, after two years of straw removal. Experimental design was completely randomized. Treatments consisted of four sugarcane SRL: 0% removal (12 Mg ha^{-1}), 50% removal (6 Mg ha^{-1}), 75% removal (3 Mg ha^{-1}) and 100% removal (bare soil) in 20 cm depth. Soil is a Rhodic Kandiudox with sandy clay loam texture, and straw was collected after harvest in a sugarcane area (cv. SP80-3280). The study was made in a set of lysimeters of PVC tubes with 20 cm of diameter. In the base there were perforated stainless steel plates with 2 mm and a sieve mesh (125 µm). At the bottom there was a funnel stuck with a rubber ring, connected to a hose, which conduced soil solution to the glass collector. Lysimeter system was placed in open area with natural sunlight and rainfall. After each rainfall, the percolated solution was measured and collected. Samples were filtered analyzed in automatic analyzer TOC to quantify DOC content and with the volume of percolated solution was calculated DOC flux. At the end were perform soil BD and C stock. DOC results showed that 0% SRL showed low DOC flux, in almost whole events, and a low cumulative value, only higher than bare soil. This shows that DOC conformation is high, but probably DOC has been retained more strongly in soil profile. The cumulative values of DOC flux in this period were 114, 175, 203 and 180 kg ha^{-1} to 100, 75, 50 and 0% of SRL, respectively, what shows that 50% SRL released higher value in soil profile. The C stock did not show relevant differences among the treatments, being 13.9, 14.68, 14.35 and 14.6 Mg ha^{-1}, respectively, although the BD was higher in 100 and 75% SRL, being 1.24, 1.24, 1.21 and 1.22 Mg m^{-3}, respectively. The C stock takes more time to undergo changes because it is a stable fraction, however, more labile fractions can be quickly modified

Keywords: DOC, soil organic matter, bioenergy, crop residues

Financial support: CAPES, BNDES, RAIZEN

(2079 - 2313) Evaluation and Quantification of Environmental Sustainability of Different Tillage Treatments in South Texas.

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The world population is expected to reach 9 billion over the next 30 years and it is crucial that we develop alternative crop production systems which support high productivity while curtailing depletion of natural resources. Current management practices in South Texas include winter fallow and repeated tillage, which leaves the soil uncovered and prone to erosion, reducing water infiltration, and increasing runoff. The adoption of more sustainable management practices like conservation tillage could be helpful to increase water infiltration, buffer soil temperature, decrease soil erosion, decrease greenhouse gas emissions and support microbiome environment. The Fieldprint® Calculator is a pioneering tool created by the Field to Market® organization to provide a quantitative index of sustainability given specific management practices. This project aims to evaluate the agricultural performance and sustainability of cotton production in a long-term cotton/sorghum rotation system under different tillage treatments. This study has been conducted at the Texas A&M AgriLife Research and Extension Center in Corpus Christi, TX since 2011. Cotton/sorghum rotation plots were established in a split plot design with no-tillage and conventional tillage practices as sub-plots in a rainfed field. Plant canopy height, canopy cover, canopy volume and Normalized Difference Vegetation Index (NDVI) were captured weekly by Unmanned Aerial System (UAS) to analyze plant growth patterns. Soil samples were collected in the fall and analyzed. Lint yield was measured at the end of the season upon harvest. All 2017 field data was uploaded into the Fieldprint® calculator and graphs/reports were generated. No-tillage plots outperformed conventional tillage plots in

all parameters measured and had lower environmental impact according to the Fieldprint® calculator. Moreover, due to the ability of no-tillage systems to increase water infiltration and to store water in the soil more efficiently, this practice could be advantageous on dry years and/or in places where rainfall is not evenly distributed within the season.
Keywords: Tillage; Sustainability; Environment.
Financial support: Texas A&M AgriLife Research, Cotton Incorporated.

(6788 - 3077) Evaluation of the water footprint under production tecnificada of guava (Psidium guajava) in the Valley of the Cauca (Colombia - South America)

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Evaluation of the water footprint under production tecnificada of guava (Psidium guajava) in the Valley of the Cauca (Colombia - South America) Trejos-Arana, Ana Maria*1,2; Correa, M.; D. L1; Grajales G., L.C. 1; Tafur, H.; H.2 1Colombian Corporation for Agricultural Research. atrejos@corpoica.org.co; 2 Universidad Nacional de Colombia, Palmira campus. The main objective of this work was to quantify the volume of green (rain water) and blue (irrigation) water used in the production of guava (Psidium guajava) from the establishment of irrigation treatments, for the generation of management strategies for the rational use of soil and water resources. This research was carried out during the years 2015, 2016 and 2017, covering three production cycles on guava cv. ICA-1 material under environmental conditions of the southern region of Valle del Cauca, Colombia. A randomized complete block design with an arrangement in divided plots was used. The treatments evaluated correspond to three irrigation water levels, based on the reference evapotranspiration (ETo), determined by the FAO Penman-Monteith equation, L1 = 0.50ETo, L2 = 1.0ETo and L3 = 1.30ETo. In each cycle, the number and weight of fruit/tree and the yield (t/ha/ cycle) of each treatment were evaluated. The crop evapotranspiration green (ETc) and blue ETc were estimated for each cycle and irrigation treatment. The water footprint was determined according to the established values based on the manual of evaluation of the water footprint developed by a research group of the University of Twente in Holland, evaluating the total water footprint (total WF), green water footprint (greenWF) and blue water footprint (blueWF). According to the results, the most relevant factors that affect the water footprint between cycles are precipitation, yield and the amount of irrigation that is applied to the crop. The response variables, namely, number of fruits per tree, yield and quality of fruit, did not show significant differences due to the treatments of irrigation water levels during the cycle. The average water footprint values for the irrigation treatments are for L1 (0.50ETo) total WF = 245.38 m3/t, L2 = 1.0ETo totalWF = 416.43 m3/t and L3 = 1.30ETo totalWF = 360.87 m3/t. Sheet 2 was the best response in terms of average production between cycles with 34.6 t/ha. Keywords: water footprint, blue water, green water, evapotranspiration, guava cultivation.
Keywords: water footprint, evapotranspiration, guava cultivation.
Financial support: Corporación Colombiana de Investigación Agropecuaria Corpoica

(8040 - 479) Extending the Soil Lifespan: Positive Steps to Enhance the Long Term Sustainability of Soil Resources

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With the growth in population comes an unprecedented demand on global soil stocks and an increase in the intensity with which we exploit them. In an effort to meet this current unparalleled demand, delivering agricultural products in the short term is often favoured over ensuring the long term sustainability of the soil resource. With 66% of the world's soils presently degraded, and soil erosion frequently exceeding the rates of formation by more than an order of magnitude, soils are thinning across the planet. Despite the fact that the United Nations suggests there are 60 years of topsoil left, we present a positive and constructive response, outlining that such a short soil lifespan can be substantially extended by adopting certain management practices. We begin by outlining the universally applicable concept of the soil lifespan and, using data collected around the world, we demonstrate the average lifespans expected for soils under conventional land management regimes. We go on to illustrate the substantial extension of these lifespans by adopting novel agricultural practices. In some instances, soils begin to thicken which we suggest is one of ultimate ambitions for any soil sustainability initiative.
Keywords: Soil Lifespan; Sustainability; Soil Erosion
Financial support:

(1217 - 191) Green economy improved soil water productivity in drylands of China

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Water resource shortage limits the sustainable developments of agriculture and economy in dryland regions of Northwest China (mainly including Inner Mongolia, Gansu, Qinghai, and Xinjiang provinces). Furthermore, due to overgrazing in grassland, soil water erosion problem is still serious in these regions. A landscape ecological design approach is suggested for integrated control of soil erosion. Massive afforestation has been conducted in drylands of China since 1978. Artificial forest had taken up 13% of the total forest area. At the regional scale, soil erosion areas showed a decreasing trend, especially after the year 2000. The runoff coefficients and water resource amounts of Qinghai and Xinjiang showed increases, mainly linked to climate change. Rainwater harvesting in orchards could reduce surface runoff, improve soil water storage, as well as enhancing fruit production. Therefore, combing rainwater harvesting with drip irrigation is recommended as the best agricultural water management approach for improving water productivity and soil water use efficiency of orchards in drylands of China. This study helps elucidate the paradox of vegetation restoration in arid regions, and gives some suggestions on ecological restoration and combating desertification in other drylands of the world.
Keywords: soil water use efficiency; soil and water conservation; arid region; desertification
Financial support: The National Natural Science Foundation of China (Grant No. 41761059) and the National Key Research and Development Program of China (2016YFC0501402-4).

(6577 - 194) Intercropped Woody Species in the Sahel to Resist Drought: Agronomic Performance and Soil Quality

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The Sahel is an ecologically fragile, under threat from over populations, livestock grazing, and intensification of cropping with continuing soil degradation. In-season drought periods are common, causing chronic low yields, crop failures, and food insecurity, which will only increase with climate change. The mainstay carbohydrate food source is millet and sorghum for the majority Sahelian populations who depend on local production and consumption. Green Revolution technology has not been successful in the region and production rates of staple cereals such as millet have remained flat for more than five decades. Biologically based systems are needed that utilize local resources and buffer drought in the Sahel. The Parkland system of randomly distributed trees is an approach to address these challenges, but trees are slow growing and can compete with crops for water, nutrients, and/or light. Conversely, two native shrubs, *Piliostigma reticulatum* and *Guiera senegalensis,* coexist with row crops throughout the Sahel and until recently have largely been overlooked. Unfortunately, the current management of coppicing and residue burning prior to cropping, is not utilizing this organic matter effectively. Here we report results of the agronomic performance of a non-thermal, shrub intercropping system in the Sahel. Two experiments (4 reps) (11 yrs) in Senegal showed the intriguing ability of *G. senegalensis* and *P. reticulatum* under optimal conditions (~1500 shrubs ha^{-1} with residue returns to soil) to dramatically increase yields of millet and groundnut, with or without fertilizer and maintain yields in drought years. F. Importantly, high water use efficiency of crops (kg yield ha^{-1} mm^{-1} precipitation) was maintained by shrubs in dry years compared to non-shrub plots. Shrubs reduce time to harvest by about 15 days - a valuable asset for the semi-arid Sahel with its erratic rainfall patterns. Simulated drought experiment showed *G. senegalensis* performing “bioirrigation”. These results are attributed to hydraulic lift and improved nutrient availability, microbial diversity, and soil quality. Shrub intercropping more than doubled C sequestration/storage with *G. senegalensis* after 10 yrs. Optimized shrub-intercropping is advantageous for subsistence farmers, because it is a local resource, regenerates degraded soils, increases crop productivity, and resists drought even without inputs.

Keywords: Rhizosphere, hydraulic lift, microorganisms
Financial support: US National Science Foundation

(4896 - 1872) Lignite amendment of feedlot manure: mechanism for nitrogen retention and dynamics during composting

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Though feedlot cattle excrete about 80 % of their dietary N intake as manure, 50 -75 % of this excreted N is lost, mainly through NH_3 volatilization, before the manure is collected from the pen. This loss of N poses environmental threats and also decreases the value of the manure as fertilizer and soil amendment for improved soil fertility. Lignite (brown coal), due to its high cation exchange capacity, high pH buffering capacity, high total and labile carbon contents and low pH, has been shown, in previous studies, to reduce NH_3 volatilization from manure by 30 - 66 % when applied to cattle feedlot pen surface. However, the key mechanisms by which the lignite retains N in the manure, its effects on the N dynamics during composting of the manure and the agronomic value of the lignite amended manure compost are not well understood. This, ongoing, research aimed to address these gaps. The research approach involves the characterization of five different lignites, application of lignite in commercial cattle feedlot pens, composting of the lignite amended manure and then the determination of the effects of the lignite-manure compost on soil properties and plant yield. Preliminary results of the characterization show that, the lignite materials were acidic with pH_{CaCl2} of 3.0 -5.4 and pH buffering capacity of 174 - 357 $mmol_c$ kg^{-1} pH^{-1}. These two properties are important in N retention through the reduction of the manure pH since NH_3 volatilization becomes significant at higher pH. Lignites have high levels of carboxylic acid functional group which imparts ion-exchange properties and pH dependent charges. These were reflected in the CEC (6.2 - 73.4 $cmol_c$ kg^{-1}) and the NH_4^+-N adsorption capacities (7.9 - 19.2 mg g^{-1}) of the lignites with the adsorption increasing by up to 3 folds when the initial pH of the lignites were increased to about 7. The adsorption of NH_4^+-N is critical to the retention of the excreted N in the manure as significant fraction of the excreted N exits as urinary urea which quickly undergoes hydrolysis to produce NH_4 and then lost as NH_3 at high pH. The lignites had total C of 54.8 - 63.2 %, with labile C fraction of up to 14.3 %. This is necessary for N retention through biological immobilization. The understanding of the N retention mechanism of lignite, its effects on the composting process of the manure and the agronomic value of the compost are important to improving the manure as fertilizer and amendment for improved soil fertility.

Keywords: Lignite, Nitrogen, Composting, Manure, Ammonia
Financial support: 2. Australia-China Joint Research Centre (ACJRC)

(4262 - 847) Long-term fertilization improves soil water dynamics and aggregate stability differently in an Ultisol

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Soil water dynamics drives soil structure and chemical properties change in highly-weathered soils. The soil aggregate structure change in turns regulates the soil water dynamics. Such relationship may further depend on different types of long-term fertilization. The objectives of this study were to evaluate the influence of different long-term fertilization on the soil water dynamics, aggregate stability, associated chemical properties, and to determine the relationship between soil water dynamics and aggregate stability on a red soil (Ultisol). 17- years manure, NPK + rice straw, and NPK were applied continuously in replicated in the field since the year 1998. The frequent soil water content, aggregate stability (MWD), organic matter (OM), Fe-oxides, and zeta potential of clay from 0-10 and 10-25 cm depth were measured in one-year-period in 2017. Our results showed that manure and NPK+ straw significantly increased the soil water value and water dynamics compared to control but NPK treatment did not. The manure and NPK+ straw treatments also significantly improved the soil aggregate stability ($P < 0.05$) (e.g., MWD 1.13 vs. 0.74 mm for manure vs. control at 0-10 cm) due to increase in the macroaggregate fraction. The aggregate under these two organic treatments was highly resistant to their high soil water dynamics which was confirmed by the non-significant correlation between MWD and previous water indices. This is because soil water dynamics promoted the Fe-oxides change and OM content and then influenced the aggregate formation. The results suggest that long-term manure and NPK+ straw can improve the soil water dynamics and enhance the aggregate resilience to water but NPK did not which is regulated by the Fe-oxides and OM in red soil.

Keywords: Water dynamics; Soil aggregate; Long-term fertilization
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(7350 - 2708) Meeting Global Agricultural Demands with Sustainable Phosphorus Management

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Phosphorus (P) is the key to life, and its sustainable management is

critical for global food and soil security. As the world's population grows by a projected two billion people by 2050, global food production will need to increase considerably. As the demand increases for agricultural products, so does the demand for P fertilizer. This results in the complex challenge of increasing outputs in a sustainable manner that minimizes the environmental impact while producing wholesome products. Addressing this challenge requires a holistic approach to agricultural management which initiates with responsible crop nutrition and extends to include conservation practices implemented to reduce soil loss and improve soil health. Mineralization of organic matter provides a significant portion of the P available for crop use, therefore, maintaining soil organic matter is important for controlling P availability. Additionally, as soils become acidic through weathering, removal of plant material, or excess nitrate leaching, the availability of P is impacted due to low phosphate solubility and reduced crop root development. When P fertilizer is applied inappropriately, an increase in P inputs can result in an increased risk to nutrient runoff losses. Some conservation practices adopted to reduce soil and nutrient loss have resulted in unintended consequences of increased P runoff losses. However, sustainable P management can be achieved by adopting 4R nutrient stewardship practices to improve use efficiency by applying P according to crop needs (right time), placing P correctly to maximize uptake (right place), at an amount which optimizes growth (right rate), and by using the most appropriate nutrient source (right source). Edge of field data demonstrating the benefit of holistic agricultural management incorporating 4R nutrient stewardship practices with traditional conservation practices will be discussed as a sustainable approach to meet global production needs while improving soil health and minimizing environmental impacts.

Keywords: 4R nutrient stewardship, phosphorus, fertilizer, nutrient management
Financial support:

(3026 - 2763) Mixed/intercropping systems as a new paradigm for soil resilience, sustainable food and economic sovereignty.

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The protection and sustainable management of soils in all pedo-climatic conditions is based on new models of sustainable agro-bio-development that combine knowledge on the bio-physical aspects by taking into account the logical "knowledge and empirical know-how" of peasants and the analytical and predictive "scholarly knowledge" of researchers. They are based primarily on run-off control systems and agro-ecological run-on management. To ensure resilience, protection and thus sustainable soil management necessary for maximum stable production, the control and management of run-off must be designed by: 1° Almost total control of the run-off by wooded parks, prairie-fallow, mixed/intercropping systems and permaculture. 2° Trapping the entire run-on by Zaï/tassela and half-moons. All these bio-physical techniques crossed with the agro-ecological systems provide significant benefits / ha and even more important for the same surface of 1 ha and Benefits Equivalent Ratio higher than 1. Thus for all pedo-climatic conditions, the conceptualization of a global agro-eco-development that integrates soils (with resilience-fertilization-protection-sanitation), and which protects agro-ecosystems (enrichment in more active biological community), improves the superior production of richer and healthier foods and provides higher benefits in intercropping than mono-cropping. These spectacular effects of multiple agro-ecosystems or "triple green revolution" are due to the free Eco-Systemic Services calculable but also to those only estimable produced by the plants, which lead to a so desired food and financial sovereignty.

Keywords: Soil resilience/protection, free EcoSystemic Services, run-off and run-on control/management, mixed/intercropping systems, sustainable food and economic sovereignty
Financial support:

(2407 - 1814) Nitrogen budget in an intensively farmed peri-urban region

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Urban regions worldwide are growing and importing increasing amounts of nutrients as food, fertilizer, pet food, etc. Farms in the peri-urban region that surrounds cities also import nutrients to support intensive production of fresh, local foods used mainly in the cities. We studied the farm and urban nutrient budgets in the Lower Fraser Valley (LFV), a peri-urban region with 2.6 million people and 55,000 hectares of intensively farmed agricultural land. Our previous work showed that the region has an annual P surplus of over 8 kt, a little under a half accumulating in farm soils. In the current study we quantified the N budget of the LFV. Nitrogen input to agriculture was mainly as livestock feed (19kt) and fertilizer (5kt), of which 6.7 kt was lost as ammonia and 6.8 kt remained in the soil after crop harvest and lost by leaching and denitrification in fall and winter. About 4.2kt N was exported from farms to the cities as local food and an additional 10 kt N was imported as food into the region. We estimated that more than half of the N imported to the city was lost to the atmosphere and most of the rest to water, landfills etc. Although there are recycling programs for organic wastes, very little N was returned to the sources of the imported N. New strategies are needed to improve N cycling in peri-urban regions.

Keywords: Nutrients, Fertilizer, Feed, Food, Cities
Financial support:

(6454 - 337) Plan of Responsible Soil Use and Management: 4 years after its implementation in URUGUAY.

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In 2008, the Ministry of Livestock, Agriculture and Fisheries (MGAP) generated a modification of the soil conservation policy with Decree N^{O} 405, approving the Plan of Responsible Soil Use and Management (SUMP) as a good practice of soil conservation. In 2009, Law N^{O} 18.564 adding that when the land tenant is not the land owner, the last is jointly liable with the tenant in case of regulatory violation. Since 2013, the implementation of a defined public policy, of a mandatory nature, that seeks to regulate the use of land based on its soil use capability, is being implemented in the country. The universal soil loss equation (USLE-RUSLE) has been selected as a tool to design them. This equation has been validated and adapted to national conditions. This public policy has been applied to reduce the risk of soil water erosion, the most relevant environmental problem linked with agriculture in the country. This soil degradation aspect, affects both resource productivity, and water quality. This public policy has been declared mandatory for rainfed agriculture in all areas of more than 50 hectares. In 2015 by Law N^{O} 19.355 this requirement was incorporated into the Law of Use, Management and Conservation of Soils and Waters (Law N^{O} 15.239). It is established that the presentation of SUMP consists, geographic location, the soil type, slope, the crop/rotation/tillage practices projected, and estimated annual soil erosion rate estimated with USLE-RUSLE which needs to be less than the soil loss tolerance. Four years after its implementation, 1.52 million agricultural hectares have been declared their SUMP (15.539 plans). The total estimated cropland area in Uruguay is 1.6 million ha; therefore, almost all the agricultural area is under the soil management plans. Based on the total area of crops declared in the plans, winter crops (cash winter crops plus cover crops) declared in 2013, had the same area of summer crops, with soybean as the major

crop. Therefore certified private agronomists need to include both cash winter crops and cover crops in planned crop rotations with soybean to reduce the risk of soil erosion. Considering the soil use capability the area of perennial pastures in rotation with annual crops has also increased. The new public policy has become a very useful tool to help the design of appropriate crop rotations and best management practices to reduce the soil erosion problem at the country level.

Keywords: Keywords: natural resource conservation, soil erosion, rainfed agriculture

Financial support: Financial Support: Funding from Ministry of Livestock, Agriculture and Fisheries, Government of the Oriental Republic of Uruguay, Loan 8099-UY Project Sustainable Management of Natural Resources and Adaptation to Climate Change. (DACC-World Bank)

(5255 - 232) Sustainable Management of Soil Fertility and Land Resources in Sub-Saharan Africa*:* A Holistic Approach

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The soils of Sub Saharan Africa (SSA) are generally characterized by the poverty of the original materials in nutrients, low content in clay and organic carbon, low exchange capacity, lowly acidic and prone to acidification with cropping activities. There is high pressure on land resources with the quick growth of population and demand for food. The quick decline of soil fertility with cropping activities under the hot climate of SSA with the removal of soil nutrients without replacement by external inputs through mineral and organic fertilizers or recycling of crop residues is the bottleneck that limits agricultural productivity. Significant progress was made since the paradigm of ''external input'' of the 1960s and 1970s to the latest concept of Integrated Soil Fertility Management (ISFM). But these approaches remain crop-oriented or livestock-oriented. The product-oriented approaches do not capture the global challenges of the decline of soil fertility, land degradation and deforestation imposed by the continuous pressure lands and management of land resources. However, the rural communities are at the center of the problematic of management of lands resources. This paper suggests a new integrated and holistic approach involving local communities for land resources management, including cultivated soils and rangelands. A global framework is proposed for development of management options of land resources with local communities. The proposed working strategy is a dynamic process of participative management of lands as providers of services for the entire community.

Keywords: Soil, lands degradation, local communities

Financial support: EU/IFAD: Restoration of Degraded Lands for Food Security and Poverty Reduction in East Africa and the Sahel: taking successes in land restoration to scale.

C3.3 - Soils and land use Change

C3.3.1 - Nitrogen use efficiency (NUE) in tropical soils

(2581 - 1360) Ammonia and greenhouse gas emissions from maize-grass rotation systems

Camila da Silva Grassmann[1]; Eduardo Mariano[1]; Bruno Rosolen Gilli[1]; Lucas Felipe Brunini de Souza[1]; Ciro Antonio Rosolem[1]

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The use of integrated systems where a cash crop [e.g., maize (*Zea mays* L.)] is grown in rotation with forage grasses such as brachiarias is a sound practice in tropical regions, improving agricultural economic returns and chemical, physical, and biological soil properties. The introduction of this system will certainly affect N use efficiency along with NH_3 and greenhouse gas (GHG) emissions. It has been shown that some brachiaria species can decrease nitrification, thus reducing N_2O production by heterotrophic soil bacteria. The objective of this study was to evaluate NH_3, CH_4, CO_2, and N_2O emissions from maize-grass rotations as affected by N fertilization and grass species. Guinea grass (*Panicum maximum*), palisade grass (*Urochloa brizantha*), and ruzigrass (*Urochloa ruziziensis*) were grown in the off-season for two years, and maize received 0, 70, 140, and 210 kg N ha^{-1}. In the second year of the experiment, from Dec. 2016 to Dec. 2017, NH_3 loss was evaluated in all plots and GHG emissions were assessed in the control and with 140 kg ha^{-1}. Cumulative NH_3 loss was decreased by 15%, on average, in the maize-palisade grass in comparison to other rotation systems, regardless of N rate. Furthermore, N addition decreased CH_4 consumption by 34%, but increased N_2O emission in the same proportion (34%). No effect of brachiarias or Guinea grass was observed on N_2O emission. There was no difference between treatments for cumulative CO_2 emission. Weak correlations were observed of CH_4, CO_2, and N_2O fluxes with soil temperature and moisture. Nitrogen fertilization and herbicide application resulted in NH_3 loss peaks over the period. Primarily in control treatments, a distinct CH_4 consumption peak was identified following a heavy rainfall. In general, CO_2 fluxes followed the soil moisture pattern, and peaked right after lime application. Furthermore, as expected, N addition produced peaks of N_2O emission. The increased soil N availability (NH_4^+ and NO_3^-) resulting from N fertilization might have changed the activity and composition of the soil methanotrophic community, thereby reducing CH_4 consumption, whereas nitrification and denitrification processes were the main drivers for N_2O flux. Therefore, while N fertilization plays a key role in CH_4 consumption and N_2O emission, the use of palisade grass in rotation with maize can mitigate NH_3 losses to atmosphere.

Keywords: *Zea mays* L.; *Brachiaria*; *Panicum*; Nitrogen fertilizer; Nitrogen losses.

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(1668 - 2258) *Brachiaria brizantha* may help to reduce N_2O emissions

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Brachiarias are common in Brazil and some species are known to produce biological nitrification inhibitors (BNI) with the potential to increase nitrogen use efficiency (NUE). One BNI is brachialactone, which is exuded from roots of several *brachiaria* species in different amounts. This study aimed to evaluate nitrous oxide emissions in soils with roots of brachiaria and maize. A mesocosm experiment was set up using soil columns (30 cm of height and 15 cm in diameter) where maize had been grown for twelve weeks after which the above ground part was cut. Treatments (six), with four replications, consisted of two brachiaria species sown after maize (*Brachiaria humidicola* and *Brachiaria brizantha*) and a control (soil with residual roots of maize) and two N rates (0 or 100 kg ha^{-1}) as ammonium sulfate. The soil columns were maintained in a greenhouse with air temperature ranging from 24 to 33ºC and soil moisture at 60% of field capacity. Nitrous oxide emission was monitored for 66 days after fertilization using the static chamber method. N_2O concentration was determined using GC. At the end of the experiment, the greater cumulative N_2O emissions were observed in treatment with maize roots+100 kg N ha^{-}

^{1} (M_{100}). When compared with M_{100} a reduction of 65 and 18% of N_2O emissions was observed in soils with *Brachiaria brizantha*+100 kg N ha^{-1} (B_{100}) and *Brachiaria humidicola*+100 kg N ha^{-1} (H_{100}), respectively. The N_2O emissions were lower in the treatments with no N addition than in treatments where ammonium sulfate was added; however, in the treatment where no N fertilizer was added, plots with maize roots (M_0) presented higher emissions than treatments with *Brachiaria humidicola* (H_0), which were higher than in *Brachiaria brizantha* (B_0). The N_2O emission factors observed in M_{100}, H_{100}, B_{100} were 4.1, 3.3, 1.4%, respectively. This experiment showed lower N_2O mitigation by *B. humidicola* than by *B. brizantha*. The experimental conditions may not have been favorable to brachialactone production or the time was too short for BNI production by *B. humidicola*. However, *B. brizantha* reduced in 65% the N_2O emissions from fertilizers, which could be attributed to root architecture or the BNI production by this species.

Keywords: biological nitrification inhibitors; nitrogen use efficiency; nitrous oxide emission.
Financial support: FUNDAG; CAPES; FAPESP [2015/50305-8]; FAPEG [2015-10267001479]; [RCUK-02771/16]; BBSRC [BB/N013201/1].

(4955 - 301) Distribution and chemical speciation of nitrogen and inhibitors from banded enhanced efficiency fertilizers

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Enhanced efficiency fertilizers (EEFs) are proposed as a key tool for improving nitrogen (N) use efficiency in agricultural systems. Substantial literature documents the performance of EEFs in settings of temperate climates and broadcast / incorporated application, however little information is available for agricultural systems which operate in tropical environments and / or where N-fertilizer is sub-surface banded. Incubation studies using EEFs based on nitrification inhibitor (NI), urease inhibitor (UI), and polymer-coating (PCU) technologies applied to urea have identified that chemical conditions developing in and around the fertilizer band may impede the effectiveness of the various EEF technologies. Rapid hydrolysis of urea-N leads to sharp increases in pH and free ammonia (NH_3) concentrations which are inhibitory to ureolytic and nitrifying microorganisms. These conditions make NIs and UIs redundant within the fertilizer band. Moreover, NIs and UIs do not diffuse further than 2 cm from the band in a Vertosol, although this distance is likely to be dependent on soil type. In contrast, elevated ammonium (NH_4^+) and nitrate (NO_3^-) concentrations at distances of 4 - 6 cm (NH_4^+) and 4 – 10 cm (NO_3^-) from the band suggest asynchronous distribution of inhibitory chemicals and the transformation processes these chemicals are targeting. In contrast, semi-permeable polymer coatings can control the release of N from a fertilizer granule to the surrounding soil solution, but rely on a strong concentration gradient from the granule to the surrounding soil to ensure complete or near-complete release of urea-N via diffusion. However, a low proportion of fertilizer recovered as urea-N suggests impeded release of N from these products, probably due to poorly developed concentration gradients that result from granules in a fertilizer band being in close proximity to each other. Low concentrations of N transformation products suggest that while urea release is restricted, chemical conditions inhibitory to ureolytic and nitrification activity are still achieved within a band of PCU. Understanding the interactions of soil type, moisture, application method and N species change will be the keys to development of management practices that effectively utilize the different mechanisms that EEFs rely on to control fertilizer N release or soil N transformations.

Keywords: nitrogen; enhanced efficiency fertilizers; soil; chemistry
Financial support: The National Environmental Sciences Program (Tropical Water Quality Hub) and Sugar Research Australia (SRA) support this research. Scholarship support from the Australian Government RTP, the Howard Memorial Trust, and SRA is gratefully acknowledged.

(2212 - 1410) Fate of ^{15}N fertilizer in maize-forage grasses cropping systems

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The association of forage grasses with cash crops is a successful cropping system in tropical areas. Furthermore, biological nitrification inhibition by some brachiaria species can reduce N losses, increasing N use efficiency. However, it has been reported that ruzigrass (*Urochloa ruziziensis*) decreases N accumulation and yield of the succeeding maize, depending on N fertilization. Therefore, growing brachiarias before maize may affect the fertilizer use efficiency of the crop. A 2-year field ^{15}N microplot experiment was conducted in southeastern Brazil to investigate the influence of forage grasses on maize grain yield, N uptake, and the fate of the fertilizer applied to maize under no-till. Guinea grass (*Panicum maximum*), palisade grass (*Urochloa brizantha*), and ruzigrass were grown without fertilization. Maize was planted over the forage residues and then fertilized with 140 kg N ha^{-1} as ^{15}N-labeled ammonium sulfate. After maize harvesting, grasses where grown during the off-season. In the second year, maize was supplied with unlabeled ammonium sulfate. In the first year, ruzigrass decreased maize yield by 8.3% as compared with palisade grass. There was no difference among grasses for dry biomass, total N uptake, ^{15}N recovery in maize shoots, ^{15}N recovery in forage straw, and residual ^{15}N recovery in the soil (0-40 cm). Higher proportion (44%) of ^{15}N was detected in grains than other plant components. In the soil, most of the ^{15}N (68%) remained in the superficial layer (0-10 cm). On average, 34, 4, and 46% of ^{15}N added was found in maize shoots, forage straw, and soil, respectively. Therefore, ^{15}N recovery in the system accounted for 84% (118 kg N ha^{-1}). In the second year, a similar pattern was observed, but no differences were found for any variable and low ^{15}N recovery values were found. On average, 3, 1.5, and 20% of residual ^{15}N was recovered in maize shoots, forage-maize straw, and soil, respectively, thus totaling 25% (34 kg N ha^{-1}). Most of the N taken up by maize derived from soil (66% in the first season and 97% in the second). The results indicate that the forage grasses grown in rotation with maize do not alter the ^{15}N recovery efficiency by the grain crop, probably because it affects soil N dynamics, since most of the N in maize plant derived from soil. The extremely low recovery by maize of the residual ^{15}N clearly demonstrate the importance of annual inputs of fertilizer to sustain high yielding-levels in N-responsive sites.

Keywords: *Zea mays* L.; *Brachiaria*; *Panicum*; ^{15}N recovery; N use efficiency.
Financial support: FAPESP (grant 2015/50305-8, 2016/25253-7, and 2017/02517-1) and BBRSC/Newton Fund (grant BB/N013201/1).

(7588 - 3160) Impact of the N fertilizer application, concentrated

vinasse and nitrification inhibitor on N_2O emissions and NH_3 volatilization in sugarcane field in Brazil

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Nitrogen (N) fertilizers applied to soils are important sources of N_2O emissions to the atmosphere. N_2O emission from N fertilizers represent around 40% of the total greenhouse gas emissions from sugarcane ethanol production. However, several studies have indicated that the contribution of N fertilizers to the total emissions is considerably greater when associated with residues such as vinasse and straw. Conversely, recent studies have indicated that the use of nitrification inhibitors (NI) can be important strategies to mitigate N_2O in sugarcane fields. The aim of this study was to evaluate the impacts of N fertilizer, concentrated vinasse (CV) and NI on N_2O emissions and NH_3 volatilization in a sugarcane field. The experiment was carried out in a clayey Oxisol cultivated with the sugarcane variety CTC-4 in the 1st ratoon stage. The experimental design was randomized block with four replicates and six treatments. The treatments were: 1) control; 2) CV; 3) Urea (U); 4) CV+U; 5) U+NI; 6) CV+U+NI. The rate of CV application was 7 m^3 ha^{-1} and all treatments with urea were balanced to apply 120 kg ha^{-1} of N. N_2O emissions were measured using static chambers methodology and the analyzes were performed in a gas chromatograph. For volatilization losses, semi-open chamber methodology was set up to trap NH_3 in foam discs, following by N quantification by distillation. The higher NH_3 losses were observed in the treatments U and U+NI, accounting to 7.4% and 6.6 % of the total applied N, respectively. On average, the application of U combined with CV reduced in 14 times NH_3 volatilization losses. Highest N_2O emissions (376 µg N_2O-N m^{-2} h^{-1}) were observed in the treatment that urea was applied alone (U), followed by U+CV, U+NI, U+CV+NI, CV and control. The N_2O emissions in the treatment CV+U was 55% smaller than U. The use of NI reduced the N_2O emissions by 61% and 20%, respectively to the treatments U+NI and U+CV+NI. The application of N fertilizer combined with CV is a good strategy to mitigate N losses by volatilization and N_2O emissions. The adoption of best management practices, such as the application of N fertilizer combined with CV and use of NI are good strategies to improve the N use efficiency and to increase the sustainability of the sugarcane production in Brazil.

Keywords: GHG emission; Ammonia; Urea, Sugarcane ethanol; Bioenergy

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(2797 - 1384) Microorganisms affecting soil N under maize-forage grass rotations

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The introduction of agricultural integrated production systems where a cash crop is grown in consortium or in rotation with forage grasses is very important for the sustainability of agricultural systems in tropical areas. Brachiaria species are very popular in these systems because they produce high quality forage, grow fast and have deep, vigorous root systems, tolerant to low fertility. In Brazilian production systems, ruzigrass (*Urochola ruziziensis*) is one of the most used species, because it is ease to control. However, N deficiency and yield depletion have been observed in maize grown after ruzigrass. As *U. humidicola* was shown to decrease nitrification, it is hypothesized that ruzigrass may affect soil N transformations and availability through the effect on soil microorganism's dynamics. To assess the abundance of ammonifying microorganisms (Most Probable Number, NMP), archaea (16S Achaea) and total bacterium (16S Bacteria) in addition to specific microorganisms acting in BNF (*nifH*) and nitrifiers of the first stage of the ammonium oxidation [(*amoA* (AOA) and *amoB* (AOB)] in soil cultivated with ruzigrass (*U. ruziziensis*), palisade grass (*U. brizantha*) and Guinea grass (*Panicum maximum*) for 11 months, an experiment was carried in a clayey Typic Rhodudult in Botucatu, São Paulo, Brazil. There was no evidence of inhibition of the ammonificant microorganism population by ruzigrass, which showed a high capacity to increase the abundance of N fixers microorganisms at the beginning of its vegetative development. The abundance of nitrifying microorganisms and soil N fixers in plots cultivated with ruzigrass was positively correlated with soil NH_4^+-N content. The earliness of ruzigrass in relation to the other species and their response to the N fixers microrganism gene expression, ammonification and nitrification processes show that the phenological phase of forage grasses is what defines the intensity of the activity. Looking solely at the effects on soil microorganisms it is not possible to explain the deleterious effect of ruzigrass on maize yields and N acquisition. Therefore, further studies taking in account N losses from the system and N fixation are needed for a better understanding of this phenomena.

Keywords: Cropping systems, NUE, ruzigrass

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(8108 - 1371) Nitrogen use efficiency and physiological response of maize to improved physical condition of structurally fragile tropical soil.

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Due to negative interaction between reduced soil rootability and high atmospheric evaporative demand in the tropics, crops do not always attain optimal growth. Therefore, the objective of this study was to evaluate the effect of variation in soil chemical properties and soil strength promoted by leguminous mulch and irrigation intervals on nitrogen uptake, physiological parameters and productivity of maize in a structurally fragile tropical soil. Four replications were distributed in a completely randomized block design, including the following treatments: 4CN: 4-days irrigation intervals with soil covered by mulch and with nitrogen, 4C: 4-days irrigation intervals with soil covered by mulch, 4BN: 4-days irrigation intervals in bare soil and with nitrogen, 4B: 4-days irrigation intervals in bare soil, 8CN: 8-days irrigation intervals with soil covered by mulch and with nitrogen, 8C: 8-days irrigation intervals with soil covered by mulch, 8BN: 8-days irrigation intervals in bare soil, with nitrogen, 8B: 8-days irrigation intervals in bare soil. The mulch decreased soil water loss so that in the four days after the irrigation in all the covered plots; the moisture was higher than in plots with bare soil. The organic matter fractions also were increased by mulch. Thus, in the covered plots, the maximum the penetration strength was lower than in plots with bare soil plots with 4-day irrigation interval. Therefore, we concluded that the use of mulch on structurally fragile tropical soil could delay the drying process, decreasing the soil strength and slow down the cohesion. For maize, the main consequence of this change in soil physical condition is an increase of leaf area index, nitrogen and water uptake, dry matter production and maize yield. Strategies that seek to enhance soil rootability to reduce the water stress in the root zone may be the most suitable way to increase crop productivity and the

water and nutrient use efficiency in structurally fragile tropical soil.
Keywords: Keywords: soil strength; mulch; maize yield.
Financial support: This work was undertaken as part of NUCLEUS: A Virtual Joint Centre for UK & Brazil funded in Maranhao by FAPEMA and in the United Kingdom by BBSRC.

(9739 - 633) *NUCLEUS* (Nitrogen Use effiCiency via an integrated SoiL-plant systEms approach for the Uk & Brasil)

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Global agriculture has made significant inroads into reducing famine by improving crop varieties and increasing productivity through a better soil management and the use of synthetic fertilizers. Nitrogen (N) is a key limiting factor for crop growth and yield, demanding the routine addition of synthetic N fertilizers for most agricultural systems. It has been suggested that less than half of the reactive N added globally onto cropland is converted into harvested products while synthetic N fertiliser inputs continue to increase. This decrease in N use efficiency (NUE) means that a significant portion of the N used for crop fertilisation is currently lost into the environment via leaching and/or volatilisation. However, there is huge variation e.g. NUE in Brazil is high in intensively farmed regions but severe N-depletion occurs in former Amazonian area due to inappropriate shifting cultivation practices (e.g. fires, insufficient fallow, erosion). In the Centre, South and Southwest of Brazil, significant N losses may occur through leaching, emissions of N_2O, ammonium volatilization (a particular issue when urea is applied to no-till systems), and N loss through plant tissues and erosion. One approach to address this is to improve the synchronicity between the plants need for N and soil N availability at an adequate rate, supporting an optimal soil-plant environment that diminishes N losses. Here we explore the extent to which the release of reactive N can be mitigated through approaches related to improving agronomic NUE (e.g. via no-till, intercropping, combined crop-livestock systems, soil amendments). We report on a joint Brazil-UK based project *NUCLEUS* (Nitrogen Use effiCiency via an integrated SoiL-plant systEms approach for the Uk & BraSil) which aims to achieve this via investigating the main nitrogen pathways in the soil-plant-atmosphere continuum and identifying how N pools least prone to losses can be managed aiming at a more efficient use of N by crop plants.
Keywords: nitrogen use efficiency (NUE), intercropping, maize, leaching, sensors
Financial support:

(5504 - 2955) Reduction in ammonia emissions from the application of concentrated vinasse combined with nitrogen fertilizers and urease inhibitor in sugarcane

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The vinasse application in sugarcane is a practice used by most plants, because it has the potential to completely replace the potassium fertilization of this culture. The vinasse concentration, as well as its combination with nitrogen fertilizers, besides reducing transport costs, extends the benefits of fertilization to more distant areas. This study aimed to verify the maximum N-ammonia losses due to the most favorable conditions to the volatilization process (permanent moisture in the soil-straw system) in a greenhouse structure (high temperature). The rain effect was not simulated. The experimental design was completely randomized with 10 treatments replicated 04 times, resulting in a total of 40 experimental units. The treatments were selected according three strategies: (1) addition of different N fertilizers, (2) combination with the urease inhibitor N-(n-Butyl)thiophosphoric triamide (NBPT); (3) combination with concentrated vinasse (CV). The treatments were: (i) straw (control); (ii) urea; (iii) urea+NBPT; (iv) uan; (v) uan+NBPT; (vi) CV; (vii) CV + urea; (viii) CV + urea+NBPT; (ix) CV + uan; (x) CV + uan+NBPT. In each treatment a dose of 100 kg ha^{-1} of N and the CV application of 6.5 m^3 ha^{-1} were considered. Throughout the experiment 10 samplings were performed, totaling 28 days. The salicylate method was employed to determine the volatilized nitrogen concentrations. The cumulative N-NH_3 losses from de N fertilizers ranged between 21.5 to 87.9% of the N applied for uan+NBPT and urea respectively. Considering the effect of the NBPT on N losses of urea and uan treatments, the urease inhibitor promoted a significant and similar reduction in losses of the amide component (46% and 52%, respectively). The NBPT extended the nitrogen availability for a longer period (13 days for urea and 8 days for uan), which resulted in the delay of N volatilization. Considering the CV and urease inhibitor combination with N fertilizers, the NBPT addition, as well as the presence of the titratable acidity of the vinasse, promoted a reduction in N losses of 56%. For uan, the reduction in N losses was 86%. These results indicate that the combination with amended nitrogen fertilizers and a rich-organic matter waste may be the fertilizer solution for the sugarcane crop. Lower ammonia losses result in higher agronomic efficiency of the nitrogen fertilizer and lower contribution to the atmosphere reactive nitrogen (N_2O) that can cause global warming.
Keywords: Urea; Uan, Urease inhibitor.
Financial support: KOCH Fertilizer, Project Number DD 1088.

(2678 - 2422) Total CO_2 emission is not affected by liming in an integrated cropping system

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An important proportion of greenhouse gases (GHG) emissions to the atmosphere has been attributed to agriculture as C and N_2O emissions can be high. Agricultural practices such as tillage, fertilizer application and liming may be managed to control the emissions of GHGs. In agricultural systems under no-till lime is applied to ameliorate soil acidity, and phosphogypsum is used to neutralize subsoil Al and improve root growth. Despite its importance in alleviating soil acidity, liming was shown to increase CO_2 emissions due its dissolution in soil and by a priming effect due to pH increase. The objective of this study was to evaluate CH_4, N_2O and CO_2 emissions as affected by soil acidity amelioration with lime and phosphogypsum, and nitrogen (N) rates in an integrated cropping system where soybean was grown in the summer, followed by maize intercropped with Guinea grass (*Pannicum maximum*) as a relay crop. The study was conducted in Botucatu, SP, Brazil from 2016 to 2017. The treatments were control, lime and lime + gypsum, applied before soybean sowing, and two levels of N (0 and 160 kg ha^{-1}) applied to maize. Soil GHG were sampled using closed static chambers and analyzed by gas chromatography. There was a high consumption of CH_4 when lime was applied along with phosphogypsum as compared with lime alone and the control. Lime application increased N_2O emission over the control, disregard of phosphogysum. Afterwards, during de maize + forage cultivation, highest consumption of CH_4 was observed in the absence of lime, and the presence of N fertilizer showed higher consumption, and no interaction was observed.

However, an interaction between lime and N application was observed for N_2O emission. When pH was not increased and 160 kg ha^{-1} of N was applied to maize, there was higher emission of N_2O, while the lowest emission was observed with lime + gypsum and the treatment without N applied to maize. There was no effect of liming or N application on CO_2 emission. Therefore, despite a peak in CO_2 emission right after lime application, total emission is not affected. However, liming and N fertilization increases N_2O emissions, which is at least partially compensated by CH_4 consumption.

Keywords: Greenhouse gas emission, Phosphogypsum, no-tillage, soybean, maize
Financial support: FAPESP (grant 2015/50305-8, 2017/00398-5) BBRSC/Newton Fund (grant BB/N013201/1)

(3348 - 1734) Volatilization of N-NH3 from different nitrogen sources after lime application in no-tillage system

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In tropical soils under no-tillage systems, lime is applied to the soil surface, causing pH increase and nitrogen (N) losses by volatilization of ammonia (NH_3), from nitrogen fertilization. The aim of this work was to quantify the losses of N by volatilization of NH_3 from different nitrogen sources after application of lime and its relation with the surface soil pH. The experiment was carried out in the city of Maringá-PR in an Oxisol clayey (772 g kg^{-1}). A randomized complete block design was used in a 4x4 factorial arrangement. Four dolomitic lime rates (0.0, 2.6, 5.4 e 8.1 Mg ha^{-1}) in four different nitrogen sources (Urea; Urea + Cu e B; Urea + NBPT and ammonium sulfate) in the rate of 100 kg ha^{-1} of N were applied on the soil surface. The losses of N-NH_3 were quantified until to the 18th day after fertilizer application, using a semi-open static chamber, according to methodology described by Miyazawa (2007). After the 18th day, soil samples were collected inside the chamber at a depth of 0.00-0.05 m to determine the pH ($CaCl_2$) of the soil. The volatilization accumulated over time was submitted to non-linear regression analysis using the logistic model (y = a/1+exp(-b(time-Xo)). On the other hand, the maximum volatilization and the pH of the soil were submitted to analysis of variance and polynomial regressions. The maximum accumulated volatilization ranged from 15.8 to 31.9 kg ha^{-1} N-NH_3 for Urea, 11.9 to 31.4 kg ha^{-1} N-NH_3 for Urea + Cu and B, 6.9 to 18.9 kg ha^{-1} N-NH_3 for Urea + NBPT and 0.3 to 6.1 kg ha^{-1} N-NH_3 for ammonium sulfate at the rate of 0 and 8.1 Mg ha^{-1} of lime, respectively. The addition of NBPT to urea delayed the peak of maximum volatilization in 2.5 and 4.5 days and decreased the volatilization peak in 38 and 41% in the rate of 0.0 and 8.1 Mg ha^{-1} of lime, respectively. The soil surface pH raised according to the increase of lime rate, ranging from 4.75 to 6.88 at the rate of 0.0 and 8.1 Mg ha^{-1} of lime, respectively. Pearson's linear correlation was observed between total volatilization and soil pH of 0.98 for Urea, 0.99 for Urea + Cu and B, 0.96 for Urea + NBPT and 0.97 for ammonium sulfate, demonstrating the effect of lime on the soil surface pH on N-NH_3 losses in no-tillage system.

Keywords: soil pH, ammonia, liming, efficiency, logistic model
Financial support: National Council for Scientific and Technological Development (CNPq)

C3.3.2 - Nutrient budgets in agricultural soils

(9740 - 1458) Biomass and macronutrient demand estimation of fast-growing forest species in Corrientes - Argentina

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Argentina has more than 1000000 ha planted with Pinus and Eucalyptus. Corrientes state holds 40 % of the area of these forests in the country. Fertilizer recommendation based on nutritional balance between soil supply and crop nutrient demand is fundamental for forest production sustainability. The aim of this study was to develop an accurate method to estimate biomass and macronutrient demand based on diameter at breast height (dbh). This variable reflects cumulative growth and results in models with a higher degree of universality if compared to the use of chronological age (site-specific variable). Ninety-three trees were cubed and sampling of leaves (Ls), branches (Bh), wood (Wd) and bark (Bk) was done in: seminal (SEg) and clonal (CEg) E. grandis, P. taeda (PT) and hybrid pine (HP) in different regions of Corrientes. Sampling was done following chronosequences and considering three diametric classes (upper, middle and lower). Biomass and macronutrient (N, P, K, Ca and Mg) contents were determined in tree components of each species. Then, biomass and macronutrient contents were plotted against dbh. As a result, allometric equations were obtained to estimate these variables for aboveground tree components with R2 average values of 0.80, 0.85, 0.95 and 0.91 for Ls, Bh, Wd and Bk, respectively. Literature data of nutrient allocation to roots, allowed to include this component also as functions of dbh. Allometric equations, based on wood volume, were adjusted for each species (R2 > 0.95) in order to estimate dbh. Assuming a dbh of 20 cm several observations were identified. On average eucalyptus produces 70 % more Wd than pine for this dbh. When compared to pine, eucalyptus demands: 1.1, 1.5, 2.6, 4.7 and 2.7 times the amount of N, P, K, Ca and Mg to attain this dbh. SEg produces more Bs (62 %) and Bk (11 %) than CEg, which produces slightly more Ls (6 %) than SEg. SEg requires more Ca (27 %) and Mg (48 %) than CEg, which demands more N (22 %), P (11 %) and K (2 %) than SEg. PT produces more Bs (94 %) and Wd (8 %) than HP, which produces more Ls (6 %) and Bk (60 %) than PT. PT requires more N (39 %), P (49 %), K (4 %), Ca (8 %) and Mg (31 %) than HP. This example demonstrates the importance of estimating nutrient demand considering specific allometric equations for each species. We conclude that dbh could be used to estimate biomass and macronutrient demand of Pinus and Eucalyptus. This is useful for fertilizer recommendations based on nutritional balance.

Keywords: Eucalyptus, Pinus, Fertilization, Plant nutrition, Allometric equations
Financial support: PEC-PG (Graduate Scholarship Program of the Brazilian Government), DPS/UFV (Dept. of Soils, Federal University of Viçosa, Brazil), Ministry of Production of Corrientes. The forestry companies: Pomera Maderas, EVASA, Zeni, MASISA and Bosques del Plata

(3307 - 842) Cultivation of forest caused larger loss of soil nutrients from Oxisols at the forest–savanna boundary in Cameroon, Central Africa

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Forest–savanna mosaic is widespread in tropical Africa, mainly occurring on nutrient-poor Oxisols. Slash-and-burn is practiced for

subsistence agriculture under both forest and savanna; however, commercial agriculture is becoming widespread under the increasing population density. Nitrogen flux through the soil profile is reported to be large in this forest regions due to the legume dominance. Therefore, soil basic cations can be rapidly depleted in the process of NO_3^- leaching. In this study, to establish sustainable agricultural practices, the cultivation effects of original vegetation (i.e., forest vs savanna) on nutrient losses and nutrient balance of Oxisols cropland was evaluated over 2 years in Cameroon. Solute fluxes at 30-cm depth in maize croplands derived from forest (CR_{FR}) and savanna (CR_{SV}) were compared with those in adjacent forest (FR) and savanna (SV) ecosystems. Dissolved nutrient (as major ions) inputs by rainfall, outputs from solute leaching and cropland grain removal, and soil nutrient stocks measured at 0–30 cm soil depth were investigated. Cultivation of former forests resulted in increased rates of NO_3^- leaching and basic cation leaching than cultivation of former savanna, which reflects the nutrient flux rate of the original vegetation. The 2-year NO_3^- flux in CR_{FR} (160 kg N ha^{-1}) was double that in CR_{SV} (78 kg N ha^{-1}), leading to greater 2-year K leaching in CR_{FR} (120 kg K ha^{-1}) than in CR_{SV} (37 kg K ha^{-1}). The K^+ concentration was negatively correlated with solution pH. Therefore, a low soil solution pH value, as observed in CR_{FR} (4.5–5.4) but not in CR_{SV} (5.5–6.6), would accelerate K^+ release from the soil. The ratio of 2-year nutrient losses to total soil stocks was the greatest for Ca in both CR_{FR} (5%) and CR_{SV} (4%), while K loss reached 5% only in CR_{FR}, which contrasts with 0.8% in CR_{SV}. Because the nutrient flux of savanna cropland is smaller than that of forest cropland, annual crops for subsistence such as cassava, which tends to cause nutrient depletion shortly, represent a feasible option for savanna cultivation with Ca input from outside resources. In forest croplands, however, the pump-up effect of deep-soil nutrients by plant root systems of forest vegetation should be utilized with external K, as well as Ca, input. Agro-forestry and/or mix cropping of trees with annual crops could be one of the feasible options for capturing leached nutrients from subsoil in forest regions of Central Africa.

Keywords: Ferralsols nutrient leaching sustainable agriculture land reclamation mineral dissolution
Financial support: JSPS KAKENHI (Grant Number 17H06171)

(1793 - 826) Effects of Potassium Budgets on Soil Fertility and Mineralogy

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A potassium (K) budget quantifies the net addition or removal of K from the soil. A complete budget accounts for all inputs and outputs from a given volume of soil. In practice, partial budgets are often used that account for only managed K applications and K removal by crop harvest. Potassium budgets can be performed at a variety of scales and are a useful sustainability indicator. Soil tests, as used in production settings, may not reflect K budgets. Additionally, both net K removal as well as net K addition can affect soil mineralogy.

Keywords: soil fertility, nutrient budgets
Financial support:

(7708 - 3157) Natural capital accumulation in agricultural soils under no till grain cropping in Brazilian Cerrado

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Brazilian agriculture experienced a great frontier expansion over the Cerrado region in the 70's. Area mostly covered with heavily weathered soils, the Cerrado was previously considered of marginal agriculture due to limited soil fertility. The agricultural production was extremely low or null as for no nutrient input practices. For soil mineralogy matters, inputs would have generally low agronomic efficiency, having most of the phosphorus fixed within soil sites not been available to plants. However, grain cropping has become economically viable as high input doses were applied, leading Brazil amongst major consumers of phosphate and potash fertilizers. In the beginning of the agricultural frontier expansion, soil management practices were predominantly mechanic operations including soil tillage and plowing. Traditional management practices have shown inappropriate, increasing soil erosion risk due to the Cerrado soil structure and tropical climate with heavy summer rains.Early 90's conservative practices, such as no till, start to grow fast among farmers. As consequence of these changes a fast decrease of soil erosion and a consistent increase of soil organic matter levels was observed. This new scenario has provided an increase of fertilizer use efficiency. However, farmers couldn't realize this and kept their standard fertilizer doses, been higher than nutrient exportation. This practice resulted in a gradual increase of soil fertility of agricultural soils of Brazilian Cerrado. The Brazilian Cerrado soil fertility database analysis has shown along the last decade a significant increase of soil samples having P content above critical levels. There are at least 11 million hectares of soils with buildup fertility. For these soils there is no economic response from fertilizer application. Field experiments on buildup fertility conditions at different agroclimatic regions in Brazil has not shown P fertilizer response for the first crop season. Under some conditions it was necessary up to 4 crop seasons to get P response. Regarding current Cerrado soils P recommendation (80 kg ha^{-1} P_2O_5), a 50 % decreasing in doses wouldn't result in yield changes in long term. There is an actual opportunity for reducing costs without affecting soil sustainability. According soil fertility monitoring responses, it is possible to increase fertilizer efficiency along with a rational use of nonrenewable natural resources.

Keywords: Phosphorus, phosphate, fertilizer, Residual P, buildup soil fertility, nutrient budget
Financial support:

(4670 - 228) Nitrogen balance affected by tillage, crop rotation, and cultural practice

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Accounting of N inputs and outputs and N retention in the soil provides N balance that measures agroecosystem performance and environmental sustainability. Because of the complexity of measurements of some N inputs and outputs, studies on N balance in long-term experiments are scanty. We examined the effect of eight years of tillage, crop rotation, and cultural practice on N balance based on N inputs and outputs and soil N sequestration rate under dryland cropping systems in the northern Great Plains, USA. Tillage systems were no-tillage (NT) and conventional tillage (CT) and crop rotations were continuous spring wheat (CW), spring wheat-pea (W-P), spring wheat-barley hay-pea (W-B-P), and spring wheat-barley hay-corn-pea (W-B-C-P). Cultural practices were traditional (conventional seed rates and plant spacing, conventional planting date, broadcast N fertilization, and reduced stubble height) and improved (variable seed rates and plant spacing, delayed planting, banded N fertilization, and increased stubble height). Total N input due to N fertilization, pea N fixation, atmospheric N deposition, crop seed N, and nonsymbiotic N fixation was greater with W-B-C-P than CW, regardless of tillage and cultural practices. Total N output due to aboveground biomass N removal and N losses due to denitrification, volatilization, plant

senescence, N leaching, gaseous N (NO_x) emissions, and surface runoff were not different among treatments. Nitrogen sequestration rate at 0-20 cm from 2004 to 2011 varied from 29 kg N ha^{-1} yr^{-1} in CT with W-P to 89 kg N ha^{-1} yr^{-1} in NT with W-P. Nitrogen balance varied from -39 kg N ha^{-1} yr^{-1} in NT with CW and the improved practice to 41 kg N ha^{-1} yr^{-1} in CT with W-P and the traditional practice. Because of legume N fixation and increased soil N sequestration rate, diversified crop rotations reduced external N inputs and increased aboveground biomass N removal, N flow, and N balance compared with monocropping, especially in the CT system. As a result, diversified legume-nonlegume crop rotation can be productive and environmentally sustainable compared with monocropping, regardless of cultural practices.
Keywords: Cropping system, Management practice, Nitrogen input, Nitrogen output, Nitrogen budget, Soil total nitrogen.
Financial support:

(5363 - 1935) Nutrient Budgets and Use Efficiency Indices in Grain Crops of Argentina

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Global demand for food, feed, fiber, and biofuels has driven a strong increase in grain production in Argentina, x3.7 between 1990 and 2016. This has been based mainly on a strong expansion of the planted area, especially soybean, and, to a lesser extent, on yield increases. Fertilizer use at Argentina has been historically low but it expanded sharply from the early 90´s, from 360 thousand t in 1993 to 3.6 million t of fertilizer products in 2016. A continuous increase was observed between 1993 and 2007, a slow down between 2008 and 2015, and a sharp recovery in 2016. The evolution of the fertilizer consumption was related to grain and fertilizer prices, and/or governmental policies. Field crops (soybean, maize, wheat, sunflower, barley and sorghum) explain approximately 80% of the total fertilizer consumption, with an average rate of 75 kg/ha of fertilizer product in 2016. The significant growth in fertilizer consumption helped to improve nutrient budgets in field crops, but these are still far from reaching levels considered sustainable. Removal of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) by grains from 1990 to 2016 was estimated at 26.6, 7.7, 18.6, and 4.1 million t, respectively. In the same time period, the application of N, P, K, and S in grain crops was of 10.7, 3.7, less than 1.0, and 1.0 million t, respectively. Thus, total nutrient replenishment was of 40%, 48%, less than 1%, and 26% for N, P, K, and S, respectively. Estimations of nutrient use efficiency indices, such as the partial nutrient balance (PNB, removal to application ratio) show values of 1.4 to 3.0 for N and 0.8 to 1.9 for P for the different grain crops as averages in the period 2011-2016. Estimations for partial factor productivity (PFP, grain yield per unit of applied nutrient), average 156 and 74 kg grain per kg N applied in maize and wheat, respectively, and 695, 386, and 265 kg grain per kg P applied for maize, soybean, and wheat, respectively. High PNB and PFP values would indicate a soil nutrient mining scenario, and the need to increase nutrient application rates to sustain high crop yields and soil quality conditions. Declining soil organic matter and extractable P, as well as growing deficiencies and responses to S and micronutrients, are evidence of the need to develop and implement 4R nutrient management practices in grain crops of Argentina.
Keywords: balances; fertilizer use; sustainability; soil quality
Financial support: IPNI, Fertilizar AC, and INTA.

(8898 - 2333) Nutrients balance of the main agricultural products of Uruguay, years 1990, 2000 and 2010.

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The structural changes of the last twenty years have been characterized by the increase in the intensity of soil use. The production in 1990 was of 3 millions t and in 2010 was 13 millions t, were the exported production means a 28% and a 65% respectively. It has been done a balance for the total production and other for the exported production, for the years 1990, 2000 and 2010. The inputs were the imported nutrients and the outputs were the nutrients of the productions considerer: wheat, soybeans, barley, rice, corn, sunflower, sorghum, sugar cane, citrus fruits, non-citrus fruits (peach, apple, pear and vine), vegetables (sweet potato, onion, potato, tomato, carrot and squash), forestry, beef, dairy, sheep and wool. These productions in 2010 represented 86% of the exportations in economic terms and 99% in surface. The data were obtained from the fertilizer import records and for productions were used the references source (MGAP, BCU, INAC and SUL) and the nutrients extraction were calculated with table for each product. The nutrients of the fertilized were taken to surface unit and then were assigned according to the occupy surface by the production that use this fertilizer in particular. In 2010 was observed an excess of N y P in the balance by the total productions, by N expressed as a fertilizer was of 163000 t of urea and by P as phosphorite of 347000 t, both represent a value of 46 millions of dollars. That balance change in N for each particular production, with excess in bovine meat, dairy and forestry, where the rest of the productions shows deficiencies. By K, Ca, Mg and S the tendency during that years went to the deficit, in 2010 was of 40, 15, 104, 12 thousands t of KCl, limestone, dolomite and sulfur respectively, in total represent a value of 21 millions of dollars. The exported productions on the three years maintains differences in all nutrients, due to the increase in exports of products with greater extraction per unit area. The replacement of nutrients should accompany the level of extraction to avoid the excess and differences in a scenario of exportation growing and thus contribute to a sustainable management of natural resource. Finally, in economic terms, they make evident the economic and productive inefficiencies, as well as potential environmental risks. These costs should be considered in the economical results of the productions.
Keywords: production, fertilizers, sustainability
Financial support:

(9450 - 1885) Should soil nitrogen be mined?

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Misunderstanding of the intricacies of nitrogen (N) cycling in agricultural soils has led to improper fertilizer N use in important global agroecosystems, ranging from excessive use to unsustainable exploitation (mining) of soil organic matter reserves. This must be addressed to avoid excessive N accumulation and to ensure adequate N reserve. Here we develop a framework for answering the question “Should soil organic N be mined, and if so, for how long?” to maintain sustainable agricultural production in major agroecosystems worldwide. Agricultural systems where external N input exceeds the capacity of the soil to form soil organic matter are prone to leak reactive N to the environment. Excessive additions need to be halted, and where excess reactive N remains in these systems it needs to be mined, at least for some time. In other agroecosystems, external N input is low and current use of the land mines N acquired through the mineralization of soil organic matter. Thus the paradox of mining soil organic N, where on the one hand it can be desirable for agroecosystem health and on the other threatens agroecosystem function. Untangling the paradox of mining soil organic N and revealing the residual effect of fertilizer N will answer the question of whether N use efficiency is as low as perceived. This has major implications for food security and environmental quality.
Keywords: Mining soil nitrogen, nitrogen use efficiency, agriculture

Financial support:

(1358 - 2569) The conundrum of low crop yields and negative nutrient balances in sub-Saharan Africa

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Crop production systems in sub-Saharan Africa (SSA) are characterized by low crop productivity and extremely negative nutrient balances that are driven by complex soil fertility constraints and low use of nutrients. Long-term historical trends of nutrient balances for SSA show large negative values, and losses of the most limiting nutrient, N, are estimated at 20-70 kg ha^{-1} annually. Analysis of the partial factor productivity for major crops in SSA shows very high values in excess of 100 kg grain/kg N and >200 kg grain/kg P and K. These large negative balances and high partial factor productivity values reveal over-exploitation of soil nutrient stocks, as farmers use low levels of nutrients in both organic and inorganic form, coupled with removal of nutrients in harvested produce and losses mainly through erosion. Fertilizer use in SSA is the lowest in the world with only an average of about 15 kg of nutrients applied per ha of cropland. The nutrient use trends also show a growing inclination to reinforce unbalanced nutrient use, with N application increasing notably between 2009 and 2017, while K application remained low and static during the same period. As a consequence, a trajectory of increasing N balance, stagnant P balance and decreasing K balance is emerging. Despite large negative nutrient balances, great inter-country variability occurs, with generally low balances in the more-productive east and relatively higher values in the central and western part of the continent. At low spatial scales, farms having good access to resources have positive nutrient balances, while balances tend to be negative for the large proportion of farms with fewer resources. Analysis of intensification pathways for smallholder agriculture in SSA highlight the need for increased and balanced use of fertilizer as an entry point to alleviate the prevalent and pervasive challenges of land degradation and negative nutrient balances. Investments in integrated soil fertility management (ISFM) technologies, including use of manure in integrated crop-livestock systems and increased production of legume crops, will also be critical to recapitalize soil nutrient stocks and soil organic matter following decades of soil nutrient mining.

Keywords: sub-Saharan Africa, negative budgets, degradation
Financial support:

(5636 - 1093) Why Do Smallholder Farmers in Papua New Guinea, Fiji, Kiribati, The Philippines and Central West Africa Not Invest in Management of Soil Fertility?

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As livelihood expectations (better education for children, better housing, better food security, better financial security) increase for many tropical rural farming communities, there has been a shift to incorporating commercial market-oriented farming into traditional subsistence farming systems. Thus a previously nutrient-conservative system (subsistence farming) has changed to a nutrient export system as crops (and nutrients within them) are moved from the farm to the market place. However, many farmers do not invest in nutrient mangement strategies because they are either unwilling, unable, or do not understand the importance of long-term nutrient management to maintain soil fertility. This paper, based on over 25 years of observation, discusses the many and varied reasons (disincentives) why smallholder farmer families in Papau New Guinea, Fiji, The Philippines, Kiribati and Central West Africa do not invest in maintenance of soil fertility even though the long term maintenance of soil fertility is absolutely vital for long term improvements in livelihoods. Such reasons include lack of land tenure; but also include unexpected reasons such as lack of road infrastructure and lack of access to a bank account.

Keywords: soil fertility, smallholders, disincetives
Financial support: CSIRO

C3.3.3 - Advancement of plant nutrition studies for sustainable agriculture

(6409 - 2104) Canola Root System Architecture Response to Urea, Urea Ammonium Nitrate, and Ammonium Sulfate.

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The banding of nitrogen fertilizer below seeds is common practice in dryland wheat production regions using no-till or reduced tillage systems. With the addition of canola into a wheat dominated rotation it is important to re-evaluate the implications of banding nitrogen fertilizers on root systems architecture (RSA). Canola plants have a tap root system which has previously been shown to be more susceptible than the fibrous root system of wheat to fertilizer banding below the seed. In this study we examine the interactions between fertilizer source (urea, urea ammonium nitrate, and ammonium sulfate) and the rate at which the fertilizer is applied on the root system architecture of canola. High temporal and spatial resolution image data of root system architecture was collected using flatbed office scanners. The image data was analyzed and tap root depth and branching rates were measured. Dose response curves were fitted for each fertilizer source. The order of toxicity of the fertilizers were urea > ammonium sulfate > urea ammonium nitrate. This data can be used to establish safe planting guidelines for land managers trying to maximize the amount of nitrogen they can apply in a single pass no-till system while protecting the root system from the adverse effects of over fertilization.

Keywords: Root, Right Source, Right Rate
Financial support: Washington State OIlseed Commission

(6084 - 2454) Efficiency sulfur sources for the corn crop

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Although production has grown in recent years, average grain yield in Brazil has remained stable, and can be improved. One of the hypotheses of this stagnation is the deficiency of sulfur (S) in the soils, due to the frequent use of fertilizers without S and the low use of gesso by the producers due to its high cost, mainly in the Cerrado. To meet S demand for crops, fertilizers containing elemental S, are being marketed frequently. However, little is known about an application of the source in tropical soils. The objective of this study was to evaluate the effect of sources and rates of S on the dry mass and accumulation of S in plants and corn grain yield. The experiment was conducted under field conditions, in Andradina-SP in a Oxisol sandy texture, low S content (<5 mg dm^{-3}) in a factorial 2x5, and two sources are applied in the planting furrow, ammonium sulphate (AS) and elemental S + bentonite (S^0) and five levels: 0, 5, 10, 25 and 50 kg ha^{-1} S, distributed in a DBC with 4 replications. The efficiency of the sources was evaluated through the yield of dry mass and the accumulation of S in plants at 30 days after sowing and grain yield. Soil S-SO_4^{2} levels were also determined at depths of 0-0.2 and 0.2-0.4 m after maize harvest. The data were analyzed through analysis of variance, comparison of means (Tukey's test) and regression analysis at 5% probability. There

was interaction between sources and sulfur doses for the variables dry mass, accumulation of S in plants and yield. Interaction occurred between rates and sulfur sources for variables and S dry mass in plants, and in both occurred only for setting SA dry mass: y = 563.34+20.86X-0.418X^2 accumulation and S y=0.96+0.078X-0.0014X^2. Regarding the productivity of corn was observed interaction between sources and rates S, S^0 adjusted to a linear model: y=8125+19.6X and AS the exponential model y=7849+1477(1-exp(-0,179X). The maximum yield with the use of AS, was obtained with the application of about 17 kg ha^{-1} of S in the planting furrow. In relation to the S content in the soil, we observed only effect of doses and sources, without interaction. At depth of 0-0.2 m the sulfur levels were: AS, 5.65a and S^0, 3.71b and at depth of 0.2-0.4 m the sulfur levels were: AS, 6.47a and S^0, 4.87b. In relation to the effect of the rates, there was a quadratic effect at a depth of 0-0.2m (y=2.14+0.27X-0.004X^2) and linear at 0.2-0.4m (y=3.71+0.11X). Ammonium sulfate was more efficient than elementary sulfur.

Keywords: fertilizer; ammonium sulphate;elemental sulfur; plant nutrition
Financial support: CAPES; FUNDAG

(6531 - 2536) Enhancement of site specific nutrient management (SSNM) approach for rainfed rice: Framework and Advantages.

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Productive and sustainable agriculture is dependent majorly upon soil nutrient management and field moisture condition. Yields of the crops have reached a plateau or are on the decline. Excessive fertilizer application has caused climatic imbalance affecting soil and water quality. For rainfed rice, low soil nutrient and moisture stress is a major yield constraint and these need to be monitored to reduce risk and increase resilience. Recognition of within-field variability in soil characteristics, crop nutrient need, nutrient supply and crop yield, by Site-Specific Nutrient Management (SSNM) is gaining popularity as technology advances. Furthermore, transfer of this information on real time basis at times when it is required, lay the foundation for sustainable information. *Rice Crop Manager* (RCM) is one such tool developed by International Rice Research Institute (IRRI) in 2013, which uses principles of SSNM, is available for use by extension workers and farmers to guide them through the decision making process. While RCM has effectively improved rice productivity in favourable environments, there is still scope to enhance the robustness of the tool to provide recommendations to further enhance the capabilities of RCM in meeting the emerging needs of rainfed rice farming in a changing climate. The present study has been implemented in farmers' fields from the different blocks of 11 districts of Odisha, India to test the effectiveness of RCM guidelines provided to farmers in rainfed environments with use of more suited stress tolerant rice varieties remote sensing, crop modelling and weather data for in-season adjustment of real-time nutrient management and better decision making process. The mean percent yield gain with use of SSNM guidelines in local variety (LV) was 17.7 and was 18.6 with stress tolerant rice variety (STRV). The mean percent yield gain by using SSNM+STRV over farmer's practice (with local variety and self-guided fertilizer use) was 27.9 with net benefit of 202 US$/ha. Geographic Information System tool (GIS) uses conditions and environment prevailing in the area to estimate the yield. GIS based target yield approach results net fertilizer saving of 29 US$/ha and percent agreement of 74.3 percent over the estimated yield. Integration of information from these studies can positively help to use RCM for rainfed rice and make it automated through use of GIS tool for estimating target yield, thus increasing the outreach.

Keywords: *Rice Crop Manager* (RCM), GIS, target yield, rainfed rice
Financial support: Govt. of Odisha, ICAR, RICE CRP

(1935 - 426) Evaluation of Polyhalite for Grain Production in Pampean soils of Argentina

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Polyhalite is a natural fertilizer which contains 19.2% of sulfur (S), 14% of potash (K_2O), 12% of calcium (Ca), 3.6% of magnesium (Mg). The objective was to evaluate the effect of Polyhalite on the grain yield of soybean, maize, and wheat in Pampean region, Argentina. Four field trials were conducted in Mollisols in the 2016-2017 season, two in 9 de Julio with wheat and maize, and two in Mercedes with soybean and maize. The experiments had six treatments based on different sources of S to apply at sowing a single rate of phosphorus (P) and S with fertilizer combinations. (1) A control of regular MAP with no S applied; (2) single superphosphate (SSP, 0-20-0-12S); (3) a bulk blend of MAP (0-52-0-0S) with gypsum (0-0-0-17S); (4, 5 and 6) bulk blends of MAP with Polyhalite at three rates (100, 200 and 300 kg/ha), which supplied increasing amounts of S, K, Ca and Mg, but all the same P_2O_5. All fertilizer treatments were applied at sowing. The maize and wheat received a banded fertilization with N as urea or UAN at V6 and at tillering stage of each crop respectively. Significant increases in grain yields in response to S fertilization were found for all crops in both locations. However, the contribution of K and Mg to give yields above the S applied treatments varied among the site and crops. No differences were found among S sources in 9 de Julio for either wheat or maize. On the other hand, in Mercedes, there were statistical differences for both maize and soybean among the Polyhalite and the other S sources treatments. The average response to S was 19%, but the contribution of Polyhalite over the other treatments that received S was about 7%. Soybean in Mercedes showed the biggest response to Polyhalite with 313 and 573 kg/ha of increase over other sources with the same level of S, indicating the response to the contribution of K or else, since to site was low in exchangeable cations. In the same location, maize did not respond to K or other cations contained in Polyhalite, likely due to short N supply or other production factors, since highest yield was significantly below the potential yield of the location. We can conclude that Polyhalite is a suitable source for S supply of grain crops of Argentina, as good as others currently used in bulk blends with P fertilizers. Moreover, Polyhalite use might result in further gains in yields where soils do not have adequate levels of K, or when is not normally supplied in the regular fertilizer programs.

Keywords: *sulfur response, potassium supply, starter fertilizers*
Financial support: International Potash Institute

(4820 - 2607) Genotypic variation in tolerance to low pH and Aluminium toxicity in chickpea and wild Cicer

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Soil acidity restricts plant growth mainly due to the toxicity effects of soluble Al and Mn. Deficiencies of Mo, N, P, Ca and Mg can also occur in acid soils. In Western Australia, Al toxicity is most prevalent on acid soils. Under pH_{CaCl2} less than 4.5, some forms of aluminium are solubilized to release Al^{3+} and $Al(OH)^{2+}$, ions that are highly toxic to roots and bacteria. Aluminium toxicity inhibits cell division and reduces root elongation of plants. Such effects on root growth not only impair nutrient acquisition by crops but may also exacerbate drought by restricting access of roots to soil-soil water storage. Chickpea *(Cicer arietinum* L.) is reported to be highly sensitive to Al toxicity. While considerable genotypic variation in Al tolerance occurs within many species, there has been limited examination of variation for chickpea or its wild relative. The objective of this research was to

identify chickpea and wild Cicer germplasm that are tolerant to low pH, high Al conditions. Thirteen domesticated chickpea varieties were tested in dose response experiments (low pH 4.2 and +/- Al 0 to 90 µMol). In an initial experiment with 5 cultivars there was no effect of the treatment by cultivar interaction. There were significant decreases in root and shoot weight with increasing Al concentration from 15 to 90 µM. The lowest Al concentration that showed a significant decline in root and shoot growth was at the 30 and 45 µM Al levels. In a second dose experiment on 8 additional chickpea cultivars there were significant differences in root and shoot weights, and length of the longest root (LLR), with each increase in Al concentration from 0 to 15 to 30 µM. There was no difference in seedling growth between the 30 and 60 µM treatments. PBA Pistol was the cultivar that had the greatest LLR, and root weight. Within the treatment by cultivar interaction, PBA Pistol had a greater LLR at 15 µMol Al than all other cultivars and similar LLR to some of the cultivars with no Al in solution. Screening of 118 wild *Cicer* accessions in solution culture has been completed at pH 4.2 with 15 and 60 uMol Al. Within these accessions there is variation in LLR, root tolerance index and root and shoot weights that indicate there is some potential for tolerance of wild *Cicer* accessions to low pH, high Al conditions.

Keywords: soil acidity, chickpea
Financial support: Grains Research & Development Corporation (GRDC), Project Number UMU00044

(5773 - 1945) Growth and physiological aspects in tomato genotypes in response to boron supply

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Boron (B) is an essential microelement for plant growth and development but both its deficiency and toxicity are a major issues affecting crop yields. Notably, the soil concentration range between B deficiency and toxicity is generally narrow. Compelling experimental evidence suggest that ethylene is likely involved in root responses to B levels. To further understand the connections between ethylene and B here we investigate the function of ethylene underlying growth and physiological responses to deficiency and excess of B in tomato (*Solanum Lycopersicum*) by using ethylene mutants. The plants were germinated and transplanted to pots with Hoagland nutrient solution, the experimental design was randomized block, with three genotypes, Micro-Tom (WT), *nor* (nonripening) and *rin (*ripening inhibitor), which block ethylene perception and inhibit fruit ripening, three conditions of B supply, namely deficiency (0 µmol L^{-1}), adequate (25 µmol $L^{-1}$and excess (640 µmol L^{-1}), four repetitions. A multiple comparison between means by the Tukey test followed and individual ANOVA ($p<0.05$). Our results show that both B deficiency and excess inhibit plant growth. Under B excess, visible symptoms of toxicity appeared in roots, but also the margin of older leaves appeared burned. Photosynthesis, transpiration, stomatal conductance, intercellular CO_2, SPAD, electrolyte extravasation and chlorophyll fluorescence were reduced in all genotypes at both B deficiency and excess. Ethylene mutants (*nor* and *rin*) presented similar responses but were distinct from the WT particularly for SPAD and specific leaf area parameters. The physiological responses differed significantly among the genotypes in the different supplies of B. The current study revealed that B deficiency and toxicity affect plant growth most likely by impairments in several physiological processes that are mediated by ethylene. Furthermore, our results suggest that B may play an important role in regulation tomato growth, besides triggering response in the ethylene mutants.

Keywords: Ethylene; boron-deficiency; boron-excess
Financial support: This work was supported by funding from the Max Planck Society, the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq-Brazil), and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG-Brazil). We also thank the scholarship

(4609 - 1266) Improvement of soil fertility and biodiversity by beneficial microorganisms isolated from natural environment

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Sustainable agriculture is constantly looking for innovative products, which improve soil properties in order to obtain higher yield and to minimize negative environmental impact. Organic matter in soil is one of the basic indicators of soil quality. It affects physicochemical properties of soil, biological activity, stabilizes soil structure and reduces susceptibility to degradation by water or air erosion. Content of organic matter in agricultural soils is being reduced by about 2% annually, therefore there is a need to effectively increase the content of humus compounds and biodiversity, which are one of the most important factors affecting soil fertility. INTERMAG R&D center has developed product based on microorganisms isolated from natural environment, which allows for the effective use of nutrients contained in soil and crop residues. *Bacillus subtilis* and *Bacillus licheniformis* used in product, have been selected from over 200 bacterial strains by analyzing kinetics of specific enzyme synthesis according to the method using 3,5-Dinitrosalicylic acid (DNS). Both strains of bacteria multiply rapidly in the soil, transform organic matter into humus and increase content of plant available nutrients. This contributes to improving soil structure, increasing water and sorption complex capacity and enhancing microbiological biodiversity and activity of soil. Additionally, *Bacillus spp*. used in the product, can solubilize insoluble forms of phosphorus and therefore increase the content of plant available form of this nutrient. These factors contribute to better plant growth and higher yield. The effectiveness of both strains of bacteria has been confirmed in numerous experiments carried out in independent scientific units and on farms by end users.

Keywords: Microorganisms, Soil Fertility, Plant Growth, Plant Nutrition, Biofertilizers,
Financial support:

(3551 - 335) Improving nitrogen use efficiency through balanced N and S supply for optimal canola production

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Improving nitrogen use efficiency through balanced N and S supply for optimal canola production B. L. Ma Ottawa Research and Development Centre, Agriculture and Agri-Food Canada, Ottawa, ON, Canada, K1A 0C6 (baoluo.ma@agr.gc.ca) Balanced plant nutrition is essential to achieve high yields of canola (*Brassica napus* L.) and get the best economic return from applied fertilizers. A field study was conducted at 9 site-years across eastern Canada to investigate the effects of nitrogen (N) and sulfur (S) fertilization on canola nutrient uptake, nutrient stoichiometry, and their relationship to canola yields. Fertilizer S application greatly improved seed yields at six out of nine site-years, and the highest N use efficiency was in the N150+S20 treatment. Sulfur application generally increased seed S concentration, seed S removal, and plant total S uptake. At the early flowering stage, plant tissue S ranged from 2.2 to 6.6 mg S g^{-1}, but the N:S ratio was over or close to the critical value of 12 in the N150+S0 combination at 5 site-years. On average across 9 site-years, canola reached a plateau yield of 3580 kg ha^{-1} when plants contained 197 kg N ha^{-1}, 33 kg S ha^{-1} and 200 g B ha^{-1}. The critical N and S values

identified in this work and their potential for posteriori nutrient diagnosis of canola should be useful to validate fertilizer requirements for canola production in eastern Canada. Keywords: *Brassica napus;* nutrient balance; critical concentration; nutrient removal; Sulphur; nitrogen use efficiency

Keywords: *Brassica napus*; nutrient balance; critical concentration; nutrient removal; Sulphur; nitrogen use efficiency
Financial support: Agriculture and Agri-Food Canada (AAFC), Eastern Canada Oilseed Research Alliance (ECODA), Canola Council of Canada (CCC)

(3505 - 1274) Interactions between selenium and cadmium in soil and crop: can Cd content in crops be controlled by Se fertilization?

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Concern that the dietary cadmium (Cd) intake with food, mainly through cereals and vegetables, may come close to the maximum recommended level [1] requires to find mitigating strategies. Even crops produced on arable soils where Cd concentrations are not above native background concentrations may contain high Cd levels. Finding strategies to mitigate Cd uptake by crops is essential but also challenging. One possibility is to identify fields with high risks for Cd accumulation and use crops as fodder. However, a large spacial variability of Cd in soil constrain soil Cd mapping [2]. Liming as an option reduces labile Cd, decreasing Cd contents in crops, but Cd-rich soils are often also calcareous. A recent option discussed is to what extent selenium (Se) fertilization can be a possibility to mitigate Cd in wheat [3]. Selenium, an essential element for humans and animals, is known to be involved in Cd toxicity alleviation. Furthermore, dietary Se intake can be low or below the recommended level and Se deficiency affects 1 in 7 people worldwide [4]. Cereals represent the major source for Se in most diets [5]. Hence, if controlled Se fertilization can increase Se and reduce the Cd contents in crops, this would be a win-win situation by 1) decreasing the concentrations of Cd in food, 2) increasing Se intake avoiding possible deficiency, and 3) reducing Cd toxicity in humans due to sufficient Se supply. About 40 articles have been published during the last decades about interactions between Cd and Se in plants. We reviewed the data from the articles. A large variability in the experimental conditions and results required stringent evaluation in order to come up to conclusions about the efficiency of Se fertilization. The outcome of the meta-analysis, showing encouraging results, will be presented. Moreover, unpublished data, from 7 field experiments in Sweden, of the impact of N fertilization on Se-Cd interactions will also be included. [1] EFSA. 2009. The EFSA Journal 980, 1-139. [2] Söderström, M., and Eriksson, J. 2013. Geoderma 192, 323–334. [3] Rizwan, M., Ali, S., Abbas, T., Zia-ur-Rehman, M., Hannan, F., Keller, C., Al-Wabel, M.I., and Ok, Y.S. 2016. Ecotoxicol. Environ. Saf. 130, 43–53. [4] Jones, G.D., Droz, B., Greve, P., Gottschalk, P., Poffet, D., McGrath, S.P., Seneviratne, S.I., Smith, P., and Winkel, L.H.E. 2017. Proc. Natl. Acad. Sci. 114, 2848–2853. [5] Rayman M.P. 2012. Lancet 379, 1256–1268.

Keywords: Selenium, Cadmium, Meta-analysis, Food security
Financial support:

(1757 - 359) Polyhalite efficiency as source of sulfur for soybean and cotton in Brazil

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Soybean and cotton are two important crops in Brazilian Cerrado. The management of fertilization is an essential strategy to reach higher yields and profitability, and to maintain sustainability of farmers. The aim of the researches was to evaluate the effect of the mineral fertilizer Polyhalite as a source of sulfur for soybean and cotton in Brazil. Polyhalite is a natural fertilizer extracted from a single crystal complex with two molecules of water of crystallization, the chemical formula of the mineral is: $K_2Ca_2Mg(SO_4)_4.2(H_2O)$, and it contains 19.2% of sulfur (S), 14% of potash (K_2O), 12% of calcium (Ca), 3.6% of magnesium (Mg). One important characteristic of Polyhalite is the slow release and higher availability of nutrients, especially in relation to S. Two trials were conducted at Rio Verde Foundation farm, in Lucas do Rio Verde, Mato Grosso, Brazil. Soybean trial had 6 treatments and 4 replications comparing Polyhalite, single superphosphate and pastilled elemental sulfur as sulfur sources, in broadcast or furrow application. Cotton trial had 8 treatments and 4 replications comparing Polyhalite and ammonium sulphate as sulfur sources, in broadcast application and different times of fertilization. Polyhalite was found to be viable for use in soybean fertilization, both for broadcast or furrow application, and the yields were higher than the other treatments, being an excellent source of sulfur and other nutrients for the crop. In cotton trial, better yields were with ammonium sulphate applied 20 days after sown, Polyhalite applied 5 days after sown, and Polyhalite splited at 5 and 20 days after sown. Polyhalite was an effective sulfur source to cotton fertilization, achieving yield statistically equal to other commercial sulfur sources.

Keywords: Polyhalite, sulfur, soybean, cotton
Financial support: International Potash Intitute; ICL Fertilizers

(7231 - 1905) Potassium nutrition and coffee quality

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The potassium chlorine is the main fertilizer used to supply potassium in crop fertilization, including coffee trees. Due to the high saline level of KCl (116) and chlorine concentration (48 % w w^{-1}), high doses of this fertilizer could negatively affect seeds germination, productivity and fruit quality. The aim of this study was to evaluate the effect of two sources (KCl e K_2SO_4), varying doses of nutrient (60, 120 e 250 mg dm^{-3} of K) in soil K availability (Mehlich -1), productivity (variety IAC 44) and coffee beverage quality. Coffee plants has been cultivated for four years in green house conditions, in plastic pots with 50 dm^3 of soil (Oxissol Yellow Red). Liming and fertilizers with N, P, K, S and micronutrients were applied aimed to not limit the growth and productivity. The treatments were distributed on randomize blocks with six replications. Representative soil samples of each pot were collected before the treatments application (July August) and in grain filling stage (February March), during two consecutive years. The K fertilizers were applied in October and February (50 % each aplication). The fruits were harvested in four phases, between May and August, removing only the ripe fruits. They were left 24 h immersed in water and later pulped, after were separated the heavier (cherry) and the lighter (float) fruits. Dry process was accomplished in the green house, until the fruits to reach between 10 and 11 % of moisture content. Posteriorly, the coffee beans were stored in cold chamber until the preparation of samples to toast and tasting. The beverage quality was evaluated by four certified testers (Q-graders) based on sensorial criteria, clean cup, flavor, sweetness, acidity, mouth feel, after taste and balance, on a scale score ranging between 36 and 100. When better are the quality of beverage evaluated, higher are the scores. Effects of sources and doses of K were observed in the quality of coffee beverage. The lower scores (y = 79,81) were obtained when KCl was applied in high doses (250 mg dm^{-3}). On the other hand, the higher scores (y = 85,38) were achieved for K_2SO_4 in the dose of 120 mg dm^{-3}. For this same dose of K (120 mg dm^{-3}) the average note (y = 84,81) was obtained when the source was KCl. In conclusion, higher doses of KCl can negatively affect the quality of coffee beverage, and these effects may be the result of excessive Cl^- and/or salinity.

Keywords: potassium chlorine, potassium sulfate, *Coffea arabica*, beverage
Financial support: Capes

(2127 - 1826) Selenium uptake by different plants as affected by characteristics of Some Egyptian Soils

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Selenium (Se) is an essential micronutrient for humans and animals and some species of microorganisms but lead to toxicity when taken in excessive amounts. Plants are the main source of dietary Se, but essentiality of Se for plants is still arguable. However, Se at low doses protects the plants from variety of abiotic stresses such as cold, drought, and metal stress. Selenium induced oxidative stress and distorted protein structure and function are the main causes of Se toxicity in plants at high doses. Soils in certain regions of the world included Egypt are Se-deficient while others are becoming Se-toxic due to natural and anthropogenic activities. Both the problems of Se deficiency and toxicity are harmful to humans and animals. WHO has recommended 50–55 µg/day Se in human diet all over the world. In humans, Se deficiency occurs when dietary intake of Se is (<40 µg/day) and chronic toxicity is observed above levels of (>400 µg/day). The objective of this study was to investigate the Se uptake by different plants grown in soils at different regions in Egypt as effected by indigenous soil properties. Soil samples from different depth (0-30, 30-60 and 60-90 cm) were collected from different Egyptian regions (*i.e.*, Matrouh, El-Arish, El-Hesynia Plain, El-Tina Plain, El-Mansoura, El-Gabal EL-Asfar, and El-Fayoum and Toshki). At the same regions, plant samples were collected from different plants grown in such as parsley, tomato, watercress, egg plant, alfalfa, wheat, onion, corn, olive, guava, mango and cotton. The results indicated that the total and available Se in soil were different depending on the soil location, soil sampling depth and the soil characteristics. The parent material is one of the most important factors controlling the Se content in Egyptian soils. The soils which resulted from fluvio lacustrine deposits were higher in Se content, whereas the lowest one from aeolian deposits. The Se uptake in different plants ranged from 0.024 to 0.490 mg. kg^{-1} dry matter. This variation was accordance with soil locations and properties.

Keywords: Plant Se uptak; total and avialble Se; soil proparties; parent materials, Egypt
Financial support:

(9426 - 1864) Short-term response and nitrogen use efficiency of biogas residue application on different soils cultivated with wheat

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The demand for sustainable energy sources risen worldwide in recent years. In Germany, biogas energy is one of the faster growing renewable sources, chiefly because it entails a small carbon footprint. However, biogas production creates a lot of residues, which can be used as an attractive organic fertilizer, since it enables the recovery of elements that were used for crop fertilization. Despite the use of N mineral fertilizers is well-known, studies evaluating the use of biogas residue as a N source on field level and particularly on different soils are still scarce. Therefore, the aim of the study is to evaluate the N-use efficiency and to investigate the influence of different soils on the fate of N from biogas residue in the soil-plant system. Field trials were conducted in Dürnast, where pits with 1.5 x 2.0 x 0.3 m were excavated and re-filled with distinct soils from 8 regions in Bavaria. During the 2-year experiment (2016 and 2017), winter wheat followed by spring wheat was grown on the plots. In addition to residue application, plots fertilized with ammonium sulfate and unfertilized plots were also investigated. In the fertilized treatments, N application was split into 3 doses, according to practices adopted by regional farmers. The application of biogas residue was interspersed with two mineral fertilizations, amounting to 40-100-40 N $kg.ha^{-1}$ based on NH_4-N content. Practices to avoid N volatilization were implemented. In order to evaluate the N dynamics, fertilizers were enriched with the isotope ^{15}N. In different growing stages, plant and soil samples were taken to measure N content, biomass and grain yield, as well as to quantify the ^{15}N, which permits the identification of the N source. Spectral reflectance measurements were assessed in the field with the Greenseeker and HandySpec spectrometer devices to track the development of plants, biomass and N uptake. The results showed no significant differences in yield between both fertilized treatments, what could encourage the use of biogas residue by farmers. However, a soil influence during the first experimental year was observed. The proportion of N uptake by plants from fertilizer or soil pool varied, mainly due to the initial amount of residual N in soil and soil texture. Sensors proved to be very efficient and highly indicative to evaluate plant properties, with the benefit of easy use and fast results, without the need of destructive plant sampling. Further results will be presented.

Keywords: biogas residue; N stable isotope labeling; field-spectral measurements
Financial support: National Council for Scientific and Technological Development (CNPq – Brazil)

(5732 - 1669) Solubility of Ten Iron Fertilizers in Eleven North American Soils

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University of Florida[1]; North Carolina State University[2]; Auburn University[3]; Ohio State University[4]; Mississippi State University[5]; University of Nebraska[6]; New Mexico State University[7]

Iron (Fe) is a common component of granular fertilizers applied to horticultural and agricultural crops. Chelating agents are required to maintain Fe solubility and increase plant uptake. Numerous products are marketed Fe chelates but few have been confirmed to increase Fe solubility is soils. The objective of this study was to determine the solubility of Fe from ten common Fe sources applied to eleven North American soils. Brookston, Cecil, Fuquay, Hallandale, Marietta, Marvyn, Nunn, Pinavetes, Stephenville, Troup, and Zook soils were incubated with soluble Fe applied as sulfate, glucoheptonate, polysaccharide, humate, oxide, citrate, IDHA, EDTA, DTPA, or EDDHA. At 1 h, 1 d, 1 wk, 2 wks, and 3 wks, soils were extracted with 0.01 mol L^{-1} $CaCl^2$ and analyzed for Fe. In each soil 1 h after application, greater than 99% of applied Fe was rendered insoluble from each Fe source except from IDHA, EDTA, DTPA, and EDDHA. The chelates EDTA, DTPA, and EDDHA increased Fe solubility for 3 wks after application with solubility ranging from 5 to 40% of applied Fe. The organic chelate IDHA increased Fe solubility in most soils for 1 d, but soluble Fe from IDHA declined to untreated soil levels thereafter. Granular Fe fertilizers should be limited to IDHA, EDTA, DTPA, or EDDHA.

Keywords: iron, iron chelate, solubility
Financial support: N/A

(4148 - 2058) The chemical properties and fungal community composition in vermicompost as endproduct with different co-composting techniques

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The role of earthworms as soil or compost environment activators is significant. The vermicomposting includes organic waste turnover which is a time consuming process. The usage of composting process activators or supporting materials could be suggested to speed up the organic matter degradation or to gain higher quality of the end product. Increasing the metabolic, reproductive and feeding rate of earthworms by enhanced microbial communities could promote the vermicomposting process. However, there are still many uncertainities by vermicomposting. For instance the plant pathogen persistence. It is reported that number of plant pathogens will be suppressed by passing the earthworm gut, the end product quality is still not clear. In vermicomposting the thermophilic phase is not applyed because of heat intolerance of earthworms. It is not so clear whether the patogenic organisms survive the production process and how many fungal organisms are eliminated during the vermicomposting. The organic substrate digested by earthworms should benefit from the effective microorganisms (EM), bokashi technology and biochar application. The current study was initiated to find out the influence of EM, bokashi and biochar application during the vermicomposting on *Eisenia fetida*. We wanted to find out if there are differences in fungal communities on used application materials to composting. The metabolic and reproduction rates of *E. fetida* were measured and analyzed in parallel with the chemical changes in soil matter. The living culture of *E. fetida* was introduced in each module with organic food waste. The treatment with EM, bokashi or biochar was carried out (control, EM treatment, bokashi, biochar). The metabolic rate of *E. fetida* was measured as indicator to the treatment or application materials. High-throughput sequencing technology was applied to find out which fungal organisms are still present in end products of differently treated composts. In total 16 compost and 16 earthworm samples were collected on different substrates of four experimental variants. As result we found that earthworm metabolic rate was related to the nutrient and enzyme content in substrate. Also, the enzymes activity was influenced by the treatments. We also found differences of fungal community compositions between variants where effective microorganisms, bokashi or biochar were applied during the vermicomposting.

Keywords: vermicomposting, effective microorganisms, biochar, bokashi, molecular identification
Financial support: Estonian University of Life Sciences, developmental fund (6HMX170049PKML)

(2344 - 2605) The importance of soil-applied Cu at sowing for canopy photosynthesis and pod yield of peanut grown on low Cu sand

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The importance of soil-applied Cu at sowing for canopy photosynthesis and pod yield of peanut grown on low Cu sand Thinh Nguyen Thai[1], Mann Surender[2] and Bell Richard[2] [1]ASISOV, Qui Nhon, 8200, Vietnam,(thinhvasi2003@yahoo.com); [2]Murdoch University, Murdoch, Western Australia, 6150 On sands, copper (Cu) deficiency is quite common. Peanut (Arachis hypogaea L.) is well adapted to sands. However, the mechanism of uptake and delivery of Cu from soils to other organs of peanut, particularly for pod growth in the soil, is not clearly understood. The aim of this study was to (i) determine the effect of time of application of Cu to soil (sowing, flowering and podding) on the distribution of Cu from root to different organs of peanut; and (ii) determine whether Cu affects peanut yield by improving viability of pollen or increased rate of leaf photosynthesis. A low Cu sand (DPTA Cu: 0.17 mg/kg) was treated with purified basal nutrients applied as solutions to 10 kg aliquots of soil that had been air-dried, seived and throughly mixed. Basal fertilizers were applied at the following rates (mg/kg): KH2PO4 , 90.7; K2SO4, 174.3; CaCl2.2H2O, 98.0; MnSO4.4H2O, 14.7; MgSO4.7H2O, 23.3; H3BO3, 0.14; CoSO4.7H2O, 0.4 ; Na2MoO4.2H2O, 0.2. The experiment had four Cu treatments with four replicates viz: T1 : Control (no Cu); T2: mixing 0.33 mg Cu/kg soil (~ 1.3mg CuSO4.5H2O/kg) before sowing; T3: adding Cu at flowering stage with 0.33 mg Cu/L solution (~0.33 mg Cu/kg); T4: adding Cu at podding stage with 0.33 mg Cu/L solution (~0.33 mg Cu/kg). Triple deionized water (TDW) was added to soil to reach field capacity (13 %, w/w) and was maintained daily. The application of Cu to soil before sowing produced the highest yield of peanut. The Cu applied later at flowering and podding was less effeective in incresing yield. Copper application increased the rate of photosynthesis of young mature leaves while it had no significant effects on pollen viability of peanut. Hence, mixing of Cu fertiliser at sowing appears most effective for Cu uptake by peanut including supply to the pods underground. The increase in peanut yield can be attributed to increasing leaf photosynthesis rather than pollen viability of peanut. Key words: Soil-applied Cu; photosynthesis; peanut; sand

Keywords: Soil-applied Cu; photosynthesis; peanut; sand
Financial support: ACIAR, project SMCN/2012/069

(9263 - 241) Ultrastructure characterization of manganese toxicity symptoms in soybean plants

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São Paulo State University - UNESP - Ilha Solteira[1]; University of São Paulo (USP)[2]

Manganese (Mn) is an essential element in plants that participates in protein structure and phosphorylation enzymes. However, its excess is also harmful because of toxicity to plants. The present study hypothesizes that the soybean tolerance mechanism to excess Mn is a direct result of interaction with calcium. Based on the this information, the present study sought to evaluate tolerance mechanisms and characterize Mn toxicity symptoms in soybean plants by energy-dispersive X-ray spectroscopy (EDS) techniques for studies on the localization of Mn and other nutrients in the cells of plant tissue. Soybean seeds of the variety BMX Potência RR were germinated in plastic pots with vermiculite. After 5 days of plant adaptation in the nutrient solution, Mn treatments of 2 and 300 µmol L^{-1}, with 100% ionic strength of the nutrient solution were applied. Via the EDS technique, the distribution of the nutrients K, Ca, Mn, Mg, and P was characterized in the necrotic area caused by Mn toxicity in soybean leaves. The other essential elements with potential characterization by scanning electron microscopy showed no change in the distribution pattern. The greatest intensity outside the lesioned area was observed for K, characterizing an antagonistic distribution effect with Mn and Ca between the healthy and lesioned area. A greater intensity of Mn and Ca was observed between necrosis and the uninjured leaf tissue. For Ca, the highest intensity was observed in the necrotic tissue. The results of the present study enhance the understanding of several basic mechanisms of Mn toxicity in soybeans, which are still poorly understood.

Keywords: manganese, soybean, phytotoxicity
Financial support: São Paulo State University - UNESP - Ilha Solteira

C3.3.4 - Greenhouse gases emissions associated with fertilizer use

(8554 - 808) Determining the mechanisms of N_2O emission using ^{15}N tracer in paddy soil planting with WDR variety under different water management

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Breeding new rice varieties that show increased drought tolerance and an ability to retain water may be an effective way to sustainably address the water scarcity issue. In recent years, a series of new rice varieties have been developed and are called Water-saving and Drought-resistance Rice (WDR). They are characterized by having a similar yield potential and grain quality, but require less water. Water management techniques could effectively mitigate CH_4 emissions from irrigated rice fields, but stimulate N_2O emissions due to changes in moisture content and soil redox potential. Nitrification and denitrification are the dominant processes producing N_2O in agricultural soils, and the relative contribution of each process depends strongly on soil moisture conditions. Two forms of fertilizers ($^{15}NH_4NO_3$ and $NH_4{}^{15}NO_3$) and three types of water management (100%: continuous flooding; AWD: alternate wetting and drying; and 30%: about 30% of the 100% water input) were employed in a rice pot experiment to investigate the contributions of nitrification ($^{15}N_2O$ derived from $^{15}NH_4^+$) and denitrification ($^{15}N_2O$ derived from $^{15}NO_3^-$) under different water conditions over a whole growing season. The application rate for the N fertilizer (NH_4NO_3) was 225 kg ha^{-1} (1.1 g pot^{-1}), which was applied at a ratio of 5:3:2 (w/w/w) as base, tillering and heading fertilizer in the form of solutions that were added to the soil surface. In conclusion, total N_2O emissions significantly varied among the water management treatments, but were not affected by the fertilizer treatments. The N_2O emissions were highest under AWD for both fertilizer treatments, and were 1.7–1.8 and 2.3–2.4 times greater than the 30% and 100% treatments, respectively. In contrast with N_2O emission, total $^{15}N_2O$ emissions were not influenced by water management technique, but were significantly altered by fertilizer treatment. The $^{15}N_2O$ emissions from the $NH_4{}^{15}NO_3$ treatment were 1.3–2.1 times greater than from the $^{15}NH_4NO_3$ treatment, which suggested that denitrification dominated the formation of $^{15}N_2O$. Additionally, rice plants could more efficiently use NH_4^+-N than NO_3^--N, regardless of water conditions.

Keywords: Nitrification, denitrification, nitrogen stable isotope, nitrous oxide, rice field

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(9086 - 2129) Dynamics of Greenhouse gas emissions regulated by the strategies of straw return and N fertilization

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Crop residues management and N fertilization affect microbial community dynamics and shape key biogeochemical processes of carbon and nitrogen cycling. Evidences have shown that simultaneous applications of crop residues and N fertilizer significantly increased greenhouse gas emissions. To facilitate systematic studies of interactions among crop residues management practices with biogeochemical emissions of CO2, N2O and CH4 from fertilized soil, we evaluated different crop residue returning methods (incorporation of straw or straw derived biochar or the combination) coupled with the timing of N fertilization. The present study aims to investigate the effects of straw and straw derived biochar addition as well as N fertilization on greenhouse gas emissions and microbial biomass dynamics. The groundedstraw and straw derived biochar are used, and N fertilizer is added after different drying-rewetting cycles. dry. The spatial and temporal distribution of key parameters in the microdomain of biochar - soil interface is visualized using high - resolution planar optode technology. This study advances our understanding on the effects of straw/biochar incorporation and N fertilization on soil fertility and greenhouse gas emissions, therefore provide effective alternative methods to promote sustainable agriculture and mitigate climate change.

Keywords: straw incorporation;straw derived biochar;planar optode;drying-rewetting cycles

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(1147 - 1342) Greenhouse gases emissions during pasture intensification

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The main system adopted in Brazilian pastures to cattle grazing is often called extensive because there is no grazing improvement and large areas are necessary to a little quantity meat production. Management practices are carried out in such areas to increase yields, however it can impact soil structure, microbial diversity and, hence, greenhouse gases (GHG) emissions. To better understand implications of conventional soil tillage and fertilizer application the experiment aimed, simulating the pasture intensification process, assess the GHG fluxes during two years in São Paulo state, Brazil. In the first year (2013-2014), tillage operations and fertilizer application were done in an extensive pasture area. During the second year (2014-2015), only fertilizer application were carried out. The nitrogen fertilizer rates were 60 kg N ha^{-1} of NH_4NO_3, 40 kg P_2O_5 ha^{-1} of superphosphate, and 40 kg K_2O ha^{-1} of KCl. The treatments were: P, no-till pasture without mineral fertilizer application; TP, tillage pasture without mineral fertilizer application; TPF, tilled pasture with mineral fertilizer application. Gas samples were analyzed by gas chromatography. Carbon dioxide fluxes were always positive while CH_4 and N_2O fluxes were sink or source to the atmosphere. In the first cycle, carbon dioxide fluxes start to increased just after the soil tillage operations were carried out. Nitrous oxide peaked during the nitrogen fertilizer reaction period. The annual emissions in the first year of pasture conversion were of 9.32, 8.50 and 9.30 Mg $ha^{-1}yr^{-1}$ for CO_2 while for N_2O emission were of 0.10, 1.06 and 2.09 kg $ha^{-1}yr^{-1}$ respectively for the P, TP and TPF treatments. In the second year of evaluation, the pasture conversion showed annual emissions of 15.70 and 19.63 Mg $ha^{-1}yr^{-1}$ to CO_2 in TP and TPF, respectively, which were 46% and 53% higher than first year of evaluation. Nitrous oxide annual emissions were of 0.25 kg $ha^{-1}yr^{-1}$ in TP and 0.37 $ha^{-1}yr^{-1}$ in TPF. The first and second year did not vary significantly in fertilized treatments. The CO_2–eq values observed during the first year were 33.27 kg $ha^{-1}yr^{-1}$ to P, 507.97 kg $ha^{-1}yr^{-1}$ to TP and 971.003 kg $ha^{-1}yr^{-1}$ to TPF, while to the second year were 97.1 kg $ha^{-1}yr^{-1}$ in TP to 175.2 kg $ha^{-1}yr^{-1}$ in TPF. The data showed the GHG emissions were highest when both soil tillage and nitrogen fertilizer application were carried out on soil if comparing with the emissions resulted of the fertilizer application

alone.

Keywords: pasture management; carbon dioxide; nitrous oxide
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(3560 - 2179) Implication of straw removal for bioenergy production on soil N_2O emissions in sugarcane fields in Brazil

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Sugarcane straw is an abundant crop residue that can be used to produce bioenergy and can be maintained on the field to improve soil quality and biomass production. However, there are evidences that straw mulching increase soil N_2O emissions. This study aimed to quantify N_2O emissions, mineral N availability, soil moisture and temperature, and biomass production in sugarcane areas under amounts straw in Campinas, São Paulo, Brazil. Additionally, we calculated the intensity of N_2O emission (kg CO_2 eq per Mg of sugarcane stalks). Two filed experiments in clayey Oxisols were used to quantify soil N_2O emissions under four straw rates (without straw, 5, 10, 15 Mg ha^{-1}) and different crop seasons. The experiments were conducted in 2016/2017 agricultural year using a randomized block design with three replicates. All plots were fertilized with 120 kg ha^{-1} of N fertilizer as ammonium sulfate. N_2O emissions were measured using static chambers methodology three times a week during the first 90 days and after that, the samplings were spaced according to gas flux stabilization, totaling 52 sampling events. The mineral N content, soil moisture and temperature were monitored along the experimental period. Sugarcane was mechanically harvested and the biomass was weighed using an instrumented truck. In both experiments, the maintenance of straw reduced mineral N availability, increased soil moisture, reduced soil temperature and increased N_2O emissions. In dry season experiment, we observed cumulative N_2O emissions of 1.1, 1.9, 1.8 and 2.4 kg ha^{-1}, while in wet season 1.6, 2.1, 4.1 and 2.8 kg ha^{-1} were obtained, respectively from 0, 5, 10, 15 Mg ha^{-1} of straw. However, the maintenance of straw mulching significantly increased sugarcane yield. Compared with no straw treatment, the maintenance of 5, 10 and 15 Mg ha^{-1} resulted in stalk yield gains of 27, 31 and 26 Mg ha^{-1} in dry season and 8, 11 and 19 Mg ha^{-1} in wet season. The N_2O emission intensity were 5.3, 6.4, 5.9 and 8.3 kg CO_2 eq Mg^{-1} of stalk in dry season and 11.6, 12.7, 22.5 and 13.9 kg CO_2 eq Mg^{-1} of stalk in wet season, respectively from 0, 5, 10, 15 Mg ha^{-1}. We concluded that removal of sugarcane straw reduces N_2O emission and but also reduces sugarcane yield. The N_2O intensity emission is a powerful indicator and should be used to integrate the impacts of crop residues removal to bioenergy production on net greenhouse gas emissions.

Keywords: GHG emission; Crop residues, Sugarcane; Soil quality; Bioenergy
Financial support: Sugarcane Renewable Electricity project – SUCRE/PNUD

(3406 - 331) Responses of soil organic carbon turnover to nitrogen enrichment depended on nitrogen addition rates: derived from soil ^{14}C evidences

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Understanding the dynamics of soil organic carbon (SOC) under nitrogen (N) enrichment is an important aspect of the studies of global carbon cycle. Although many studies have examined the effect of N enrichment on SOC turnover by means of N addition experiments, the effects were reported to be different across studies. N addition rate in previous studies was usually designed with only one single level and it differed across studies, thus, the inconsistent results could be associated with N addition rates. To test the argument, we conducted a field experiment with multiple N addition levels (0, 3, 6, 12, and 24 $g{\cdot}N{\cdot}m^{-2}{\cdot}yr^{-1}$) in Inner Mongolia Grassland, China. In this study the SOC turnover rates were calculated by using the ^{14}C contents in SOC, which is thought to be a quantitative tool to obtain the residence time of SOC. In addition to ^{14}C measurements, this study also investigated the changes in soil and plant properties and soil microbial composition to explore the potential mechanisms of responses of SOC turnover to N enrichment. Our results showed that compared with CK treatment (0 $g{\cdot}N{\cdot}m^{-2}{\cdot}yr^{-1}$), SOC turnover was inhibited when N addition rate was 3 $g{\cdot}N{\cdot}m^{-2}{\cdot}yr^{-1}$, whereas SOC turnover was not affected by N enrichment when N addition rate was 6, 12, and 24 $g{\cdot}N{\cdot}m^{-2}{\cdot}yr^{-1}$. Our results suggest that N addition rates account for the diverse responses of SOC turnover to N enrichment in natural ecosystems. Thus, this study highlights that it should be considered in the climate prediction model that varied atmospheric N deposition levels across regions have different impacts on local SOC turnover, i.e. the amount and rate of soil released-CO_2, which affects global climate change.

Keywords: Nitrogen enrichment, Soil organic carbon, ^{14}C contents, Global carbon cycle, Grassland
Financial support: This research was supported by a grant from the National Natural Science Foundation of China (No.41772171) and the Chinese National Basic Research Program (No. 2014CB954202).

(7711 - 585) Significant contribution of soil inorganic carbon in atmospheric CO_2 following nitrogen fertilization: a global assessment

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Nitrogen (N) fertilization is a worldwide indispensable agricultural practice serving the survival of half of global population. Nitrogen transformation in soil as well as plant N uptake leads to release of protons and enhancing soil acidification. Neutralization of this acidity in soils containing carbonates ($6.64\ 10^9$ ha; ca. 45% of global land surface area) leads to CO_2 release corresponding to 0.21 kg C per kg applied N. Based on the global N fertilization map and the distribution of soils containing $CaCO_3$ we calculated the amount of CO_2 released annually from acidification of soils containing pedogenic and geogenic carbonates as $25\ 10^{12}$ g C y^{-1}. This level of continuous CO_2 release will remain constant at least until soils will be fertilized by N. In the second half of the study, we estimated that about $240\ 10^{12}$ g C are released annually in the same process of $CaCO_3$ neutralization but by liming of acid soils. These two CO_2 sources correspond to 3% of global CO_2 emissions by fossil fuel combustion or 28% of CO_2 by land-use changes. However, the duration of CO_2 release after land-use changes usually takes only 1-3 decades before new C equilibrium is reached in soil. In contrast, the CO_2 released by $CaCO_3$ acidification cannot reach equilibrium until it will be completely neutralized – and this is nearly unlimited - will take centuries or even millennia. This emphasizes on prohibiting soil acidification as an effective strategy to inhibit

millennial CO_2 efflux to the atmosphere. Hence the N fertilization should be strongly plant demand calculated and avoiding any over-fertilization not only as the N is source of local and regional eutrophication, but also because of continuous CO_2 release by global acidification.

Keywords: Nitrogen fertilization, Nitrogen use efficiency, Soil acidification, Soil inorganic carbon, CO2 emission
Financial support:

(4509 - 1912) Soil greenhouse gas fluxes from vinasse and N application in sugarcane areas with straw removal for bioenergy production

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Sugarcane crop produces ~10 Mg ha^{-1} of residues which is maintained covering the soil surface and accumulating harvest after harvest. The benefits of the mulch are mainly the nutrient, but is still a doubt the impact of its removal on greenhouse gas (GHG), mainly when we consider some fertilization practices. We test the hypothesis that greenhouse gases (GHG) soil emission is reduced after vinasse (V) and nitrogen fertilizer (N) application when the part of the sugarcane straw is removed. We performed the experiment within the largest sugarcane-producing region of Brazil (São Paulo state), to assess GHG fluxes and straw decomposition changes induced by four sugarcane straw removal intensities (*i.e.*, no-removal – 12 Mg ha^{-1} kept on soil surface; medium removal – 6 Mg ha^{-1}; high removal – 3 Mg ha^{-1}; and, total removal – bare soil) with and without vinasse (100 L ha^{-1}) and N mineral fertilizer (80 kg ha^{-1} ammonium sulphate). The quantification of GHG fluxes were performed over 60 days, until to stabilize the flux using static chambers. The addition of vinasse and N emissions increase the cumulative CO_2 and N_2O by 3-3.5 and 4-6 times respectively The non-removal of straw increased N_2O emission under V+N addition. It also increased about 40 % of CH_4 the influxes between no removal and the others removal management. N_2O emissions factor from N released by straw decomposition and V+N was estimated in 0.26-0.38 %, increasing in relation to straw removal.

Keywords: *Saccharum* spp., crop residue management, vinasse, fertilizer, climate change
Financial support: CAPES, CNPq, BNDES

(6354 - 532) Soil nitrification, denitrification, N_2O emission and associated microbial community and abundances as impacted by long-term fertilization strategies

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Nitrogen is one of the most important major nutrients associated with soil fertility and crop performance. As is well known, nitrification and denitrification, the most important nitrogen transformation processes realted to nitrogen loss, are microbially driven, and significantly impacted by fertilization regimes. However, how these processes are influenced by long-term fertilization remains largely unknown. In this work, we explored the impacts of long-term organic (OM) and inorganic (NPK) fertilization and their combination (MNPK) on soil nitrification and denitrification and associated microbes in northeast China using microbial molecular tools (T-RFLP and qPCR). The results show that long-term manuring significantly increased potential nitrification rate (PNR) in dark brown soil, while mineral fertilizer decreased it; this change coincided with the variation of community structure of ammonia oxidizing bacteria (AOB), not ammonia oxidizing archae (AOA); Organic fertilization increased denitrification potential (DP) in a black soil, but inorganic fertilization had no impacts; the increase of DP was mirrored by the shift of *nirS* denitrifiers' community structure but not by that of *nirK* denitrifiers'. Furthermore, the change of DP coincided with the variation of abundances of both denitrifiers. In the black soil tested, *nirS*-type denitrifier rather than *nirK*-type denitrifier was more active in denitrification. Different fertilization regimes significantly influenced the N_2O emission pathways. Application of manure increased the proportion of potential N_2O derived from denitrification. The abundance of archaeal *amoA* gene copies increased under all fertilizer treatments, but that of bacterial *amoA* only increased under mineral (NPK) fertilization. Meanwhile, abundance of *nirS*, *nirK* and *nosZ* only increased under OM and MNPK fertilization. Path analysis show that N_2O emission could be 'directly' influenced by *nirS*-type denitrifier community. It can be concluded that long-term fertilization strategies could significantly alter nitrification, denitrification, N_2O emission and associated microbial community and abundances, thereby playing an important role in linking agricultural practices to nitrogen loss and nitrogen use efficiency.

Keywords: Nitrification; denitrification; nitrogen; microbial community
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(2518 - 245) Treated domestic sewage irrigation significantly decreased the CH_4, N_2O and NH_3 emissions from paddy fields with straw incorporation

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Straw incorporation and treated-domestic sewage irrigation have been recommended as an environmentally friendly agricultural practice and are widely used not only in China but also in other countries. The individual effects on yield and environmental impacts have been studied extensively, but the comprehensive effect when straw returning and domestic sewage irrigation are combined together has seldom been reported. This study was conducted to examine the effects of straw returning and domestic sewage irrigation on rice yields, greenhouse gas emissions (GHGs) and ammonia (NH_3) volatilization from paddy fields from 2015 to 2016. The results showed that the rice yield was not affected by the irrigation water sources and straw returning under the same total N input, which was similar in both years. Due to the rich N in the domestic sewage, domestic sewage irrigation could reduce approximately 45.2% of chemical nitrogen fertilizer input without yield loss. Compared to straw removal treatments, straw returning significantly increased the CH_4 emissions by approximately 7-9-fold under domestic sewage irrigation and 13-14-fold under tap water irrigation. Straw returning also increased the N_2O emissions under the two irrigation water types. In addition, the seasonal NH3 volatilization loss was significantly increased by 88.8% and 61.2% under straw returning compared to straw removal in 2015 and 2016, respectively. However, domestic sewage irrigation could decrease CH_4 emissions by 24.5-26.6%, N_2O emissions by 37.0-39.0% and seasonal NH_3 volatilization loss by 27.2-28.3% under straw returning compared to tap water irrigation treatments. Global warming potentials (GWP) and greenhouse gas intensities (GHGI) were significantly increased with straw returning compared with

those of straw removal, while they were decreased by domestic sewage irrigation under straw returning compared to tap water irrigation. Significant interactions between straw returning and domestic sewage irrigation on NH3 volatilization loss, CH_4 and N_2O emissions were observed. The results indicate that domestic sewage irrigation combined with straw returning could be an environmentally friendly and resource-saving agricultural management measure for paddy fields with which to reduce the chemical N input, GHG emissions, and NH_3 volatilization loss while maintaining high rice productivity.

Keywords: Paddy, straw returning, Greenhouse Gas, Ammonia voltalization, yield

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(6324 - 1046) Biological nitrification inhibition as a method to reduce nitrous oxide emissions from grazed pasture soils: a New Zealand perspective

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Grazing livestock urine deposition onto pasture soils is a significant source of nitrous oxide (N_2O) emissions, a potent greenhouse gas and ozone-depleting substance, accounting for 10% of global N_2O emissions. Inhibition of nitrification, a key microbial process in soil N_2O production, has been shown to significantly reduce urine patch N_2O emissions. However, targeted application of synthetic inhibitors to urine patches is difficult due to the uneven distribution of urine patches in the pasture after a grazing event. Certain plants, such as *Brachiaria* grasses or sorghum (*Sorghum bicolor*), have been shown to produce and release compounds into soil that inhibit nitrification, a process known as biological nitrification inhibition (BNI). Plants exhibiting BNI activity could be used in pasture systems to reduce nitrification, and resulting N_2O emissions, from grazing ruminant urine patches, either through root exudation of BNI chemicals or through grazing animals consuming plant leaf matter that contains BNI chemicals and excreting these chemicals in their urine onto pasture soils. *Brachiaria humidicola*, a tropical pasture grass species, has been shown to significantly reduce bovine urine patch N_2O emissions, however, a temperate pasture species with BNI activity has not been identified. Plantain (*Plantago lanceolata*), a common herb species in New Zealand pastures, contains an active metabolite, aucubin, which has been shown to reduce nitrification in soils. This presentation will summarize the findings from five laboratory and field studies, which evaluated the potential inhibitory effects of aucubin excretion in urine on urine patch nitrogen (N) dynamics and N_2O emissions. Urine was applied to soils with either a plantain leaf extract (PLE; which contained aucubin) or an aucubin solution (AS). The studies showed a varied response in N_2O emissions to aucubin application in the urine patch, with some showing no significant effect, and others showing a 50-70% reduction in N_2O emissions when aucubin was added to urine. The soil inorganic N response after urine application with or without aucubin was similarly varied between studies. This presentation will further explain the implications of these results and discuss future directions for research on nitrification regulation via BNI activity in grazed pasture systems.

Keywords: urine patch, nitrous oxide, nitrification, inhibitor, aucubin

Financial support: This research was funded by The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), in partnership with the Forages for Reduced Nitrate Leaching programme, DairyNZ, and the Ministry of Business, Innovation, and Employment.

(6948 - 846) Carbon sequestration through afforestation and reforestation in the mangrove forests of southern Thailand.

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Mangroves are ecologically and economically important forests of the tropics. Mangroves are highly efficient blue carbon sinks that sequester and store large quantities of carbon in standing stock biomass and sediments for long time periods. However, there are few empirical measurements of long-term carbon storage in mangroves or of how storage varies across environmental gradients. In Thailand, the total area of abandoned shrimp ponds in 1996 was about 67,000 ha and the abandoned shrimp ponds at Pak Phanang, Nakhon Si Thammarat (NST) occupied an area of approximately 4,000 ha. We have planted about 7 million mangrove plants (*Rhizophora mucronata* and *Rhizophora apiculata*) in the area of 1,200 ha of abandoned shrimp ponds and new mudflats since 1998 in NST, Thailand. In this paper, we aim to evaluate and estimate the carbon storage potential in mangrove biomass and sediment in rehabilitated and afforested mangrove sites. In addition, we investigate the difference of both carbon storage potential and soil properties in the control sites, the afforestation sites at new mudflats, and virgin forest sites. The tree height, the diameter at breast height, the number of growth tree and weights of all parts (stems, branches, leaves and roots) of mangrove tree were measured in all sites except for virgin forest. Soil samples were collected at each 10 cm depth interval to 100 cm, 150-160 and 190-200 cm from surface. Soil chemical properties such as pH, electrical conductivity, Na concentration and oxidation-reduction potential were measured. As a result, pH, EC, and Na concentration in soil at abandoned shrimp pond sites decreased as the years elapsed after reforestation. The carbon stock in soil surface at abandoned shrimp pond sites was higher than that in the lower depth and total carbon stock in soil was about 269 $MgCha^{-1}$ after 18 years. And there was a possibility that the carbon stock in soil is highly correlated to soil pH. The total carbon stock that added carbon content in aboveground and belowground biomass to that in soil was 544 $MgCha^{-1}$ after 18 years. The carbon stock in soil at new mudflat site after 11 years and virgin forest was 399 $MgCha^{-1}$ and 1,896 $MgCha^{-1}$, respectively. The carbon stock in mangrove forest sites that rehabilitated at abandoned shrimp ponds and afforested at new mudflats has increased year by year. Therefore, the mangrove carbon stocks in the rehabilitated and afforested mangrove forests would be as a sink source for carbon.

Keywords: Carbon stock; Mangrove; Shrimp pond; Reforestation; Soil properties

Financial support: KEIDANREN (Japan Business Federation), Kogakuin University (Japan), Create River & Sea Corporation (Japan)

(2351 - 2610) Compost but not cover crops increases soil carbon at depth after 19 years of management in irrigated row crops in a Mediterranean climate

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Agricultural land use is often viewed as a source of carbon (C) emissions rather than a C sink, especially where tillage is routinely practiced. Recent studies suggest that increasing carbon inputs to soils via cultivation of cover crops and replacement of fallow phases in crop rotations, or application of C-rich materials such as manure or

compost, are potential means to increase soil C sequestration. The Century Experiment (Russell Ranch Sustainable Agriculture Facility at the University of California, Davis, USA) is a long-term trial examining productivity and soil quality metrics among nine cropping systems typical to Mediterranean climates. We investigated soil C changes among cropping systems with different 2-yr rotations, fertility, and water inputs. Changes in soil C were measured from the start of the experiment to year 19, taking into account changes in bulk density and C fractionation in five depth increments down to 200 cm. Among the tomato-based systems, only organic maize–tomato rotations incorporating both winter cover crops and composted poultry manure (9 t compost ha^{-1} yr^{-1}) increased in soil carbon (1640 ppm; 21.8 Mg ha^{-1}) across the 0 to 200 cm profile, with greatest gain in 0 to 60 cm depth. No increases were observed in conventional wheat–tomato or maize–tomato rotations with winter fallow. Maize-tomato rotations including a winter cover crop instead of fallow showed surprisingly limited potential to increase soil C across the 0 to 200 cm profile; soil C concentration increased in the 0 to 15 and 15 to 30 cm fractions but decreased below 60 cm. There was a modest net increase in C concentration (458 ppm) across the profile but a net decline in C stocks (–13.4 Mg ha^{-1}). For wheat, only irrigated wheat–fallow receiving chemical fertilizer showed an increase in soil C (713 ppm; 17.5 Mg ha^{-1}) whereas there was no change in C in rainfed wheat–fallow with and without winter cover crops, and the non-fertilized irrigated wheat–fallow. This result was surprising given the relatively low carbon inputs in this system over the two-year rotation. In conclusion, our results indicate cover crops did not promote C sequestration. While cover crops increased surface soil C, they caused greater soil C drawdown at lower depths, resulting in no overall net gain in C. In contrast, application of composted poultry manure increased soil C at four of five depth fractions with significant net gains in soil C throughout the profile.

Keywords: soil carbon sequestration, farming systems, agricultural management, soil organic matter
Financial support:

(9631 - 2271) Estimation of soil C stocks in different scales in an intensively cropped region of Southern Brazil.

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Dep. Solos - UFRGS[1]; IFRS - campus Ibirubá[2]; Catena Planejamento Territoria[3]

Major changes in soil organic C (SOC) stocks have been detected in soils of Southern Brazil after agricultural expansion onto pristine woodlands and grasslands. Assessment of spatio-temporal changes in SOC stocks is a central component to monitor sustainable agricultural practices. Our study aimed to compare and refine existing SOC stocks estimates in the central Planalto region (subtropical highlands) of Rio Grande do Sul state. A compilation of existing studies (published surveys and research projects) and soil sampling campaigns were conducted to build a SOC geodatabase. The field study sampled surface soil layers (0-30 cm), stratified by predominant soil classes (Oxisols, Inceptisols and Entisols) and land uses (cropland under no-till and woodland - Subtropical forest fragments). Six studies reporting SOC stocks in the study region were compiled. Considering the 0-30 cm layer, the Inceptisols under woodland had the highest SOC stocks (105 Mg C ha-1). Oxisols under cropping had similar stocks in comparison to woodland, that is, similar to the original vegetation. This could be attributed to no till crop management used in the last 25 years. The integration of the point observations into GIS allowed regional extrapolation to produce an updated SOC stock map for the Planalto region. The map indicated predominance of Oxisols with mean C stock of 65.9 Mg C ha-1, and larger stocks in undulating to strongly undulated terrain, where Inceptisols and Entisols occur. The approach employed in the present study obtained the most detailed SOC stock map currently available in the Planalto region, from which the most detailed and updated ECOS map has been derived. The SOC stocks obtained allowed a comparison with the global values from IPCC and a recent global database (SoilGrids). We noted major differences between our on site/sampling approach and these reference datasets. For example, IPCC suggested C stocks were approximately 30% lower than our estimate based in samples collected in the Planalto region. This observation suggests that reference frames should be used only in situations of extreme lack of local data. The SOC maps produced refined the visualization and estimation of SOC stocks in comparison to those from previous studies and spatial databases. These results could be used to prioritize policies supporting "C-friendly" agricultural practices and their temporal changes. Additionally, data could be used to refine Brazilian SOC stock inventory.

Keywords: soil C stocks, Oxisols, no till, soil C inventories
Financial support: CNPq Project 487298/2012-8 (Universal Call 2012) and current CAPES-PRONEX sustaining grant for the Soils Graduate Program at UFRGS.

(3813 - 244) Forestry for climate smart agriculture, agro-biodiversity and ecosystem services

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Forests and trees support sustainable agriculture. They stabilize soils and climate, of millions of people, for whom they are important sources of food, energy and income. Yet, agriculture remains the major driver of deforestation globally. Since the beginning of agriculture in the world, forests have always sacrificed for agriculture in different ways. Besides food, forests have provided most of the basic needs of agrarian livelihood. A study of agro-forestry-based system under coastal agro-ecosystem in Odisha revealed that The coconut based agroforestry systems of various sizes are playing important role for better livelihood of the farmers in the region, which includes productive, protective and ameliorative, recreational and educational role as well as developmental role giving various kinds of tangible and intangible benefits. The net returns from such system were important for supporting the livelihood of farmers by providing varying levels net income ranged from Rs. 56,167 to Rs. 21,900/acre (0.4ha) depending upon size holding. The coconut based agroforestry system of the region was maintaining variety of trees/crop/fish species and livestock involving perennials-coconut, siris, rain tree, eucalyptus, acacia, areca nut, mango, sissoo, teak, jackfruit, bamboo, guava, pomegranate, papaya, drumstick, bael, citrus, banana, curry leaf ; seasonals-pine apple, yam, arrowroot, turmeric, ginger, brinjal, okra, bitter gourd, ridge gourd, chilli, greens, cowpea, tomato, cauliflower, pumpkin; mushroom-paddy straw/oyster; fish- rohu, silver crap, grass crap; cattle, buffalo, goat, poultry, duck etc. providing an inbuilt diversity and sustainability. A study comparing biodiversity noted that, when compared to organic cropping systems, conventional systems had significantly lower species richness and abundance and had significantly greater levels of pollination deficits. There are not many ecosystems in the world that are "natural" in the sense of having escaped human influence. The methods that support high agrobiodiversity are traditional agroforestry systems. Agrobiodiversity can be used as a resilient crop production system due to its useful in self-sufficiency, erosion control, carbon sequestration, soil fertility build up, drought resistance, functional biodiversity and organic production systems. Agrobiodiversity and its links to ecosystem properties have cultural, intellectual, aesthetic and spiritual values that are important to

society.
Keywords: Forestry, climate, agro-biodiversity, ecosystem services
Financial support: Dr AK Mishra needs financial support for attending the congress.

(6935 - 454) Implementation of the 4 per 1000 initiative at the regional scale: A case study for Bavaria

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The ambitious “4 per 1000” initiative launched in 2015 aims at increasing world´s soil organic carbon (SOC) stocks by 4 per mill each year in order to offset anthropogenic CO_2 emissions. Over 250 countries and institutions committed in a voluntary action plan to implement suitable practices to build-up SOC stocks. However, for practical implementation of the initiative, regional feasibility studies are needed that include a precise analysis of the status quo of SOC stocks, an estimation of the C storage potential of soils, and a comprehensive, spatially explicit development of improved land management scenarios based on an analysis of existing land management practices. In this study, we estimated the potential of SOC increases in Bavaria (Germany) by improved management of agricultural soils. A determination of the SOC saturation level showed that agricultural soils of Bavaria generally have a high C sequestration potential, as a mean SOC saturation level of 50% and 77% was found for cropland and grassland soils, respectively. In order to delineate the specific 4 per mill target for Bavaria, a SOC map was generated for the depth of 0-40 cm on the basis of 786 soil profiles using the Random Forest model. As agricultural soils of Bavaria store around 276 Mt C in the first 40 cm, a total amount of 1.1 Mt C has to be sequestered each year in order to achieve the 4 per mill target. A comprehensive and spatially explicit analysis of management options including cover cropping, improved crop rotations, organic farming, agroforestry and a conversion of cropland to grassland showed that a maximum amount of 0.37 Mt C yr^{-1} could be sequestered. Although the 4 per mill target can hardly be reached in Bavaria, the estimated C sequestration potential would significantly counterbalance regional greenhouse gas emissions from the agricultural sector in Bavaria. Moreover, there are further benefits associated with C sequestration such as improved soil fertility, soil structure and water holding capacity, a reduced risk of soil erosion, eutrophication and water contamination as well as reduced costs for fossil fuel and fertilizers.
Keywords: soil carbon sequestration, cover crops, improved crop rotation, organic farming, agroforestry
Financial support: German Federal Ministry of Education and Research (BMBF), project "BonaRes (Module B): BonaRes Centre for Soil Research, subproject C (grant 031A608C)

(9890 - 593) Long-term zero tillage minimises global warming potential

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Approximately 40% of the world’s land surface, and up to 68% in the UK, is managed by ploughing to provide optimal conditions for crop establishment and growth. Ploughing has a profound influence on the physical properties of soil and the greenhouse gas (GHG) balance, through degrading soil structure, increasing erosion and releasing greater carbon dioxide (CO_2) fluxes. These concerns have led to increased interest in conservation agriculture which includes zero tillage, a practice defined as planting into unprepared soil whilst disturbing less than a third of the soil surface. Zero tillage presents many potential benefits, including increased soil organic matter, greater aggregate stability and reduced soil erosion. There is, however, conflicting literature on its potential to reduce GHG emissions. Zero tillage may reduce CO_2 emissions through decreased use of fossil fuels in preparation for sowing and by increasing carbon sequestration. However, reduction of tillage has also been linked to increased denitrification processes through increased bulk density and soil water content, resulting in greater nitrous oxide (N_2O) emissions. Therefore, any climate change mitigation benefits through reduced CO_2 emissions may be offset by larger N_2O emissions. We report results from an extensive study that assessed and predicted how zero tillage altered soil biophysical properties and associated radiative forcing (GHG balance expressed as CO_2 equivalents) on more than 80 paired ploughed and zero tilled fields across the East Midlands in the U.K. We recorded a significantly lower net radiative forcing under zero tillage systems (30% lower than ploughing systems), with the net radiative forcing decreasing with time since conversion to zero tillage. The 3D pore structure, imaged using X-ray Computed Tomography, was strongly affected by land management and was significantly correlated with CO_2 fluxes. However, microbial biomass carbon and soil moisture content accounted for N_2O fluxes. Our work demonstrates that long-term zero tillage has a significant role in reducing radiative forcing from soil and enhances our understanding of the relevant biophysical processes at larger scales.
Keywords: Climate change, agriculture, greenhouse gases, zero tillage, X-ray computed tomography
Financial support: STARS CDT, funded by NERC and BBSRC

(4114 - 196) Mitigation of nitrous oxide emissions and nitrate leaching in grazed grassland in New Zealand.

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In grazed grassland, nitrous oxide (N_2O) emissions and nitrate (NO_3^-) leaching mostly originate from nitrogen (N) returned to grassland in animal excreta deposited during grazing, particularly animal urine. This paper reports a series of laboratory and field studies designed to assess the effectiveness of a range of mitigation technologies for N_2O emissions and NO_3^- leaching in grazed grassland or winter forage systems in New Zealand, including the use of nitrification inhibitors, alternative pastures or forage plants, and the use of catch crops following winter forage grazing. Results showed that the use of nitrification inhibitors, such as dicyandiamide (DCD), to treat grazed dairy pasture soils, reduced N_2O emissions by an average of 57%, and reduced NO_3^- leaching by an average of 30-50%, across a wide range of soil and environmental conditions (Di and Cameron 2016). The use of diverse pastures, which included plantain (*Plantago lanceolata* L.), chicory (*Cichorium intybus* L.), perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.), with an associated lower animal urine-N loading rate of ~500 kg N ha^{-1}, significantly decreased N_2O emissions by 46%, compared with the standard ryegrass/white clover pasture with a urine-N loading rate of ~700 kg N ha^{-1} (Di et al., 2016). The N_2O emissions from urine from cows grazing fodder beet (*Beta*

vulgaris L.) were 39% lower than that from kale (*Brassica oleracea* L.) with the same urine-N application rate. Planting a catch crop, such as oats (*Avena sativa* L.), following the grazing of winter forages such as fodder beet or kale, reduced NO_3^- leaching by an average of 34% (Carey et al., 2016). These results demonstrate that N_2O emissions and NO_3^- leaching can be reduced significantly in the grazed grassland/forage system by using nitrification inhibitors, diverse pastures (containing plantain) or catch crops. References Carey, P.L., Cameron, K.C., Di, H.J., Edwards, G.R., Chapman, D.F. (2016). *Soil Use Manage*. doi: 10.1111/sum.12276. Di, H.J. and Cameron, K.C. (2016). J *Soils Sediments* 16: 1401–1420. Di, H.J., Cameron, K.C., Podolyan, A., Edwards, G., de Klein, C., Dynes, R. and Woods, R. (2016). *J Soils Sediments*. 16: 2252–2262.

Keywords: Nitrous oxide, nitrate leaching, grazed grassland, mitigation

Financial support:

(9755 - 624) Pasture systems: an alternative for soil carbon storage in conditions of tropical dry climate in Santa Marta, Colombia

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The analysis of land use changes is essential to understand the current condition and to prospect the soil state whenever it can generate impacts in soil conditions, but these responses are not well characterized under dry tropical climate conditions. In a Typic ustipsamments of Santa Marta, Colombia, using a stratified random sampling, the study area (60 ha) was subdivided into three types of land use (natural, agricultural - vegetables and green areas). In each area, by random sampling, two soil depths (0-10 and 10-30 cm) samples were collected at five points with five replicates to evaluate the effects on some physical characteristics (pH, bulk density, particle density, porosity, humidity, temperature) and chemical characteristics (electrical conductivity, cation exchange capacity, organic carbon, organic matter and total-N) of soil. Results showed significant changes in carbon content, total nitrogen, humidity, temperature, bulk density, total porosity and CEC. The principal component analysis showed that four main components explained 81% of the total variability and were succeeded in separating soil characteristics by land use, where higher carbon contents were associated with green zones, the porosity with forest zones and higher values in conductivity, pH and humidity were found at the agricultural area. These evidences indicate that green zones (grassland or pastures) can be prioritized as carbon sinks. Also, forest system may contribute to water regulation, important in maintaining aquifer function. Finally, the agricultural system is losing ecosystemic functions for carbon storage and water regulation, demonstrating that land use influences soil characteristics and therefore, requires monitoring for a sustainable management.

Keywords: land use, tropical dry climate, forest, green areas, and agricultural systems.

Financial support:

(2669 - 1484) Rate of C substitution in organic matter fractions by pasture-derived C in soil under integrated systems

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Integrated crop-livestock-forest (ICLF) systems has been considered as an important strategy to enhance soil C sequestration. However, changes in soil C due to agricultural management practices, in general, are observed in long-term experiments. Our objective was to investigate short-term impacts of management systems on soil organic matter fractions. Treatments corresponded to Eucalyptus plantation (*Eucalyptus urograndis*, clone H13); No-tillage – cultivated with soybean followed by corn (*Zea mays*) intercropped with *Urochloa brizanta;* Pasture - pasture of *U. brizantha*; and ICLF – integrated crop-livestock-forest system, comprising of three rows of eucalyptus, soybean followed by corn intercropped with *U. brizantha* cultivated between tree rows. An area under Native Forest was used as reference. Soil samples were taken after 3 (three) years establishment in the 0-5, 5-10, and 10-30 cm layers for quantification of light- and heavy-fraction C stocks as well as their C isotopic composition ($\delta^{13}C$). Light fraction was isolated by flotation in high density solution (NaI). The remaining soil residue after light fraction separation contained the heavy fraction. The C content in the heavy- (C_{HF}) and light- (C_{LF}) fractions were determined by dry combustion (Vario Macro). Values of C_{HF} varied from 66.5 to 80.1 Mg ha^{-1} in the 0-30 cm layer. C_{HF} stocks represented, on average, to 75% of the total soil C stocks. After three years establishment, all evaluated treatments showed similar values to that observed under Native Forest. However, Eucalyptus had the lowest C_{HF} stocks values. C_{LF} varied from 12.3 to 16.6 Mg ha^{-1}. Despite C_{LF} has been considered more sensitive to changes caused by management systems, no differences were observed after 3 years establishment on the C_{LF} stocks in the 0-30 cm layer. The $\delta^{13}C$ values of light-fraction provided important information about changes caused by the management system, especially, the substitution of C by C-derived pasture. In the pasture treatment, we estimated that around 70% of light-fraction C was pasture-derived C in the uppermost soil layer (0-5 cm). On the other hand, in the ICLF only 21% of light-fraction was pasture-derived C in the 0-5 cm layer. Despite no differences in heavy- and light-fraction C stocks, the $\delta^{13}C$ values indicated that, in short term, management systems modify soil organic matter dynamics.

Keywords: Conservation agriculture; soil management; soil organic matter; C sequestration

Financial support: CAPES, Inter-American Development Bank (IDB-"Projeto Rural Sustentavel") and Embrapa

(4533 - 3206) Response of soil microbial processes to long-term management practices in subtropical grazing lands during different seasons

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Understanding the impacts of management practices such as grazing, vegetation type and nitrogen fertilization on soil organic matter (SOC) storage in grasslands is crucial to provide the most effective soil carbon (C) management options. However, it is still unclear how the improved management practices in grazing lands can affect the carbon storage potential of Spodosol by regulating the soil microbial processes during different seasons. The objectives of this study were to i) analyze the effects of long-term (>24 years) management practices on soil microbial processes and C storage in Spodosol ii) Evaluate the seasonal variations in soil microbial carbon and activity in sub-tropical grazing lands. The experimental site consisted of two management systems including improved pasture and native rangeland. The native rangeland consisted of woody and non-woody perennial plant species, whereas improved pastures consisted of only non-woody perennial grass species with continues grazing throughout the year. The native rangeland was never fertilized, however, improved pastures, on the other hand, received 67 kg N ha^{-1} yr^{-1}. The soil samples were collected in March and September 2017 from A1, A2, E and Bh horizons from both management systems. The data from

this study indicated that improved management practices resulted in increased SOC stocks from 31 Mg ha^{-1} in native rangeland to 63 Mg ha^{-1} in improved pastures with the majority (10 Mg ha^{-1} in native rangeland and 24 Mg ha^{-1} in improved pastures) of C being stored in the spodic horizon. Moreover, improved pastures significantly ($P<0.05$) promoted the microbial biomass carbon and activity of extracellular enzymes involved in C and N mineralization compared to native rangeland system. The activity of β-Glucosidase, N-acetyl- β-D-glucosaminidase, and Leucine aminopeptidase enzymes were significantly higher ($P<0.05$) in September as compared to March probably due to increased substrate availability as indicated by higher cold and hot water extractable carbons and higher microbial biomass carbon. Our results indicated that improved management practices can be helpful in storing more C in soil along with supporting cattle industry in subtropical grazing lands.

Keywords: 1. Grazing land 2. Soil organic carbon 3. Soil microbial processes 4. Spodosol

Financial support: USDA NIFA Award 2016-67003-24962

(4342 - 2825) Soil methane and microbial communities in the soil profile under Amazon forest-to-pasture conversion

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The forest-to-pasture conversion on Amazon soils impact in the soil quality and in the microbial diversity. This contribute to increase of atmospheric methane and its effects to global climate changes. we aim to understand how the forest-to-pasture conversion impact the methane flux in the soil profile and its relationship with microbial community in dry season in Amazon Oxisol. Soil and gas samples were collected in three treatments (forest and pasture in clayey and sandy soils), four soil depth (0-10; 10-20; 20-30; and 30-40cm) in two sites (5 replicates per site). That was performed during dry season in october 2017 in central-eastern Amazon rainforest (Tapajos National Forest, near Santarém, Pará). Soil methane flux was measured with an ultra-portable greenhouse gas analyzer (UPGA, Los Gatos Research), over 10 min. Soil samples were collected for physical, chemical and DNA extraction (PowerLyzer kit - MOBIO). The qPCR analyses were used for quantification of functional-marker genes *pmoA* (methanotrophic) and *mcrA* (methanogenic). In dry season occur only consumption over the soil profile in all land use and soil texture. Changes in methane flux were strongly associated with land use. Soils under pasture decrease methane consumption in relation to native forest. Methane consumption was decreased as deeper was analyzed under forest soil, however, under pasture the methane consumption was not changed. That showed the impact of land use on soil quality and methane flux. Soil texture not changed methane flux under pasture conditions, however, that changed the microbiology community. Forest-to-pasture conversion have no influence in the methanotrophic community. Pasture site showed a reduction in methane consumption, likely due to increases in the methanogenic community. Pasture use in clayey soils favors increasing methanogenic community until 20 cm depth, already in sandy soil that occurs over the soil profile. Methane consumption was increased linearly with a ratio of *pmoA*/*mcrA* genes. Soil profile methane flux is strongly related to land use, with reduction of methane consumption under pasture areas. Soil methane consumption occurs in both forest and pasture soils during the dry season. The methanogenic communities were favored all over the soil profile in pasture condition under sandy soils, whereas in clayey soils methanogenic anaerobic microbes were found predominantly in the top soil (0-10cm), probably associated to soil compaction due animal trampling.

Keywords: greenhouse gases; land use change; methanogenic community; methanotrophic community; Oxisol.

Financial support: São Paulo Research Foundation - FAPESP Project Number 2017/18327-7 and 2014/50320-4.

(5499 - 2111) Soil organic carbon sensitivity to management and climate change in rice based cropping systems

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IRRI[1]

Soil organic C (SOC) remains an important component of the global C cycle, containing three and two times more C than the biosphere and the atmosphere. The effects of climate change, particularly warming, and management on SOC in cropping systems have been inconsistent. Two separate long-term experiments were established to monitor the effects of i) nutrient management and ii) crop rotations on rice productivity in South East Asia. Three crops per year were grown since 1963 for the nutrient management experiment while the rice-maize rotation was initiated 1993 with two crops annually. Despite a $4^{o}C$ increase in minimum temperature over 55 years and straw removal, SOC content has been maintained at 25 g C kg^{-1} soil in the no N treatment but increased in treatments with optimum N additions. In contrast, there was a 15% decline in SOC content in the rice-maize cropping system with no N additions over 18 years. However, the addition of N fertilizers negated the C decline in this system. These results suggest sustainability and maintenance of SOC in continuously flooded lowland rice cropping systems. Crop diversification on the other hand, with lowland-upland rotations that require an aerobic phase favour organic matter decomposition and loss of SOC. Nevertheless, a more complete evaluation of SOC in deeper soil profiles is needed as processes in upland systems tend to mix SOC with mineral soil to a greater depth whereas in lowland soils SOC tends to accumulate in surface layers.

Keywords: Rice Warming Crop rotation

Financial support: International Rice Research Institute

(7124 - 3027) Soil organic carbon stock in assessment of the relative importance of location and land use in southeastern Nigeria

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The amount of organic carbon stored in any depth of the soil could be a reflection of the interaction between location (climate and soil) and land use. In some regions of the world, differences in local climate and parent material are important but land use culture is similar. Relative weighting of the contributions of location and land use to soil organic carbon (SOC) stock in such regions is necessary to guide planning of SOC sequestration projects. In this study, SOC stock was assessed in southeastern Nigeria typifying the above scenario. The assessment was done in 12 locations, each under three adjacent, common land use type in the region namely secondary forest (SFT), grassland fallow (GLF) and bare-fallowed soil (BFS). Mean annual rainfall in the locations is within the range of 1,500-2,200 mm. Sampling was done from the topsoils (0-30 cm) and subsoils (30-60 cm). The locations show differences in clay content (range, 75-193 g/kg) but not silt content (range, 38-228 g/kg). Location and land use had no interaction in SOC stock. Soil bulk density, microporosity, organic carbon and hence SOC stock differed among the locations and land use types. The highest and lowest values of SOC stock (45.10 and 17.40 t/ha) were obtained at Isinyi-Nando I and Ikem-Nando, respectively; for land use types, the highest and lowest values (40.40 and 19.10 t/ha) were recorded under SFT and BFS, respectively. Clay content was lower in topsoils than subsoils, but organic carbon and SOC stock showed the reverse trend. The soil properties controlling SOC stock were organic

carbon and microporosity (r = 0.94** and 0.25**, respectively). These are two soil properties influenced by both location and land use, as also evident in this study. At the present level of data analysis, it is difficult to determine which of location and land use influences SOC stock the more in the region. Hence, we are currently exploring more robust analysis to highlight the stronger between these two factors, information that would benefit soil management for SOC sequestration.

Keywords: local climate; soil texture; soil management; soil microporosity; carbon sequestration
Financial support:

(9058 - 2078) System of rice intensification (SRI) in temperate regions to improve grain yield and to mitigate greenhouse gases

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System of rice intensification (SRI) was first developed by Fr. Laulanié in 1980s in Madagascar. Since then, it has been introduced to worldwide by Prof. Norman Uphoff of Cornell University. It was successfully adopted by farmers mostly in tropical regions whereas few successful applications of SRI were reported in temperate regions such as in Korea and Japan. The basic idea of SRI is to transplant a young single seedling per hill with a wide spacing, e.g. >25 cm, and to intermittently irrigate water. We found that the intermittent irrigation reduced emissions of greenhouse gases, CH_4 and N_2O, from experimental paddy fields in central Japan and Thailand. With intermittent irrigation, the grain yield of some rice varieties increased in Thailand whereas that of the same varieties decreased in central Japan. In Japan, water stress on young rice seedlings applied by intermittent irrigation especially in the first 3 weeks after transplanting might be attributed to the yield reduction. When we modified the original SRI by flooding water in the first 3 weeks to reduce water stress, the grain yield was similar or a little over that grown with the conventional continuous flooding procedure. In the filed experiments in Thailand, for a rice variety well adopted to intermittent irrigation, aerenchyma was well developed for both intermittent and continuous flooding conditions. In the meanwhile, for rice varieties poorly adopted to intermittent irrigation, aerenchyma was not developed for the intermittent condition. We speculated the aerenchyma development might be the key factor to increase grain yield with intermittent irrigation.

Keywords: intermittent irrigation methane gas nitrous oxide gas water stress
Financial support: KAKENHI research A (#23255014, #25252044)

(1065 - 2192) Temporal soil carbon dynamics and conservation practices in a semi-arid cotton producing region of Texas

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Semi-arid production regions of Texas are challenged with maintaining crop production under depleting ground water resources and diminishing soil health. To enhance the longevity and economic viability of crop production, conservation tillage, crop rotation, and cover crop practices must be implemented. When optimized for regional conditions, these practices shouldconserve water and soil resources through increased water holding capacity and soil organic C (SOC), which thereby reduces irrigation water requirements, while also improving soil health. Increasing SOC content will likely enhance aggregate formation and reduce soil degradation, erosion, and compaction, and thus increase water and nutrient availability to plants and microorganisms as well as the soils capacity for C sequestration in long-term cropping systems. Demonstration of these conservation practices is vital for ensuring the productive capacity of soil in semi-arid farming regions. Management practices for securing our soil are being demonstrated in an intensive monoculture cotton cropping system in Lamesa, TX. These practices, including conservation tillage and rye cover were implemented 19 years ago. Soil organic C in the top 10 cm has doubled using conservation tillage and rye and mixed species cover compared to conventional practices. The effects of conservation practices, including soil water content, nutrient availability, and cotton yield are also being monitored.

Keywords: Soil organic carbon Root C contributions Conservation practices No-tillage Cotton
Financial support: NRCS-CIG

(7425 - 1299) Tidal Wetland Soils for Greenhouse Gas Mitigation: Scientific Progress and Research Gaps

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The conservation and restoration of tidal wetland soils has significant potential for greenhouse gas mitigation through enhanced carbon sequestration and decreased methane and nitrous oxide emissions. Carbon storage and greenhouse gas emissions from tidal wetland soils has been described generally by the term “blue carbon”. The past decade has seen a dramatic increase in blue carbon research driven by the potential for carbon financing of conservation and restoration projects. This research has been accompanied by the development of new international greenhouse gas accounting methodologies by organizations such as the Verified Carbon Standard that allow projects to generate offset credits for sale in voluntary carbon markets. In this presentation, I will discuss research developments and needs related to carbon sequestration, methane emissions, and nitrous oxide emissions in marsh, mangrove, and seagrass systems. Topics will include the use and misuse of default values, allochthonous carbon quantification, soil profile sampling methods, estimation of methane emissions, soil carbon fate following erosion, and estimation of carbon dioxide emissions that have been prevented through conservation or other practices that avoid soil degradation. I will also discuss management practices that have the greatest potential greenhouse gas benefits in these systems.

Keywords: blue carbon, carbon sequestration, methane emissions, marshes, mangroves
Financial support:

(2752 - 1275) Tillage and cropping systems and nitrogen fertilization affected carbon accumulation in superficial and subsuperficial soil layer after 30 years in Southern Brazil

Murilo Veloso[1]; Cimélio Bayer[1]; Denis Angers[2]; Tales Tiecher[1]; Sandro Giacomini[3]; Jeferson Dieckow[4]
UFRGS[1]; AAFC-Canada[2]; UFSM[3]; UFPR[4]

The potential effect of NT on SOC sequestration under tropical and subtropical soils will help Brazil meet its 37% GHG reduction target by 2025. Coupled with legume cover crops, NT could result in even larger C sequestration than just no soil disturbance exclusively. Using a factorial long-term field experiment, the objective of this study was to disentangle the respective effect of NT, legume cover crop and nitrogen fertilization on C sequestration of superficial and superficial soil layers. The experiment compared the effect of NT vs. CT combined with cover cropping systems with or not legume cover crop and mineral N fertilization in an Acrisol of Southern Brazil. Thirty years of contrasted management practices results in large differences (up to 35 Mg ha^{-1}) in SOC stock in the whole soil profile (0-100 cm), explained around 80% by C inputted via cropping systems and N fertilization. All three management factor contributed to soil C sequestration, but the combination that provided the greater rate was NT with legume cover crops and N fertilization (1.15 Mg ha^{-1} $year^{-1}$).

When considered individually, legume cover crops had the greater effect on SOC stock followed by NT and N fertilization. Besides that, we found out that legume cover crops convert 1 kg of residue inputted to 0.30 kg of SOC, while were 2 times more efficient in SOC sequestration than nitrogen fertilization alone. The high C sequestration rate after 30 years are due to increase in soil subsuperficial layer. The contribution of crop residues to subsuperficial SOC was confirmed by soil carbon isotope signature (from 14.8 to ~17.5‰ in 75-100 cm). When expanded to the large agricultural area in Brazil, our high C sequestration rate suggest a potential addition of 5.6 Tg CO_2 $year^{-1}$, which may represent one-third of the mitigation set as target in the Paris agreement for Brazil.

Keywords: no-tillage, legume cover crops, soil carbon sequestration, climate change

Financial support: UFRGS, FAPERGS, CNPq, CAPES, AAFC-Canadá

C3.3.6 - Sustainable phosphorus fertilizer use in tropical soil

(9629 - 597) Animal manures applied to soil as a phosphorus source: Impacts on soil legacy phosphorus to crops and for runoff losses

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Phosphorus (P) was included in the EU Critical Raw Materials in 2014 warning about the need of reuse or recover of P in agriculture. The continuous use of P fertilisers in many cases above plant needs led to P saturation of arable soils and to losses to waterbodies causing their eutrophication. The sustainable use of P should considered not only the reuse of P contained in composts or animal manures but also the soil legacy P. Soil legacy P can be considered as an important secondary resource to plant needs. The aim of this work was to evaluate the contribution of soil legacy P to (i) crops and (ii) losses to runoff waters, after two years of no-P fertilisation. A field trial was conducted at an erosion experimental station. The initial treatments were: cattle manure (*M*); solid fraction of pig (*SS*) and duck slurries (*DS*) and superphosphate (TSP), each applied at a rate of 50 kg P ha^{-1} after *Lolium* sp was sown. This trial was conducted in two consecutive years (2012-13; 2013-14). After that the P fertilisation and the addition of manures were stopped and *Lolium* sp was sown in the years 2014-15 and 2015-16 only with N mineral fertilisation. At the end of 2015-16 crop cycle soil Olsen-P, crop biomass and P losses to runoff waters were evaluated. In the 2013-14 crop cycle Olsen-P (mg kg^{-1}) was high in all treatments with values between 73 in *DS* to 36 in *M* treatment. Olsen-P remains high at the end of 2015-16 crop cycle with values ranged from 70 in *DS* to 27 in *M*. In 2015-16 the crop biomass (dry matter yield) was significantly lower in *TSP* (2,319 kg ha^{-1}) than in *DS* (3,444), SS (3,287) and *M* (3,472). The same was observed with P uptake *TSP* (2.5 kg ha^{-1}) < *M* (4.8) ≈ *SS* (6.4) < *DS* (8.0). P losses by runoff waters in 2015-16 ranged from 0.08 in *TSP* to 0.03 kg ha^{-1} in *SS* and were lower than in 2013-14 were P losses ranged from 1.2 in *DS* to 0.1 kg ha^{-1} in *M*. After two years of no-P fertilisation soil legacy P originated from animal manures showed higher increases of crop biomass and P uptake than when legacy P was originated from mineral fertilisation. Although soil Olsen-P remains high P losses to runoff waters decreased significantly compared with the P losses soon after P fertilisation. P losses were higher in treatments that had been fertilised with mineral P than with animal manures. In conclusion, when soil legacy P comes from animal manures P remains more available to crops and causes lower losses to waterbodies than when it comes from mineral fertilisers

Keywords: Eutrophication; Olsen-P; phosphorus sustainability

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(4652 - 2389) Changes in phosphorus fractions due to the forest-pasture-sugarcane conversion in Brazil

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Sugarcane is largely cultivated in Brazil in almost 9 Mha and it is expanding to new areas previously used for grain yield and cattle grazing, due to higher demands for ethanol and sugar. These areas were originally forest and converted to pasturelands. This strategy is especially appealing in Brazil because pasturelands cover approximately 200 Mha, approximately three times the arable land area of the country. Soil organic matter (SOM) depletion and loss of soil nutrients such as phosphorus (P) associated with SOM have been appointed as important indicators of soil quality degradation. Soil P is present in organic and inorganic forms, ranging from ionic forms in solution to highly stable compounds with SOM and/or clayey minerals. The distribution of P into organic and inorganic compounds varies, reflecting soil use and composition of both natural ecosystems and agroecosystems. Therefore, P fractionation and grouping into chemically defined pools, such as labile, moderately labile and non-labile (organic and inorganic) is useful for quantifying the fate of native and applied P in both systems. This research work hypothesizes that the conversion of forest-pastureland-sugarcane can change the dynamics of P pools in the soil over time. This research was conducted in Sorocaba, the southeast region of the State of São Paulo, with an altitude of 600 m a.s.l, the annual average temperature and precipitation of 21.4°C and 1300 mm, respectively. The area has an average slope of 6.5% and has been used for low-input dairy livestock for the last 30 years, after conversion from forest, without the addition of fertilizer, manure or any especial practice. The sugarcane trial was converted from pasture last year. According to the Brazilian soil classification the predominant soil type is Latossolo Vermelho with a high content of clay, 650 g kg^{-1}, and only 17 g kg^{-1} of sand. The forest located in the Floresta Nacional Ipanema distant approximately 20 km from the agricultural plots. Soil samples from the depths of 0-10 and 10-20 from the forest, pasture, and sugarcane trials were collected and analyzed for chemical P fractionation. Soil P fractionation will be conducted according to the methodology described by Hedley et al. (1982). Our samples are under analysis and the results will be written in February, 2018. It will be a great pleasure for us if you give us the opportunity to attend in 21WSSC and update our abstract by the end of February, 2018.

Keywords: Land-use change; phosphorus fractionation; sugarcane

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(1438 - 1598) Development of activated dolomite phosphate rock fertilizers for sustainable agriculture in tropical and subtropical regions

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Phosphorus (P), one of the major nutrients for plant growth, animal production, and human health, is mainly mined from phosphate rock (PR). Globally, 90% of the mined P is used for food production, as fertilizers and animal feed. The demand for P is increasing due to rapidly expanded world population and widespread of P deficient soils, especially in the tropical and subtropical regions. However, phosphate reserves are very limited, particularly those adequate for phosphoric acid production. Alternate technologies need to be sought

for exploring the value of low-grade phosphate ores, which are left in the mining sites in large quantities. In this study, we developed new technologies that can convert low grade PR into slow release fertilizers, which are needed to replace water soluble P fertilizers that often cause environmental pollution in modern agriculture. Dolomite phosphate rock (DPR), one of the low grade PRs from central Florida, was tested with the newly developed technologies, in which DPR power is subjected to activation by reacting with pre-screened organic molecules under optimized conditions. The results indicate that the activation process could dramatically raise water soluble P in the DPR. Moreover, the activated DPR is featured with slow release characteristics by continuously supplying P to crop plants to meet their growth needs. This slow release property is related to relaxing of Ca-P and/or Mg-P bond due to interactions with organic molecules during the activation process. Compared to conventional P fertilizers, the activated DPR fertilizers can meet the nutritional requirement of crops for P while minimizing P loss into the environment. In addition, the activated P fertilizers have great potential for application in organic farming as they are not considered as chemicals.

Keywords: Activation, low-grade phosphate, soil quality
Financial support: Florida Institute of Phosphate Research (Contract # FIPR 15-01-208)

(1186 - 2450) Maize growth as a function of residual phosphorus of soluble phosphorus sources applied in very clayey soi

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The objective of this experiment was to evaluate the influence of the phosphorus (P) residues provided by the soluble phosphate sources triple superphosphate (TSP), monoammonium phosphate (MAP) and TSP associated with urea (SN), which provided N equivalent to that provided by MAP in the production of accumulated dry matter of corn plants (*Zea mays*) in 14 cultures, grown in pots containing 5.5 kg of very clayey soil. The effects of the dose of 300 mg kg^{-1} P and its residues from band application (BA) and effluent for the soil (EF), the fertilization contact time of 0, 30 and 120 days before maize were evaluated. The accumulated dry matter in these 14 cultures was similarly influenced by the MAP, TSP, TSP + N sources, and no effect of the contact time prior to the first cultivation was observed. There was a trend of higher growth in treatments with localized fertilization than treatments in total soil volume. The incorporation of N in the SN treatment to compensate for the N effect of the MAP did not result in alterations in the growth when compared to the MAP, indicating that the nitrogen fertilization performed during the cultivations was adequate. EF and BA residues from phosphorus sources had a positive effect on maize dry matter, with the dose - dependent effects of residue rather than on the source of phosphorus. With the increase of the residual dose of P there was an increase in dry matter accumulated in the 14 crops, with data being adjusted to the linear model. The higher yields observed in the treatments corresponding to the EF residues are admitted, mainly, to be associated to the dose effect, than to the nature of the residue, when the dry matter accumulated in 14 crops is considered. MAP, TSP presented similar effects on maize growth. keywords: banded phosphorus, effluent phosphorus, monoamonium phosphate, triple superphosphate Financial Support: State University of Maringá.

Keywords: banded phosphorus, effluent phosphorus, monoamonium phosphate, triple superphosphate
Financial support: Universidade Estadual de Maringá

(8998 - 2793) Organic acid loaded nanoclay polymer composite and phosphate solubilizing bacteria for solubilization of Indian rock phosphates: A step towards sustainable P management

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Non-renewable resource of rock phosphate (RP) across the globe is going to be exhausted in near future. In this context, we developed a strategy to solubilize low-grade Indian RPs from Purulia and Udaipur through organic acid (citric and oxalic) loaded nanoclay polymer composite (NCPC) and phosphate solubilizing bacteria (PSB, *Pseudomonas striata*). Oxalic acid and citric acid were loaded @ 2% (w/w) in NCPC having 10% clay (OA-NCPC and CA-NCPC). Organic acid loaded NCPC (2 g kg^{-1} soil) containing 40 mg acid kg^{-1} soil was then mixed with RP (100 mesh size) at three rates of P (0, 50 and 100 mg P kg^{-1} soil) with and without inoculation of PSB and tested as source of P along with a control and commercial diammonium phosphate (DAP) through an incubation and a greenhouse experiments under wheat-rice cropping sequence. The incubation experiment showed a positive impact of the organic acids in their ability to release P from RPs sources, and oxalic acid performed better over citric acid in solubilizing P from RPs. The two indigenous RPs maintained almost comparable available P in soil throughout the period of incubation. With increase in levels of P application, there was an increase in the amount of release of P from both the RPs. Similarly, with the increase in levels of organic acid both Udaipur and Purulia RPs showed increase in the available P in soil. Data emanated from greenhouse experiment revealed that RP along with oxalic acid loaded NCPC and PSB inoculation performed significantly better than control in terms of yield, P uptake by crops and build-up in available P in soil. Yield and P uptake by wheat was at par for DAP and oxalic acid loaded NCPC+RP treatments but residual impact of oxalic acid loaded NCPC+RP was better than DAP in rice. The changes in inorganic P fractions were also interesting due to inclusion of RP along with organic acid loaded NCPC and PSB. The Fe-P fraction was more dominant in soils compared to other fractions. However, the Ca-P fraction showed a higher value with the increase in levels of P application. The oxalic acid loaded NCPC performed better in most of the cases compared to citric acid loaded NCPC and proved to be a more efficient solubilizer of P from RP. This study demonstrated that availability of P from low-grade Indian RP could be improved with the interventions of organic acid loaded NCPC and PSB which could be used as novel alternative P source and reduce the dependence on commercial DAP amidst P scarcity.

Keywords: Organic acid; nanoclay polymer composite; rock phosphate; P solubilization, phosphate solubilizing bacteria
Financial support: Department of Science and Technology (DST) / Indian National Science Academy (INSA) / Indian Society of Soil Science (ISSS)

(7487 - 320) Phosphorus Placement for Annual Crops in the Tropics

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Highly soluble P fertilizers perform better when applied in-furrow as granules to soils with pH values ranging between 6.0 to 6.5. Recently, while looking for better operational efficiency, many farmers have been challenging this recommendation and are increasingly broadcasting on the soil surface before seeding. Gains due to more efficient farm field operations are welcome, but should not come at the expense of high yields and environmental protection. Continuous broadcast application of P may lead to water stress in dry years as

roots mainly develop within the top soil layers. Also, important to consider that P fertilization are among the factors influencing the eutrophication of waters. If P fertilizers are broadcast, soluble and particulate P will accumulate at the soil surface leaving a larger portion susceptible to reaching water reservoirs through runoff. Local research is always necessary to establish the potential risks of the different methods of P placement to runoff. In the absence of local research some general guidelines on the placement of fertilizer P are: (1) when opening new areas, if finances are available, farmers can choose to raise P by broadcasting and incorporating into the soil, (2) to correct soil P concentrations gradually, farmers should apply P fertilizer in-furrow at rates that are higher than crop removal, (3) in soils with sloping topography fertilizers should be applied in-furrow, (4) in soils with moderate P concentrations at the 0 to 10 cm and very low or low soil P at 10 to 20 cm, the higher the risk for water stress and the more sloping the field, the greater the requirement to apply P fertilizer in-furrow, (5) in soils with moderate to high P concentrations to at least the 20 cm depth, and a field landscape that offers a low risk for runoff, P fertilizer may be broadcast on the soil surface, (6) varying the P placement strategy over time can be a good way to combine the advantages of different systems, (7) farmers may rely on satellite-guided planting equipment and apply P in-furrow before seeding, (8) farmers should adjust application equipment so P distribution is uniform, (9) no-till should be managed well to promote the accumulation of organic matter, favoring P distribution throughout the soil profile, (10) soil fertility at different soil depths should be evaluated to help determine the best strategy for P placement. The general concepts above should be adapted to each and every farm field.

Keywords: P use efficiency, P placement, runoff, eutrophication
Financial support: IPNI Brazil

(1626 - 849) Poor P use efficiency and novel fertilizers - when can the latter mitigate the former?

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Fixation of phosphorus (P) in soils is often regarded as a huge problem for agriculture globally, due to the term "fixation" often being poorly defined and also often confused with P adsorption onto, or precipitation in, soils. At the same time many countries suffer from eutrophication of water bodies due to movement of "legacy" P from soils to surface water supplies. Co-existence of problems due to fixation and legacy P in the same soil or region seems paradoxical and new fertilizer products often promise to solve both issues, paradoxically again sometimes simultaneously. The agronomic efficiency of P fertilizers is primarily controlled by P reactions with the soil surfaces and interactions of fertilizer form/placement and soil moisture conditions that affect root interception of, or access to, the fertilizer. With a few notable exceptions, losses of P from soil do not markedly affect the agronomic efficiency of P fertilizer use, but certainly have the potential to cause adverse environmental effects. In many soils fixation of P has much less effect on fertilizer efficiency than is commonly believed, and products that claim to improve fertilizer efficiency have much less effect than is commonly claimed. Recent reviews of the performance of “enhanced” P fertilizers have concluded that they have no, or little, agronomic effect. Situations where we really need to be concerned about P fixation are in soils with no, or a poor, history of P fertilizer use, on soils with strong P retention due to high contents of aluminium and iron oxides, on soils rich in calcium carbonate, and where crops require large and/or rapid P uptake to grow successfully. The role of fertilizer formulation and plant breeding in these situations will be discussed in relation to improving P fertilizer use efficiency in tropical soils.

Keywords: residual value, fertilizer efficiency,
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(2193 - 1221) Response of soil Olsen-P to P budget and its relation with soil properties of three typical soil types in China under long-term fertilization

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Long-term fertilizations affect soil available phosphorus content (Olsen-P) and its relationship with P budget, which are influenced by soil properties. However relative contribution rates of soil properties to the relation of soil Olsen-P with P budget still lack. This study invested the qualitative relationship of soil Olsen-P to P budget of three typical soil types of China under long-term fertilization experiments (1989-2012). And relative contribution rates of soil properties were also studied by variance partitioning analysis (VPA). The results showed that, under treatments without P fertilizers (CK, NK), the order of soil Olsen-P decline over experimental years among the three soil types was Gongzhuling (GZL) (0.35-0.40 mg kg^{-1} a^{-1}) > Qiyang (QY) (0.25-0.27 mg kg^{-1} a^{-1}) > Zhengzhou (ZZ) (0.11 mg kg^{-1} a^{-1}). The decrease of soil Olsen-P showed significantly positive linear relation with P deficit. Under every 100 kg ha^{-1} soil P deficit, the order of soil Olsen-P decreasing was QY (2.87-4.56 mg kg^{-1}) >GZL (1.31-2.62 mg kg^{-1}) >ZZ (0.60-0.63 mg kg^{-1}). Under treatments of P fertilizers (NPK, NPKM, and NPKS), soil Olsen-P content of QY and GZL increased by 1.70-6.87 and 0.28-8.66 mg kg^{-1} a^{-1}, respectively. Soil Olsen-P content increased for ten years then decreased under treatment of NPK and NPKS of ZZ, and increased by a rate of 2.28 mg kg^{-1} a^{-1} under NPKM of ZZ. The increase of soil Olsen-P and P surplus could be simulated by simple linear equation and quadratic equation. Under treatments of NPK and NPKS, soli Olsen-P of QY increased by 3.12-4.27 mg kg^{-1} for every 100 kg ha^{-1} soil P surplus; soil Olsen-P and P surplus showed significant quadratic correlation of ZZ; because of low P surplus (about 50 kg ha^{-1}) , soil Olsen-P did not increase significantly by P surplus in GZL. Under treatment of NPKM, the order soil Olsen-P increasing was GZL (35.79 mg kg^{-1}) > QY (6.95 mg kg^{-1}) > ZZ (3.96 mg kg^{-1}) for 100 kg ha^{-1} soil P surplus. The analysis of VPA showed, soil properties of this study could explain 35.86% of the variance of the relation of soil Olsen-P and P budget. And the content of soil total P (7.85%), the fractions of labile P (6.50%), available N (4.53%), and organic matter (3.74%) were the main soil properties explaining the variance of the response of soil Olsen-P to P budget. In the process of P fertilization, the content of total P, organic matter and available N should be taken into account to improve soil P availability.

Keywords: soil Olsen-P; P budget; soil properties
Financial support: the National Natural Science Foundation of China (41471249); the Special Scientific Research Fund of Agricultural Public Welfare Profession of China (201503120)

(5215 - 2447) Using current knowledge of phosphorus fertilizer reaction pathways to improve P use efficiency

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In many highly weathered, tropical soils, a high proportion of land applied fertilizer phosphorus (P) is rapidly converted to insoluble forms (“fixed” P) with limited plant availability. Low P availability in soils is a major constraint for crop production. High nutrient loading intended to overcome P availability limitations can negatively affect surface water quality. To remedy this issue, extensive research has been conducted towards increasing the plant acquisition efficiency of P applied to the soil. As a result, various commercial fertilizer co-

additives have been developed, and their use is becoming a more common practice. Among these, humic substances (e.g. fulvic acid) and co-polymers of high cation exchange capacity and highly reactive functional group density (e.g. carboxylic acids) are currently being utilized in the tropics and other parts of the world. These substances can be incorporated or coated on granular P fertilizers or mixed into liquid P fertilizers to minimize fertilizer P "fixing" reactions upon soil application. In addition, P formulation (i.e. liquid versus granular P fertilizers; ortho-P, poly-P versus P blends) and controlling the concentration of P at the point of application via manipulating the P application method (e.g. differential P concentration) may also influence and/or alter fertilizer P fate and transport. Detailed work conducted in our laboratory to investigate these approaches has shown variable ability of the co-additives, P formulations, and application methods to influence anion exchange resin extractability, speciation, and P diffusion in select tropical soils. Further investment into fertilizer research and development of new, innovative technologies is required to overcome fundamental soil-fertilizer reactions leading to low P availability in highly weathered, tropical soils.

Keywords: tropical soils, P fertilizers, co-additives, availability, mobility, speciation

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C3.3.7 - Contribution of zero tillage (no-till) to sustainable use and management of soils

(4549 - 822) A half-century of no-tillage and crop residue retention on a Vertisol in north-eastern Australia: lessons learnt

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There is a paucity of information on the long-term effects of no-tillage and crop residue management (CRM) on productivity, soil health and environment. An experiment was established in 1968 to study the effects of tillage (no-tillage, NT vs conventional tillage, CT), CRM (stubble retained, SR vs stubble burnt, SB) and fertilizer N (0, 30 and 90 kg N/ha) on a Vertisol at Hermitage Research Station (28.2^{O}S, 152.001^{O}E), Queensland, Australia. The site is the second longest continuously maintained no-till research experiment in the world. On an average of 45 cereals crops over the 50 years, the grain yield was significantly (p=0.001) higher under NT (2.57 t/ha) than CT (2.47 t/ha) with no significant differences between SR and SB. However, SB had significantly (p=0.001) higher grain protein (13.1%) compared to SR (12.5%), although it was unaffected by tillage (NT vs CT) treatments. Nitrogen fertilization (NF) significantly (p=0.001) increased both grain yield and protein. NT with SR resulted in greater water storage efficiency by the end of the fallow period and stored more water in the soil profile at sowing. Pre-sowing soil nitrate-N levels were generally lower under SR and NT than SB and CT. Soil organic carbon (SOC) stocks measured over time showed a decrease (0.29 Mg/ha.year to 0.3 m soil profile) across the experiment and more so in the top 0.1 m under SB and CT as compared to SR and NT. SOC and total N concentrations and stocks were significantly higher under NT, SR and NF than CT, SB and N0. Aggregate stability of topsoil was generally higher under NT and SR, however, water-stable aggregates were not affected by tillage and CRM. Chloride concentration measured over time indicated that drainage rates were greater under NT and SR than CT and SB. Earthworm populations were also greatest under NT and SR with no significant changes in vesicular arbuscular mycorrhizae (VAM). Annual N_2O emissions were significantly higher in NF than N0 and were lower under NT compared to CT and under SR compared to SB. There was no significant differences in CH_4 emissions for any treatment. Using data from the experiment over time allowed examination of the APSIM crop simulation model to simulate grain yield, soil water and SOC. The experiment has provided a valuable resource for understanding long-term effects of tillage, crop residue management and nitrogen application on crop production, soil biology, physical, nutritional and water dynamic in a sub-tropical environment.

Keywords: No-tillage, crop residue, nitrogen, soil health, productivity

Financial support: The University of Queensland

(1950 - 2698) Agricultural Sector Burning: Hidden Impacts on Soils, Crop Yields, Human Health, Water and Climate

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ICCI[1]

Open burning in agriculture – defined as all intentional burning in the agro-forestry sector, including stubble and pastureland burning and use of fire to clear fallow lands, but excluding prescribed burns on wildlands -- is a practice with deep historical roots. It can take place regularly with the misconception that it renews the soil, or sometimes to save time and effort. Burning, however, damages soil and decreases its productive capacity by destroying the organic matter and soil structure - vital for high yields. With each successive burn, soils become less fertile and water retentive, and more prone to erosion, while also destroying the straw - a potentially valuable resource for energy, animal feed or bedding. In addition, it produces greenhouse gases; and when the soot and smoke (black carbon, a short-lived climate pollutant or SLCP) from open burning travels through wind forces and is deposited to the cryosphere, it accelerates glacier melt by lowering reflected solar radiation. This then impacts water resources by speeding up glacier loss already well-underway through global warming, for example in the Andes, in a vicious cycle that then decreases availability for irrigation and drinking needs. In contrast, alternative "no-burn" methods ultimately will improve crop yields and profits, while preventing emissions of GHGs and black carbon. Conservation agriculture (low-till, no-till with cover crops and injected manure) can eliminate the need for the practice of open burning entirely, thereby improving human health, food security, and rural livelihoods through better access to clean drinking water and irrigation. These methods also provide some level of adaptation and resilience: the stubble roots preserve soil structure and slowly decompose, serving to fertilize the succeeding crop; and overall increasing soil organic matter. The leftover roots also provide resilience to both extreme droughts -- through preserving moisture content; and extreme rainfall events, by holding soil in place. Both these extremes have become of greater concern for farmers in a changing climate; and there is increasing evidence that such methods also fix greater amounts of carbon in the soil (ie negative emissions). Other no-burn methods also aid adaptation, such as the use of straw stubble for bio-energy or cookstove fuel to preserve local forest resources. Switching to conservation agriculture, however, remains the most sustainable of these potential alternatives.

Keywords: no-till, burning, soil health, climate change

Financial support:

(7723 - 1048) Can Zero-tillage be justified on socio-economic grounds in the drylands of North Africa? A Moroccan case

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While the biophysical and environmental benefits of CA in North Africa have been fairly documented, the literature on its adoption levels and socio-economic viability is scanty. Using a nationally representative sample survey of 1230 wheat farmers, this paper provides estimates of the adoption level of zero tillage (ZT) at national and provincial levels. Moreover, given the importance of socio-economic factors in determining adoption of agricultural technologies, this paper provides empirical evidence on the socio-economic impacts of adoption of ZT. To this effect, we use the instrumental variables approach (IV) that is potent in correcting for the inherent estimation problems of both overt and hidden biases and endogenous treatment. Using wheat areas at farm and the different administrative levels as weights for upward aggregation, the national adoption level of Zero tillage is found to be only 5.2%. Model results show that after controlling for all confounding factors, adoption of the ZT technology leads to 277.8 kg/ha (31%) higher yields, US$172.2/ha (62.1%) higher net wheat farm income, 9.3 kg (16%) more consumption of wheat per capita per year and 100% and 55% reductions in the risk of obtaining yield levels below 500 kg/ha and 1000 kg /ha respectively. While the benefits per unit area and per household are fairly high, the low national average adoption level has undermined the ability of ZT to increase the national wheat production, reduce poverty and increase national food security. A closer look in to tillage intensity also showed that tillage has negative and significant effects on all the socio-economic indicators considered where the value of each indicator declines as the frequency of tillage increases. For example, the first tillage reduced yield by 24.8%, while the second and third tillage individually led to additional yield losses of 0.3% and 23.1% respectively. All these results provide socio-economic justifications for the efficacy of ZT and that a wider adoption of ZT has the potential of improving the productivity, profitability and sustainability of agricultural production in Morocco and other similar countries with dryland agriculture. From a policy perspective, our results suggest that North African governments should consider embracing ZT as one of the priority cropping technology packages in their national extension programs for dry areas and develop policies which overcome limitations to adoption.

Keywords: Zero-tillage, Morocco, socio-economic impacts, consumption, production risk management.

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(9627 - 880) Conservation agriculture adoption and soil physical properties dynamics. Outcomes from Northeast Italy silty soils coupling on-site 3D geophysical survey and classical methods

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Conservation agriculture (CA) adoption is a growing set of techniques all over the word promoted also in Veneto Region (Northeast Italy) as an agro-environment measure to regulate and support many ecosystem services. In this study the effects of CA on soil physical properties are presented over a 3-yr monitoring period. Experimental design was set up in 2010 on four farms in Veneto Region silty soils where CA practices (no-tillage, cover crop and residues on soil surface) were compared with conventional ones -CV- (ploughing with residues incorporation and bare soil between the main crops). Soil physical properties dynamics were monitored from 2014 to 2016 following 1-yr crop rotation cycle (maize, soybean and winter wheat) inside 24 monitoring areas at crop full bloom. Every year, inside each monitoring area, 3 undisturbed soil cores, 9 soil penetration resistance (PR) profiles and a 3D electrical resistivity tomography (ERT) were performed in the inter-row. Overall, 1944 samples were analysed in laboratory for BD, VWC and particle size distribution while 648 PR profiles and 72 ERT were performed directly on field. Results showed soil physical properties clusterization depending on soil texture. In silty loam/silt clay loam soils CA treatment was associated with higher VWC and degree of compaction (higher BD and PR) in the top soil layers as a results of crop residues on soil surface and absence of tillage operation and high traffic load respectively. Geophysical survey reflected classical measurements with low resistivity in CA shallow layers as results of both higher VWC and BD. On the contrary, coarser soil (loamy texture) with low soil organic carbon content was associated with the presence of a dense plough pan below the ploughing depth of CV treatment which was not observed in CA treatment. Such dense layer was seen with ERT survey as a high resistivity layer and with classical methods with an increase of BD and PR. This research did not demonstrate consistent benefits of CA after 4- to 6-yr of management adoption except the coarse soils where plough pan were not observed. Results clusterization according to soil texture could be explained by the strong interactions between management systems and soil local conditions. However, analysed soil physical dynamics represent only some of the numerous ecosystem services provided by conservation agriculture and long-term studies are also necessary in order to evaluate the real potential of CA on silty soils.

Keywords: no-tillage; bulk density; penetration resistance; electrical resistivity tomography

Financial support: 'Helpsoil' life + European project, LIFE12 ENV/IT/000578

(7713 - 2714) Conservation agriculture principles applied for sugarcane crop propagated by pre-sprouted buds system in Brazil

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In Brazil the sugarcane crop is cultivated in almost 10 million hectares, which 60% of plantations are concentrated in Sao Paulo state, where the majority of areas are harvested without burning. Consequently, after hervesting a great amount of residues is deposited on the soil surface increasing the cost with tillage in almost 30%. In this condition is desirable the adoption of conservation agriculture (CA) principles, but there are few scientific results for sugarcane, specially for pre-sprouted bud system. This kind of propagation system provides a reduction of seed cane from 10 to 2 Mg ha^{-1}, saves 2000 m^3 of water for irrigation, saves money and increases the tillering. On the other hand, this new method is still expensive, is very sensitive to water stress and weed competition. Regarding the benefits of CA principles, the objectives of this research were; to quantify the changes on agronomic and technological characteristics of two varieties of sugarcane in different soil managements after green manure, as well as to understand the changes on the soil characteristics. In a long-term trial started in 2003 and located at Experimental Station of APTA/IAC, Ribeirao Preto city, Brazil, two sugarcane varieties (IACSP95-5000 and Energy Cane) were planted (May 2015) under green manure straw (*Mucuna aterrima* L.), after twelve years of grain crops cultivated in a soil classified as Euthrophic Claye Red Latosol (Oxisol), according to Brazilian System Soil Classification. It was adopted a randomized complete block design in a split-plot scheme and four replications, in which the main plots consisted of three soil management; conventional tillage, reduced tillage (Rip Strip® before planting) and no-tillage. Samples of plant, roots and soil were collected from planting to harvesting in order to evaluated vegetative and roots

growth, agronomic and technological characteristics, as well as some physics (soil strength) and chemical attributes (soil carbon stock). For the plant cane, it could be conclude that the stalk yield was 10,8 and 18,4 Mg ha^{-1} higher than conventional system, respectively for no-tillage and reduced-tillage. The soil carbon stock at 0,60 m depth in no-tillage and reduced was 16,4 Mg ha^{-1} higher than conventional. When the measurements was done in February, the highest value of soil strength was observed in the conventional (5,5 MPa) at depth of 0,14 m, followed by no-tillage (2,92 MPa at 0,15 m) and reduced tillage (2,28 MPa at 0,30 m).

Keywords: *Saccharum oficinarum* hybrid, stalk yield, no-tillage, Rip Strip®

Financial support: AGRISUS Foundation (grant # PA 1494/15). Also we appreciated the CNPQ (National Council for Scientific and Technological Development) for scholarship of the first author (process # 311112/2015-2) and the CAPES for supporting the graduate student.

(2912 - 622) Do short-term conservation agriculture practices affecting stratification of soil labile carbon in Trans-Gangetic plains of India?

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Conservation agricultural (CA) systems based on the principles of minimal tillage, residue recycling and crop diversification for resource conservation and sustainable agriculture promote soil carbon restoration by tipping the balance in favor of carbon inputs relative to carbon outputs. Carbon sequestration in a soil can be achieved by maximizing carbon inputs and minimizing carbon outputs. Soil carbon fractions are influenced by the agronomic management practices adopted in conservation agriculture systems. Contrasting cropping systems, tillage and residue management have great influence soil quality, C and N cycling. SOM stratification (SR) and carbon management index (CMI) as an indicator for soil quality, related to the rate and amount of SOC sequestration generally used for natural and managed ecosystems. In general, the high values of stratification ratio (proportion of a soil property at the surface layer to that at a deeper layer) indicate good soil quality and are usually used to assess agricultural practices. This study aimed to 1) analyze the contents of (Total Nitrogen (TN), (Total Organic Carbon (TOC) and permanganate oxidisable carbon (POCX) and their vertical distributions at the depths; and 2) evaluate the soil quality of different CA management practices using SR and CMI values as the main assessment parameters. Soil carbon stock increased in zero tillage and permanent beds as compared to conventional agricultural practices. Responses of SR in different CA management practices to change of soil depth were significantly different. The SR values of TN, TOC and POCX differed significantly only (0-5:5-15 cm). Distribution and stratification of carbon stock and the pool were influenced by the short-term (4 years) practices of conservation agriculture in western Indo-Gangetic plains of India. SOM stratification ratios serve as an efficient indicator of changes offered by management practices.

Keywords: Conservation agriculture; soil carbon stock; stratification ratio; labile carbon; carbon management index

Financial support:

(2448 - 3167) Earthworm populations and the iqp index in sites under no-tillage system in south Brazil

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Earthworms play an important role in essential functions and services of terrestrial ecosystems. The production of tunnels, galleries and casts affect the formation and maintenance of soil structure, enhancing soil porosity, water retention and infiltration and the decomposition of the organic matter. However, these services can happen when the soil is properly maintained and managed. In this way, the No-Tillage (NT) system is the best alternative for sustainable soil management, since, the minimal disturbance, the permanent soil cover and the crop rotation improve significantly the physical, chemical and biological quality attributes. Considering an erosion process scenario, the Itaipu Binacional with the Brazilian Federation of No-Till Farmers, developed the Participative Quality Index (IQP) of NT, aiming to evaluate the quality of the NT practiced by farmers. The objective of this study was to evaluate the earthworm population (abundance, biomass and richness) in sites under NT system in 12 NT sites and 4 riparian forest (RF), as well, correlating these biological attributes with the IQP value and soil chemical attributes. The earthworms were sampled using the TSBF method and a complementary qualitative sampling. The species richness, biomass and abundance of earthworms data were correlated with IQP and the chemical attributes through a Principal Component Analysis. In total, 1119 earthworms were identified by the TSBF method and 101 by the qualitative method. Twelve species were identified: *Glossoscolex* sp.1, *G.* sp.2, *Fimoscolex* sp.1, *F.* sp.2, *Pontoscolex corethrurus*, *Ocnerodrilidae* sp.1, *Amynthas gracilis*, *Methaphire californica*, *Dichogaster affinis*, *D. gracilis*, *D. bolaui* and *D. saliens* (4 native and 8 exotic). The highest species richness was observed in NT sites, compared to the RF. In the ACP, correlating biological attributes (species richness, abundance and biomass), the chemical attributes (pH, Al, H + Al, Ca, Mg, K, P, C, SB, CEC and V) and the IQP value, showed 57% of the total variance of the data, with significant correlations ($p<0.05$). The biological attributes are positively correlated with P and K contents. The Al and H + Al contents are negatively correlated to IQP values and the other chemical attributes. The IQP, despite being used as an evaluation method for NT, did not present correlations with the measured soil attributes. Further analysis should be performed using data of the historical of the management of the sites.

Keywords: sustainable agriculture; soil biology; bioindicators

Financial support: ITAIPU Binacional and Embrapa through the Research Network SoloVivo and CNPq Universal process 461484/2014-5.

(3754 - 1099) Evaluation of soil moisture analysis results in strip tillage

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Tillage is one of the most significant factors which affect crop growth by changing the moisture balance of soil. During the last 25–30 years in Hungary, there have been increasing efforts to perform energy-saving, cost-saving and sustainability-focused farming methods. Proper tillage may contribute to reducing production risks. The objective of this research study is to examine the opportunities to use strip tillage based on agronomic and economic aspects. Based on the experimental database of the University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management and KITE Plc., various tillage systems were examined with maize *(Zea mays L.)* being the indicator crop. Soil moisture was determined using a FIELD SCOUT TDR 300 soil moisture probe. Soil moisture measurements were performed before sowing. Fifty measurements were carried out in the rows and between rows of ploughing and strip tillage systems each. After harvesting, maize yield and grain moisture content were determined in each tillage system. Yield and grain

moisture are two important indicators of maize production which fundamentally determine the efficiency and profitability of each tillage system. As regards the fuel consumption of the machinery in each tillage system, significant differences were observed both concerning the amount of fuel needed for primary tillage and the whole technology. The moisture preserving role of strip tillage was shown in comparison with ploughing technology. Depending on the given crop year, tillage systems without ploughing resulted in significantly higher moisture content in the upper 20 cm soil layer in comparison with the respective values in ploughing-based systems. Complex agronomic and economic analyses were performed to show the usability of strip production technology of maize.

Keywords: soil moisture, strip tillage, precision farming
Financial support: The publication is supported by the EFOP-3.6.3-VEKOP-16-2017-00008 and GINOP-2.2.1-15-2016-00001 projects. The projects are co-financed by the European Union and the European Social Fund. The experiments were supported by KITE Zrt.

(2800 - 1636) Impact of zero-till on soil properties and function in subtropical Texas, USA

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Adoption of reduced tillage and no-till cotton is one of the most rapidly growing conservation areas in the USA. However, adoption of zero-tillage in subtropical Texas is much lower than other regions of the country. Soil organic carbon is often considered the standard when evaluating the impact of zero-tillage on sustainability. We evaluated the impact of zero-tillage on soil properties and function at on-farm locations and replicated university locations across the region. Our results often showed that soil organic carbon changed very little with time and proved to be difficulty to sequester in semi-arid environments, particularly for monoculture systems in place <10 years. However, we did observe significant improvements in soil physical properties such as soil strength and infiltration. For low residue continuous cotton systems, no-till alone did not improve infiltration over conventional tillage. However, implementing a wheat cover crop system significantly improved soil infiltration. Infiltration rates were generally higher for no-till systems than conventional till systems, particularly if rotational crops such as wheat had been incorporated. Runoff rates were significantly lower for zero-till systems compared to conventional tillage systems. We concluded that crop rotation and/or incorporation of high residue crops or cover crops should be incorporated to promote C sequestration and environmental sustainability.

Keywords: Zero-tillage, soil function, sustainability, organic carbon, infiltration
Financial support: Cotton Incorporated 13-453TX; USDA-NRCS

(3515 - 655) Multiple rolling/crimping effects on rye cover crop termination, soil moisture and strength in a no-till system

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Cover crops are a vital part of conservation systems to reduce soil erosion and runoff, and increase soil organic carbon, soil moisture, and infiltration. Effective termination of cover crops is key for successful planting of cash crops directly into residue cover. In the Southern US, rollers have been used to terminate cover crops and glyphosate has been sprayed with rolling to speed up termination, but due to environmental concerns, there is a need to reduce herbicide use. Typically in the Southern US, the time between cover crop termination and cash crop planting is 3 weeks to reach >90% termination and to eliminate competition with cash crop for water and nutrients. A replicated field experiment was initiated in 2014 to evaluate the effectiveness of different rollers in mechanical termination of a cereal rye cover crop in central AL, USA. Prototype rollers field tested were: 2-stage, 4-stage, spiral rollers, and smooth drum with or without glyphosate to roll rye 1, 2, and 3 times. Standing rye was the control. Rye was terminated at the early milk stage, and evaluated 1, 2, and 3 weeks after rolling. Results are from the 2015 and 2016 growing seasons. In 2015, one week after rolling, the highest termination was found with the 4-stage roller (94%) while the 2-stage roller rolled 3 times was 91%, smooth roller with glyphosate was 90%, and smooth roller rolled 3 times was 89%. The spiral roller generated terminations from 81% to 86%; the control was 40% after one week. Two weeks after rolling, no differences among rollers were found (95% to 97%); the control was 49%. Similarly, 3 weeks after rolling no differences were detected among rollers (99% to 100%); the control was 88%. In 2016 one week after rolling, the 4-stage roller rolled 2 and 3 times and smooth roller with glyphosate was 96% and the 2-stage roller had 94% termination; the control was 29%. Two weeks after rolling, all rollers exceeded 90% termination (94% to 99%) except for smooth roller (89%) and the control (50%). At three weeks after rolling, all rolling treatments had terminations of 98% to 100%, whereas the control had 82% termination. In both growing seasons, rolled rye had higher soil moisture compared to the control and rolling 2 or 3 times did not increase soil compaction compared to rolling once. These values were below 2.0 MPa, which is the limit for soil compaction that restricts optimal root growth. Cotton stand and yield were not affected by cereal rye termination treatments.

Keywords: Conservation system, cover crop, roller crimper, soil compaction
Financial support: Institutional support

(9716 - 2283) No-till versus no-tillage system in brazilian tropical and subtropical regions

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No-till is understood as crop sowing without soil mobilization. This practice fulfils only two of the conservation agriculture (CA) precepts - minimum tillage and maintenance of crop residues on the soil surface. In tropical and subtropical regions of Brazil, these precepts are insufficient to promote soil conservation and insert sustainability conditions to agriculture. The main reason for this is the high decomposition rate of crop residues, which makes both soil aggregate stability and soil cover ephemeral. In these regions, *no-till* must be turned into a *no-tillage system* fulfilling others precepts of CA. Between these precepts, the *no-tillage system* requires crop diversification with presence of summer grasses in the production model and the minimization of the time from crop harvest until the sowing of the following crop (harvesting/sowing process). Summer grasses (cereals or forages) are among the few plants that have potential to produce organic material in quantity (above 12 ton/ha/year) and with quality (high C/N ratio), compatible with the biological demand of the soil and enough to maintain permanent soil cover. The harvesting/ sowing process facilitates crop diversification, promotes greater number of harvests per year, increases the organic material added to the soil and maintains permanent soil cover. However, in Brazil the main model for grain crop production is soybean monocropping under *no-till*. This production model does not ensures the expected benefits for CA due to the low quantity, quality, frequency and fast decomposition of the crop residues added to the soil, which damages the construction and the maintenance of the soil structure, desired for agriculture. For tropical and subtropical

conditions, summer grasses play an essential role to achieving successful adoption of *no-tillage system*, and its expected benefits. The biomass of these summer grasses (especially the root system) is responsible for forming stable aggregates and developing the soil structure, which, in *no-till system*, is a component of soil fertility, because: controls the flow of water, air and heat in the soil; determines soil penetration resistance; and, regulates soil acidity and, therefore, nutrient availability and toxic elements unavailability. Thus, for the adoption of *no-tillage system* or to convert *no-till* to *no-tillage system*, the summer grasses are essential inside production models, to generate the expected technical, economic, and environmental benefits.

Keywords: conservation agriculture; production model; grasses; soil structure

Financial support:

(1190 - 2352) Soil health assessment on a long-term soil tillage experiment from central Kansas

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Studies suggest that 25–75% of soil organic C (SOC) were lost from intensively tilled soils. No-tillage (NT) can restore SOC in response to increased C inputs and reduced soil disturbance. No-till is the key component of conservation agriculture adopted over 125 million hectares worldwide in order to address an ever-growing demand for soil and water quality, food security, and climate change adaptation and mitigation. Here we present a soil health assessment on a long-term (28 yr.) soil tillage experiment from central Kansas, United States. The experiment was arranged in split-plot randomized blocks with four replications in plots with corn (*Zea mays* L.). The tillage systems were the main plots, and N sources were the subplots. The tillage systems were chisel plow and offset disk preplant (chisel tillage [CT]) and no-till (NT) by planting directly through the crop residues with minimal soil disturbance. The chisel plow and disking operations were performed to a depth of 15 and 10 cm, respectively. The N treatments were different sources: 168 kg N ha^{-1} as ammonium nitrate or urea (MF), 168 kg N ha^{-1} as cattle manure or composted waste (OF), and a control (CO) without N amendment. No changes on SOC were noticed under CT, except when OF was applied. Under NT and MG, SOC accumulation of SOC was limited to the surface layer (0-5 cm). Organic fertilization increased initial SOC of the 0-5 cm soil layer to a level of 16.2 and 30.2 Mg C ha^{-1} in CT and NT, respectively. Decreased soil disturbance increased the proportion of large macroaggregates (> 2,000 µm) in the soil under NT. The application of OF increased C content within soil aggregates. Further analysis confirmed the saturation of physically protected SOC at the surface of this NT soil. After saturation, significant SOC accrual (1.3 Mg C ha^{-1} yr^{-1}) was observed in the 5–15 cm soil layer. Further results of soil health indicators will be presented, including soil respiration, potential mineralizable N, microbial biomass C/N, PLFA and PFLA biomarkers of arbuscular mycorrhizae and saprophytic fungi, gram+ and gram- bacteria, and enzymes.

Keywords: soil organic matter; no-tillage soil health

Financial support: USDA NIFA, NSF EPCoR

(2608 - 1282) Soil microbial community control the response of soil CO_2 emission and crop yield to drought under no-tillage

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Climate change induced drought events have increased in frequency, and have resulted in marked reductions in crop growth and grain yield. Strategies will be required for adaptation to climate change reduce its impact on the soil resource and crop yield in agriculture system. Soil CO_2 efflux, temperature and soil microbial community were measured in a long-term (15 years) tillage study in the Northeast Farming Region of China. Tillage practices included no tillage (NT) and conventional tillage (mouldboard plough: MP).Compared with NT, MP decreased maize yield by 11.3% ($P>0.05$) and 47.1% ($P<0.05$) in the dry years 2012 and 2015, respectively. The annual CO_2 emissions were not significantly different between MP and NT. Soil temperature under MP was higher than NT from March to June, but was lower than NT from November to February over the 2011-2016 years. In the dry year, soil temperature under MP was significantly higher by 8.0% and 7.0% than NT in June and July ($P<0.05$) respectively, soil moisture at 22 cm under MP was significantly lower by 40% (average value) than NT from July to August. Soil total, bacterial, fungal PLFA contents under MP were significantly lower than NT from April to September at the 0-5 cm soil depth. Soil microbial PLFA contents in dry year were lower than those in normal year except for June both in MP and NT. The difference of soil total, bacterial and fungal PLFA contents between dry year and normal year under NT were higher than those under MP. The SEM revealed that the predictors explained 46% and 62% of the variation in maize yield and soil CO_2 flux. The soil moisture was associated with maize yield through soil microbes. These results suggested that NT significantly enhanced maize yield by improving the soil water content and soil microbial community function in a dry year, indicating that conservation tillage is a positive adaptation strategy to cope with drought under monoculture maize in the black soil of China.

Keywords: CO_2 flux, drought, soil microbial community, maize yield

Financial support: National Natural Science Foundation of China (41430857), and the Key Research Program of Frontier Sciences, Chinese Academy of Sciences (QYZDB-SSW-DQC035)

(7301 - 2861) Sustainable weed management for conservation agriculture: Options for smallholder farmers

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FAO[1]

Land degradation and soil fertility deterioration are two of the main causes of agricultural production stagnation and decline in many parts of the world. The model of crop production based on mechanical soil tillage and exposed soils is typically accompanied by negative effects on the natural resource base of the farming environment, which can be so serious that they jeopardize agricultural productive potential in the future. This form of agriculture is destructive for soil health and accelerates the loss of soil by increasing its mineralization and erosion rates. Conservation Agriculture, a system avoiding or minimizing soil mechanical disturbance (no-till) combined with soil cover and crop diversification, is considered a sustainable agro-ecological approach to resource-conserving agricultural production. A major objective of tillage was supposed to be weed control, and it does not require very specific knowledge because soil inversion controls (at least temporarily) most weeds mechanically (i.e. by way of burying them). However, repeated ploughing only changes the weed population, but does not control them in the long term. The same accounts for mechanical uprooting of weeds. While in the short term some tillage operations can control weeds on farms, tillage systems can increase and propagate weeds off-farm. The absence of tillage, under conservation agriculture, requires other measures of weed control. One of the ways in which this is realized is through herbicide application. However, environmental concerns, herbicide resistance and access to appropriate agro-chemicals on the part of resource-

poor farmers, highlight the need for alternative weed control strategies that are effective and accessible for smallholders adopting conservation agriculture. Farmers in semi-arid regions contend with the additional challenge of low biomass production, and often, competition with livestock enterprises, which limit the potential weed-suppressing benefits of mulch and living cover crops. This paper reviews the applicability and efficacy of various mechanical, biological and integrated weed management strategies for the effective and sustainable management of weeds in smallholder conservation agriculture systems, including the role of appropriate equipment and prerequisites for smallholders within a sustainable intensification scenario.

Keywords: conservation agriculture; weed management; sustainability; sustainable mechanization
Financial support:

(1523 - 3237) The Economic Future of Agriculture in Mato Grosso

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Mato Grosso planted 9,4 milion hectares of soja in 2017, forecast to increase to 14.8 milllion hectares by 2025. This paper demonstrates the huge improvements in Mato Grosso's farming systems triggered by the adoption of Zero Tillage Conservation Agriculture, from 1990 onwards. Monocropping of soybeans has led to a buildup of pests and diseases and higher costs that must be met by higher yields from genetic improvements, higher inputs or a new system of agriculture. The Mato Grosso Foundation foresaw the challenge to sustainability and has obtained nine years of results comparing two check treatments with three pluri-annual rotations and three successions, including the now standard soya/maize anual succession; cover crops include Pennisetum americanum, Crotalaria spectabilis and Brachiaria ruziziensis. The check treatments represent the initial soybean farming system, the soy/fallow succession, where ZT/CA is better than the conventional system with land preparation, but neither compete with any of the other treatments. The last four years' results give hope : the longer term positive results show that cover crops and pluri-anual rotations (i.e. less summer soya), reduce pest/disease levels while this and genetic improvements enhance yields. For farmers, there is yet insufficient inducement for a 6-8 year investment in cover crops, while winter grazing has the potential to add US$ 90 /ha to farm incomes and environmental services payments for reduced carbon emissions could be even greater. The paper calls attention to two important facts : (i) results of the experiment were on clay soils, but on lighter soils, more common in Mato Grosso, results are expected to be quicker and, (ii) the long term benefits to society of sustainable farming lie in guaranteeing GDP/capita, reducing carbon emissions, preserving native vegetation, soil and water resources, lower use of pesticides per ton of food and food security. There is a well-founded argument that government incentives are required to promote adoption of such long term sustainable farming practices. These would not be subsidies, but social transfers. They would give an exceptionally high return for this public investment in farming's sustainabity, which cannot now be ignored.

Keywords: Mato Grosso, Zero Tillage/Conservation Agriculture, pluri-annual rotation, cover crop.
Financial support: Kit Nicholson, Fundação MT

(9330 - 1419) Tillage management effects on soil physical properties in sugarcane fields

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The advance of mechanization in sugarcane fields has raised concerns about the structural quality of the soil. Studies approaching the impacts of machinery traffic on soil structure reveal the occurrence of degradation process, which consequently leads to soil compaction. The latter increases soil bulk density and soil resistance to root penetration reduces soil porosity and water infiltration rates. In this sense, no-tillage (NT) have been adopted to mitigate the negative effects caused by conventional tillage (CT), but few studies have been carried out to evaluate and compare NT performance in relation to CT in sugarcane cultivated areas. The goal of this research was to assess the effects of tillage management practices during sugarcane crop renovation on soil physical properties over four crop cycles in a clayey soil located in Quirinópolis-GO (18º32'S–50º26'W). In 2013, the following treatments were delineated: (i) CT - the subsoiling was performed up to a depth of 0.45m and planting grooves were opened at depth of 0.3m after soil preparation; and ii) NT - the soil preparation was not carried out and only planting grooves were opened for the sugarcane planting. Undisturbed soil samples to a depth of 0.40m (0-0.10, 0.10-0.20, 0.20-0.40m) were collected over four crop seasons (2014, 2015, 2016 and 2017) for determination of bulk density (Bd), soil resistance to penetration (Pr), macroporosity (MaP) and microporosity (MiP). The data were submitted to analysis of variance and later were compared by the time-repeated test using Satterthwaite test ($p<0.05$). Significant differences were found during the assessed period, in which NT presented higher Bd compared to CT in the first and fourth crop cycles, and higher Pr for the second and fourth crop cycles. Regarding the soil porosity, CT presented increases in MaP only in the first cycle in relation to NT. Overall, soil physical attributes showed the same patterns for both treatments over the four crop cycles, with increases in Bd and Pr and decreases in MaP. Our findings support the conclusion that NT could be a feasible management strategy to enhance soil quality in sugarcane fields, but additional efforts should be placed to fully understand those impacts in a long-term perspective.

Keywords: *Saccharum* spp.; soil management; soil quality; soil compaction; no-till
Financial support: CAPES - 88882.143419/2017-01

C3.3.8 - International nitrogen initiative

(6197 - 1926) Benchmarking the reactive nitrogen loss for global agricultural products

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Reactive nitrogen (Nr) is essential for agricultural production, but if poorly managed, can result in significant environmental degradation. Nitrogen (N) footprint has been developed as an indicator to quantify the anthropogenic release of Nr from food and energy consumption and production. Current N footprint models are difficult to apply to all the countries due to the large data requirement, and are defective to compare among countries due to the varied data sources. It is necessary, therefore, to develop indicators for assessing the efficiency of N use in global crop and livestock production, and benchmarking the Nr loss of global agricultural products. Here we use multiple global databases to calculate the life-cycle N use efficiency and net N balance for a range of agricultural products and geographic locations. The proposed indicators are also being used to calculate the N footprints and depict the Nr loss spatial intensity for 235 countries. The information is critical for addressing the triple challenges of food

security, environmental degradation and climate change.
Keywords: Reactive nitrogen, nitrogen footprint, sustainable index, agriculture
Financial support:

(7462 - 2938) Effect of the use of a slow-release N fertilizer on the critical concentration of N in the biomass, production of aerial biomass and residual mineral N in an Andisol.

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Improving the strategy of nitrogen fertilization in agroecosystems through the use of coated fertilizers and the definition of critical periods of the crop when N deficiency is detrimental, are alternatives that can be integrated to optimize the production of the wheat crop and reduce the losses of Nitrogen (N) in the system. The objective of this work was to evaluate the effect of a coated urea fertilizer of slow release on the production of aerial vegetable biomass of wheat, the concentration of N in the aerial biomass and the content of mineral N in an Andisol, Valdivia agroecosystem. The treatments consisted of two ammonia fertilizers, commercial Urea and Urea-Nutrisphere, four doses of N fertilization (100, 200, 250 and 300 kg ha^{-1}) and three application strategies, sowing (S), partialization (P), and tiller (M), evaluated in two seasons (late sowing, 2015-2016 and early sowing, 2016-2017). It includes a control with cultivation without fertilization and plots without crop to evaluate the mineralization of N in the field. The experimental design was complete random blocks. The samples of aerial biomass and soil (20 cm deep) were collected in five growth stages (Z21, Z31, Z39, Z45, Z69 on the Zadoks scale). The variability in the production of aerial biomass in the wheat until to the phenological stage of Antesis (Z69) under conditions of the Valdivia agroecosystem, depends on the moment of application of ammoniacal fertilizer, the dose used and the date of sowing. There were no significant differences in biomass production when comparing the fertilizers evaluated between the treatments in each season. Concentrations of N in the aerial biomass below the critical level ($Nc = 5.3W^{-0.44}$, Justes et al., 1994) occurs in the early stages of cultivation (Z21 and Z31), given by the amount of fertilizer applied and the strategies of application of N. In conditions of growth in the Valdivia agroecosystem, the use of coated urea does not increase the production nor the concentration of N in the aerial biomass, in comparison with uncoated urea fertilizers. However, higher content of mineral N from coated fertilizer was determined than uncoated urea in the first 20 cm of depth in an Andisol during the season of wheat growth evaluated under field conditions.
Keywords: coated urea N critical Andisol
Financial support:

(9466 - 1679) Forecasting the contribution of soil N mineralization for sweet corn production using a temperature-based prediction equation

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Efficient nitrogen (N) management practices depend upon an accurate forecast of the timing and amount of plant-available N contributed from mineralization of soil organic matter. We estimated N mineralized from soil organic matter during summer months in fields used for sweet corn (Zea mays L.) production under sprinkler irrigation, using a variety of techniques: crop N uptake with zero N fertilizer input, buried soil incubation bags in the field, and aerobic soil incubations in the laboratory. Soils evaluated are in the Willamette Valley of Oregon, within 100 km of Salem OR, with predominantly silty clay loam or silt loam surface soil textures, in USDA taxonomic group Argixerolls or Haploxerolls, with typical soil organic matter 30 g kg^{-1} (0-30 cm). Above-ground sweet corn N uptake with zero N fertilizer input averaged 100 kg N ha^{-1} at silking, across 27 site-yr., equivalent to 1.7% of the N present in soil organic matter (0-30 cm depth). Nitrogen mineralized as nitrate-N in buried bag field incubations (84 d), or in incubations performed at a constant temperature of 22^{O}C in the laboratory (84 d) was equivalent to 2.3% of soil total N (0-30 cm). Nitrogen mineralized in the field and laboratory were in approximate agreement with forecasts of N mineralization using a temperature-based prediction equation based on a Q-10 temperature coefficient of 2 and a daily soil organic matter decomposition rate of 0.0002d^{-1} at 25^{O}C. We conclude that for the soil management regimes examined, N mineralization is a function of soil organic matter content and temperature, and forecasts based on these factors show promise in assisting farmers with N fertilizer management decisions.
Keywords: nitrogen, mineralization, soil organic matter, temperature
Financial support: Oregon Processed Vegetable Commission

(7788 - 2762) Impact of urease and nitrification inhibitors on ryegrass productivity in the high rainfall zone of southern Australia.

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Nitrogen (N) inputs to grazed dairy pastures in Australia's southern high rainfall zone are high (200-480 kg N ha^{-1} $year^{-1}$), but the efficiency of N use is often poor (20-40%) and it is subject to many loss process. This paper reports preliminary results from a study that is investigating the effects of use of inhibitors (urease inhibitor N-(n-butyl) thiophosphorictriamide (NBTPT) provided as Green Urea NV™ (GU) and a nitrification inhibitor 3,4-Dimethylpyrazole phosphate (DMPP) provided as ENTEC® (EU) on dry matter (DM) yield of perennial ryegrass pasture compared to regular granular urea application (grower standard fertiliser) under irrigated conditions. Fertilisers were applied following harvest (3 leaf stage) at rates of 0, 20 and 40 (kg N ha^{-1}) of urea, and either GU or EU depending on the expected loss pathways. An additional 10 kg N ha^{-1} rate for the GU and EU treatments was included. Harvest and fertilisation occurred 12 times over 2017. Pasture showed consistent response to N fertilisation. Use of the GU (from January to May) at rates 20 and 40 (kg N ha^{-1}) had no impact on DM production compared to urea due to irrigation and rainfall preventing significant ammonia loss. Application of EU (June till November) increased DM yield compared with urea over the wetter months (284 mm rainfall). From August to October, the application rate of 20 kg N ha^{-1} EU caused massive 827-1268 kg ha^{-1} DM increase compared with traditional urea. However, at the higher rate (40 kg N ha^{-1}) there was no significant effect on DM production with the EU, suggesting that there is sufficient N in the system even when losses occur. Interestingly, the urea inhibitor was more effective at low fertilization rate. In 83% cases of applications, the lowest application rate of 10 kg ha^{-1} EU provided statistically same DM yield as rate of 20 kg ha^{-1} U. Perhaps, because prevented N losses from inhibited urea.These preliminary finding indicates that (i) using urea coated with nitrification inhibitor is most effective in late winter – spring in the high rainfall zone; (ii) inhibited urea is likely to produce higher return at low rates of application. With increase of application rates ≥40 kg ha^{-1} difference between inhibited and traditional urea becomes insignificant.
Keywords: pasture, urease inhibitors, N losses
Financial support:

(3379 - 439) Leaching of dissolved organic nitrogen from irrigated maize fields in Mediterranean Central Chile

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Recent studies reported that, on average, dissolved organic nitrogen (DON) leaching losses are equivalent to one-third of total dissolved nitrogen (TDN) losses from cultivated soil. Establishment of cover crops (CC) during the intercropping period of maize (replacing bare fallows, F) in Mediterranean climatic conditions has been proposed to counteract the negative impacts of N leaching. However, most soils in such agroecosystems are depleted of their antecedent soil organic carbon (SOC) pool and inclusion of CC can enhance SOC and microbial activity, hence increasing the risk of DON leaching. Our study examined the combined effects of inorganic N fertilisation and CC inclusions on DON leaching from a coarse textured soil (Entic Haploxeroll) in Mediterranean Chile. The study was conducted in a temperature-controlled glasshouse (25°C), on undisturbed soil columns packed in PVC tubes (0.2 m diameter, 0.5 m long) at the Antumapu Experimental Station located in Santiago, Chile (33°34'S, 70°38'W). A total of 52 soil columns (13 treatments x 4 replicates) were established and monitored over a period of about 2.5 years (August 2015 to January 2018) to evaluate DON leaching from: 1) continuous F compared with a continuous CC (*Lolium multiflorum* or *Trifolium repens*), with 0 or 150 kg N ha^{-1} applied; and 2) maize-F and maize-CC rotations with two different N doses (250 or 400 kg N ha^{-1}) for the maize and CC (*L. multiflorum* and/or *T. repens*). Samples of soil solution percolating from the columns were taking periodically. The TDN and DON loads were calculated as the product of cumulative percolated volume times the total and organic N concentration in the solution. We found that inclusion of a continuous grass CC (*L. multiflorum*) resulted into the DON loading (31 kg DON^{-1} ha^{-1} yr^{-1}) as the dominant form of N leaching (on average 65% of TDN loading), while inclusion of a continuous legume CC (*T. repens*) or F resulted into the DON leaching load about an order of magnitude lower than the TDN load from the soil columns. We found that crop rotation with maize, optimal N fertilisation (250 kg N ha^{-1}) and a grass CC (*L. multiflorum*) had significantly higher DON loads of 8 kg DON^{-1} ha^{-1} yr^{-1} (16% of TDN loads) than all other maize-fallow treatments. The results support the suggestion that under continuous CC leaching of DON is mainly affected by greater litter production and microbial processing of the fresh organic matter.

Keywords: Agriculture; Water quality; Non-point pollution.

Financial support: Fondecyt Regular 2015, Project Number 1150572.

(2647 - 2915) Nitrogen balance and use efficiency of Japanese paddy rice production: Improvement driven by consumer behavior

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Amount of human-induced reactive nitrogen (N) (Nr: all N compounds except N_2) newly created every year has already exceeded that via natural processes. Minimum use of new Nr and maximum use of old Nr abundant in the environment should be proceeded in cooperation with consumers, the main driver of Nr flows in the N cascade. This study focused on the long-term trends in N balance and NUE of Japanese paddy rice and tried to interpret the close relationship between consumer behavior and paddy rice NUE. Annual input of new (chemical fertilizer, biological N fixation [BNF]) and old Nr (livestock manure compost, above/underground residue, irrigation, atmospheric deposition) and output of Nr (plant uptake, drainage, ammonia volatilization, nitrous oxide emission) and N_2 (denitrification) at Japanese rice paddy fields during 1960 to 2015 were estimated by using available statistical data and reviewing literature to obtain empirical equations and constants on Nr dynamics in paddy soils. The estimated Nr balance showed that paddy rice NUE was almost doubled during this period mainly due to the decrease in chemical fertilizer Nr input from >100 to 60 kg N ha^{-1} yr^{-1} while yield of rice increased from 4.0 to 5.4 Mg ha^{-1} yr^{-1}. The reduction trend in Nr input started in late 1980s when the rice taste 'Special A' ranking system started and the most popular, good-taste variety 'Koshihikari' rapidly extended its cropping area, but not in early 1970s when the Water Pollution Control Law was enacted. This variety is also characterized by less lodging resistance for Nr application; furthermore, it is well documented that rice with lower protein content generally have better taste. Thus, farmers appear to have had to reduce Nr input to meet with the consumers' preference by introducing new technologies to enable optimum growth. Moreover, the Nr balance showed that old Nr input and uncontrolled Nr input/output (BNF, denitrification, etc.) with high uncertainties play a significant role on determining NUE and sustainability of paddy rice production, indicating necessity of further investigation. These results suggest that consumer behavior can significantly change the farmland Nr balance and NUE at a country scale and emphasize the importance of sharing knowledge with consumers about Nr flows and issues by using simple indices such as 'N footprint'; this should be the key to develop sustainable food production and consumption system under all the stakeholders' responsibility.

Keywords: biological nitrogen fixation; denitrification; nitrogen footprint; protein, rice variety

Financial support: Science and technology research promotion program for agriculture, forestry, fisheries and food industry (28005A), Ministry of Agriculture, Forestry and Fisheries, Japan

(2969 - 900) Nitrogen in alpine ecosystems: adaptations to low N availability and reactions on additional N input

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We have studied N status of alpine soils and plant communities in the Northern Caucasus. The studied ecosystems were represented by low productive alpine lichen heath (ALH) and snowbed community (SBC), and more productive *Festuca varia* dominated grassland (FVG) and *Geranium gymnocaulon*/*Hedysarum caucasicum* dominated meadow (GHM). Alpine soils in general are acid, rich in the total N but poor in available inorganic N. Grassland and meadow are characterized by higher N transformation activities in soils and higher N accumulation in plant biomass, while ALH and SBC demonstrated smaller values. Alpine plants have a number of adaptation mechanisms allowing them to function successfully and support necessary N balance in the conditions of limited N availability. Symbiotic N_2 fixation provide from 40 to 90% of N nutrition for different legume species. The role of mycorrhizal symbiosis in plant N nutrition was estimated on the basis of $\delta^{15}N$ difference between roots and leaves. In general, ^{15}N fractionation was more pronounced for species growing in less N abundant soils (ALH and FG). We have also studied how N status of alpine soils and N nutrition of alpine plants have changed in conditions of long-term N, P or lime application. After 20 years of nutrients input some expected changes (increase of inorganic N, available P or pH, if

respectively N, P or lime was applied) were indicated, while concentrations of the total, extractable organic and microbial biomass C and N, as well as C to N ratios in all these pools and $\delta^{15}N$ of total soil N haven't changed. As expected, the greatest changes in plant N nutrition were found at N application. Nitrogen concentration and $\delta^{15}N$ have increased in all species except N_2-fixing legumes, indicating intensive additional N uptake and decrease of symbiosis N_2 fixation. These changes were more pronounced for the more N limited ALH and SBC species. Other fertilizers have made smaller impact on N status of plant species. Phosphorus application doesn't initiate N_2 fixation by *Trifolium polyphyllum* which doesn't fix N_2 under natural conditions. Also phosphorus application in the most P poor ALH soil as well as lime application in the most acidic SBC soil resulted in increase of $\delta^{15}N$ in leaves of the majority plant species. Similar change of $\delta^{15}N$ under correction of two unfavorable soil properties in two different soils can demonstrate indirect effects on change of plant N nutrition.
Keywords: Alpine ecosystems, N trasformation, plant N nutrition
Financial support: Russian Science Foundation (16-14-10208).

(6581 - 1596) Reducing ammonia and nitrous oxide emissions and increasing maize yields by using the 4R nutrient management strategy

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The 4R strategy has been proposed as a best management practice to reduce nitrogen losses from soils especially when precipitation can vary dramatically between growing seasons. In the first 2-year study we compared broadcast versus injected liquid UAN and three inhibitor treatments (control, urease inhibitor or a urease and nitrification inhibitor) on ammonia volatilization, nitrous oxide emissions and corn yields. In this study, about 50% of broadcast urea was lost from the soil from ammonia volatilization. These ammonia losses were reduced by 60% when a urease inhibitor was added to urea or when UAN was injected. Nitrous oxide emissions increased by ~30% when just a urease inhibitor was added as more nitrate was present in the soil when ammonia losses were reduced. Pollution swapping was avoided when both a urease and nitrification were used. Ammonia loss was virtually eliminated when UAN with a urease inhibitor was injected. Maize yields increased by 5-7% when a urease and nitrification was added with broadcast urea or when UAN was injected. The combination of two N management strategies (injection with urease and nitrification inhibitors) increased yields by 19% compared to broadcast urea application. In the second 3-year study, we compared two application times (planting versus sidedress) and 3 application methods (broadcast urea, broadcast and incorporated urea or injected UAN) with/without a urease inhibitor or a combination of urease and nitrification inhibitors on N losses and maize yields. Broadcast and incorporated urea reduced N losses compared to broadcast urea but UAN injection reduced N losses the most of the 3 application methods. Maize yields were 15% greater with the sidedress injection of UAN compared to applying broadcast urea at planting. Hence using inhibitors and improved fertilizer placement can reduce nitrogen losses to the environment and increase yields and profitability.
Keywords: ammonia volatilization, nitrous oxide emissions, improved crop N utilization
Financial support: Fertilizer Canada and Agriculture & Agri-Food Canada

C3.3.9 - Management of soils recently impacted by volcanic activity

(8418 - 1021) Analysis of research conducted on soils recently impacted by volcanic activities in Costa Rica

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Costa Rica has a territory of 51,000 km^2, with 200-300 volcanic cones distributed along the country. Within these volcanoes, 18 are classified as primary and 7 are recognized with high activity in the last 100 years. The Andisols make up 14% of the territory and they are responsible for a large part of the agricultural production. There are also many cities included in that area and the volcanoes has also tourist exploitation. Management of soils that are affected by ash eruptions, acid rain, gaseous emissions and lava flows, is a relevant subject in the country. Description of the stages that occur after each event, and research generated for the management of the soils affected by them, constitutes the objective of this work. The first stage after any type of volcanic activity is the ALARM: All those affected reclaim to scientists to describe the ashes characteristics, their effect on crops or animals, how long the phenomenon will last and what to do to fight against it. In this stage, information generated describes the erupted materials, making distinction among residual or new materials. New methodologies are generated and new equipment is used. However, it is hard to reduce the impact of the event. While the magnitude of the phenomenon is slight and there is rain or wind that quickly flushes or removes the product, the effects are very moderate and in some cases even profitable. Mild depositions of ashes on pastures cause greening of forages by S solubilization. Respiratory, skin and eyes effects in humans and corrosion on infrastructures, are more dramatic than those ones that occurs on soils. As the phenomenon is more intense and closer to the crater, the effects are destructive. Ash deposits first decreases the photosynthetic area, then, destroy the tissue and, with higher intensity, they cover the area completely. The activity is generally associated with very strong water reactivity gases clouds with severe contact effects. After the alarm stage comes the ADAPTATION. In this period, inhabitants of affected lands begin to accept the inevitability of the phenomenon, and an readjustment activities take place: some production areas must be abandoned, and tourist parks must be design insurance areas to observe the phenomena. Finally, the third stage, called ADVANTAGEMENT begins to take place 15 to 20 years later, and generates a lot of research that describes the new weathering process, which turns them into very useful and high fertility areas.
Keywords: Andisols; volcanic activity; Costa Rica
Financial support:

(9786 - 2326) Volcanic soils of Ecuador: tillage management challenges

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The intense volcanic process that developed over the original andesites and rhyolites generated large emissions of pyroclastic materials, lava flows and lahars that cover most of the Northern Highlands of Ecuador. On the other hand, as a consequence of the prevalent land tenure structure, a large group of holders of small farming plots has developed generating a sector of the economy known as family agriculture as a synonymous of subsistence agriculture. This economic model maintains its productive rationality associated to use of the family hand labor, but it does not sustain itself in time from agricultural production along, depending on the income generated out of the farm as hired hand labor or in services to make ends meet. Family agriculture not only produces for self-consumption, but also generates surplus to satisfy the demand of local markets. Population growth has forced farmers to divide the land among family

descendants creating a complicated network of smallholdings where agricultural production is limited by the scarce investment capital and by the adverse location and disposition of the plots on the slope. The traditional tillage system used by small farmers in the highlands removes the soil to prepare seed bed for planting. Farmers argue that soil disturbance is necessary to control weeds, allow better air movement, avoid soil compaction, and develop medium for root growth. In spite of the no till success in extensive areas of the world, this practice has not been adopted in the production areas cultivated by small farmers in volcanic soils of Ecuador. No-till could become a viable soil management alternative for most crops grown by small farmers. Steep and long slopes, land tenure problems, and population growth have increased pressure on the land forcing farmers to use marginal land in even steeper areas. There have been few attempts to implement no-till on small farmer fields, apparently due to the difficulty of implementing the system on small intensively used plots. For this reason, there exist ample possibilities to conduct research on tillage systems in the same volcanic soils utilized by smallholders to document the effect of tillage management on soil properties, carbon dynamics, and crop productivity.

Keywords: Volcanic soils; family agriculture; erosion; no-till
Financial support:

C3.3.10 - Beneficial management practices for sustaining soil fertility

(2363 - 775) A meta-analysis and Review on the Long-term Role of Organic Amendments in Building Soil Nutrient Fertility

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An exhaustive meta-analysis of 132 long-term (≥ 10 yr) studies worldwide was carried out to determine the effects of the use of organic amendments (OA) and OA + inorganic fertiliser (IF) on soil nutrient fertility. The responses of (i) cereal crop yield [over the whole duration of the period ($yield_m$) and at the end of the experiment ($yield_f$)], (ii) soil organic carbon (OC), and (iii) Olsen phosphorus (P) to OA and OA + IF compared with IF only (*standard control*) and no fertilisation (*nil control*) were investigated. The overall effect of OA alone on yield was significant when compared with the *nil control*, but not when compared with the *standard control*. Only when OA and IF were added to soils that met specific conditions (low initial fertility, sandy texture, near-neutral pH values, under tropical climate) they rendered a significantly greater $yield_f$ than the corresponding *standard controls* and this was attributed to the following: (i) in soils with low inherent fertility, the use of OA + IF allowed a better synchronisation of nutrient release and/or nutrients not supplied by IF were provided by the OA; (ii) the greater benefit from the use of OA and OA + IF observed in soils with near neutral pH values was associated with the generally lower initial OC content of these soils compared with those more acidic, along with the fact that a near neutral pH is optimum for the availability of most plant nutrients; (iii) when there was no nutrient limitation, the effect of OA on soil physical properties became more evident rendering greater crop yields in sandy soils; (iv) the greater response of soils under tropical climate was associated with the low initial OC content of these soils and the more favourable climatic conditions for plant growth. The continuous application of manure caused greater relative and absolute gains in soil OC than straw + IF but did not produce significant greater yields while causing a considerable increase in Olsen P over time. The use of OA and OA + IF increased the resilience of agronomic systems over that of IF alone, as inferred from the smaller coefficient of variation of crop yield over time. We conclude that while the use of OA along with IF provides some additional benefits on yields as compared with IF application alone, the selection of the OA type and application rate should be carefully considered in order to maximise the nutrient use efficiency and minimise any undesirable effects to the environment.

Keywords: soil fertility; organic amendments; inorganic fertiliser, meta-analysis
Financial support:

(9942 - 623) Agroecological Approach to Sustainable Management of Chernozems in Moldova

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The discrepancy between the ever-increasing population and limited availability of the life-supporting natural resources is among numerous causes of global warming, and it requires an urgent action at national, regional and global levels. Soil is the most critical natural resource for providing ecosystem and social services. Chernozems are among the most fertile soils of the world, but are being degraded because of soil mismanagement. Important among degradation processes of Chernozems in eastern Europe are annual uncompensated mineralization losses of soil organic matter (SOM), accelerated soil erosion, soil structural decline and severe soil compaction. Therefore, sustainable agriculture cannot be achieved on soils prone to severe degradation. Simplification of farming systems and heavy reliance on industrial inputs for crop nutrition and crop protection (e.g., weeds, pests, diseases, excessive moldboard plowing) are contradictory to the long-term goals of sustainable development of agriculture. Disintegration of rural communities, aggravated by an indiscriminate adoption of an industrial model of agricultural intensification, has aggravated the problem of soil and environmental degradation. People's health is affected by the way food is grown and consumed, especially of those in mega cities. Effectively addressing these challenges requires new agro-ecological approach to agricultural intensification. Simplistic approach to farm management should be replaced by systemic one, with the main focus on rejuvenation of soil functionality and of the rural communities. Data from the long-term field experiments (> 50 years) on Chernozems in Balti steppe of the Republic of Moldova indicate a high share of soil fertility as a yield determinant (75 -100%). Including perennials in the rotation cycle and manuring, restores soil fertility and reduces the dependence on industrial inputs. The winter wheat, after perennials (mixture of alfalfa and rye grass during the 3rd year after the first cutting), yielded on average for 21 years, 4.40-4.51 Mg/ha of grains irrespective of the systems of soil tillage and fertilization. In comparison, wheat yield after corn for sillage was 2.85 Mg/ha on unfertilized plots and 4.1 Mg/ha on fertilized treatments with manure+NPK. The SOM content of the labile fraction was 21.4 g/kg for soil in crop rotation with manured perennials and reduced tillage compared with only 8.8 g/kg for soil without perennials and conventional tillage.

Keywords: soil fertility, soil tillage, crop rotation
Financial support: Fulbright Program (USA)

(8931 - 2767) Balanced Fertilization: A Prerequisite for Effective Soil Fertility Management in Smallholder Maize Farms in Nigeria

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Fertilizer recommendations in Nigeria are presently uniform for all varieties of maize over large areas and cutting across diverse climatic and edaphic environments. This usually results in inefficient and unbalanced fertilizer use and poor economic returns. To optimize smallholder crop productivity, there is a need for a site-specific or at least area-specific fertilizer recommendation, which estimates nutrient uptake for a specific yield target. The use of simple empirical models like the *Quantitative Evaluation of Fertility of Tropical Soils* (QUEFTS) and *Nutrient Expert* (NE) can assist in developing site-specific fertilizer recommendations under smallholder resource-constrained situations. Two hundred (200) on-farm nutrient omission trials (NOTs) were carried out across major maize growing conditions in the Northern Guinea and Sudan Savannas of Nigeria in 2015 to generate data for calibrating QUEFTS and NE for N, P, and K recommendations. In 2016, 100 sets of trials were carried out to evaluate the agronomic and economic performance of NE recommendations (NER) against soil test based recommendations (STR) and the presently practiced blanket regional fertilizer recommendation (RFR). Results of the trials showed that the simulated uptake requirement for a target yield of 5,000 kg/ha was 88 kg N, 11 kg P and 142 kg K. Evaluation of the three fertilizer recommendation approaches showed that, on average the NE recommended less fertilizer N, P and K in both ecologies than STR and RFR, with an N: P: K ratio in the Northern Guinea Savanna (NGS) of 107:32:19, 112: 55: 41 and 120: 60: 60 for NER, STR, and RFR, respectively. In the Sudan Savanna (SS) the N: P: K ratio was 116: 11: 28, 119: 12: 29 and 120: 60: 60 for NER, STR, and RFR, respectively. NER gave a slightly lower grain yield than STR and RFR in the NGS with a yield difference of less than 0.3 tonnes; while in the SS, NER gave higher average yield with a lower amount of applied N, P, and K than STR and RFR. Economic analysis of the recommendations showed that NER gave higher gross returns than RFR and STR in 12 of the 13 communities where the trials were conducted. It was concluded that QUEFTS and NE are promising tools for site-specific decision-making on soil fertility management in the NGS and SS of Nigeria.

Keywords: Site-specific nutrient management, fertilizer recommendation, QUEFTS, Nutrient Expert, *Zea mays*

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(5981 - 371) Can deep placement of lime and organic material increase soil pH and improve crop productivity on acidic soils at depths?

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A long-term field experiment was established in 2016 in New South Wales, Australia to a) manage subsoil acidity through innovative amelioration methods that will increase productivity, profitability and sustainability, and b) study soil processes, such as the changes of soil chemical, physical and biological properties under vigorous soil amelioration techniques. The experiment was fully-phased with wheat (*Triticum aestivum*), canola (*Brassica napus*), barley (*Hordeum vulgare*) and a pulse crop [faba bean (*Vicia faba*) or field pea (*Pisum sativum*), depending on seasons] in a 4-year crop rotation. The major treatment contrasts were a) surface liming vs. deep liming, b) deep placement of lime vs organic materials (as lucerne pellets). There was a large crop biomass responses to the treatment with organic amendment for cereal crops and canola crop in year 1 simply due to extra nutrients supplied from organic materials applied, whereas no difference was found between treatments with deep placement of lime and organic material in year 2. All limed treatments, including surface liming and deep liming treatments, increases pH (in $CaCl_2$) in the corresponding soil depths as designed, indicating the efficacy of treatment implementation. However, the treatment with deep placement of lucerne pellets did not increase soil pH as high as anticipated based on results from the controlled environment. The research team will continue to monitor soil chemical, physical and biological properties to understand the soil–plant interactions and the factors driving the differences in crop response to the various treatments. We are particularly interested in understanding the residual effects of the amendments and how they could improve crop productivity through, for example, more efficient nutrient and water use.

Keywords: Soil pH, aluminium, lime, organic amendment
Financial support: The long-term field experiment is funded by NSW Department of Primary Industries with financial support from Grain Research and Development Corporation (2015-2020).

(2230 - 444) Effectiveness of organic amendments in ameliorating acidic cropping soils

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Acidic subsoils (pH < 5.5) severely limit agricultural productivity in many parts of the world, primarily due to high Al^{3+} and Mn^{2+} concentrations which are toxic to plants. Direct incorporation of lime ($CaCO_3$) and organic amendments into deep acidic soil layers (10-30 cm) has gained recent attention, since lime applied on the soil surface moves very slowly through the soil profile and is not suitable to ameliorate these deep soil layers in the short term. Organic amendments generate alkalinity as they decompose, improving soil physiochemical properties while also providing essential crop nutrients. The current research investigates novel (dairy compost, poultry litter) and on-farm organic materials (crop and pasture residues) as suitable amendments. Their relative effectiveness in alleviating soil pH and toxic Al concentrations, compared with lime and gypsum, was assessed in a 3-month incubation study. While novel materials have been shown to be highly effective ameliorants, these may not always be practical and/or profitable due to the high costs associated with their purchase and transport. On-farm materials may be more suitable but studies examining temporal patterns of amelioration by these are limited. While, the decomposition of crop residues grown *in situ* does not result in any net change in alkalinity within that soil profile, the redistribution of crops residues (and hence alkalinity) into hostile acidic soil layers is hoped to vastly improve the productivity of the system. This research aims to generate new knowledge to assist growers and land practitioners to better manage acid soils. It is part of a GRDC project (DAN00206) investigating innovative approaches to managing subsoil acidity in the southern grain region of Australia.

Keywords: Subsoil acidity, soil pH, crop residue
Financial support: Australian Grains Research & Development Corporation (GRDC) DAN00206

(7899 - 1791) Effects of sunn hemp rotation and sugarcane straw removal on soil chemical quality

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The limited fossil reserves and the growing concentration of greenhouse gases in the atmosphere have augmented the interest for a greater participation of sugarcane as a source of biomass for

renewable energy generation. The use of sugarcane harvest residues for the production of electricity and second-generation ethanol has been intensifying in recent years, without having a clear understanding of the implications of total or partial removal of the straw on the soil quality in the medium and long term. This study aimed to evaluate soil chemical attributes and C and N stocks in the soil as a function of total and partial sugarcane straw removal and sunn hemp rotation in the sugarcane plantation. The research was developed in Brazil in two experimental areas located in Quirinópolis / GO in soil with clayey texture, and in Quatá / SP with sandy texture. An experiment group structure was used, consisting of an experiment with planting crotalaria and another without the planting of the legume in the cane field. The experimental design was a randomized block design with three treatments of straw maintenance levels (0, 50 and 100%), that were installed after the cane-plant harvesting and reinstalled after the first ratoon. After two years, were evaluated the chemical attributes and the soil C and N stocks up to 40 cm. The treatments of sugarcane straw maintenance did not affect soil chemical attributes, while crop rotation favored increase of P in all the evaluated layers in the soil with high clay content, obtaining an increase up to 35% in the most superficial layers. The sunn hemp rotation increased the K contents in the most superficial layers (0-5 and 5-10 cm) in the clayey soil, and in the sandy soil the positive effect of the crop rotation was evident up to 0.4 m. The Cation Exchange Capacity (CEC) augmented in the soil with crop rotation in the 0-40 cm layer in the clayey soil, showing a favorable strategy for the maintenance of soil chemical fertility. Sunn hemp rotation did not affect soil C and N stocks, and maintenance of approximately 8 Mg ha^{-1} of straw favored C accumulation in the sandy soil, increasing 14% the C stock. The crop rotation in the time of sugarcane renewal and the appropriate management of plant residues in the soil, are appropriate strategies for soil conservation in sugarcane areas.

Keywords: Fertility; surface mulch; green manure; soil organic matter
Financial support: This project was funded by Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP Process 2014/05591-0).

(6227 - 310) Forms of edaphic phosphorus and its relationship with granulometric fractions under different crop rotations in Argentine pampean soils

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Agriculture produces a significant impact on the availability of P, modifying the balance between its different forms. The objective of this work was to evaluate the effect of different crop sequences on the dynamics of edaphic phosphorus forms and relate it to particles size in soils under no tillage and variable agricultural use. In an essay initiated in 1998, located in the Barrow Farm, Province of Buenos Aires, Argentina, soil samples were taken (Paleudol petrocálcico). The cultivation sequences were three exclusively agricultural and two mixed. The design was in randomized blocks. In each plot, three soil samples and one control without crop were taken at four depths. A sequential fractionation of P according to Hedley et al. (1982), and a physical fractionation by particle size (Andriulo et al, 1990). The available P Bray-Kurtz (1945) and pH were determined. In all the depths all the treatments produced a decrease of the pH, in relation to the ground of reference, mainly the intense agricultural sequence. In general, all forms of P have a decrease depending on the sampling depth. The sequence with pasture produced a decrease in the forms of available P (27.2 mg kg^{-1}) and organic and inorganic labile forms (14.1 mg kg^{-1}). The fraction of organic P moderately labile (extractable with NaOH), was the predominant fraction in all treatments and depths. However, the sequence with pastures produced the greatest significant increase of this P form (650 mg kg^{-1}), possibly favored by the greater biological activity in the cultivated pasture. Coincidentally, this sequence presented a greater correlation between this Po and the coarse fraction of the soil (R2 = 0.78). It was observed that during the period with pasture the available P decreased in favor of the accumulation of organic forms of the coarse fraction. This is possibly associated with the increase of organic matter during the livestock period. In conclusion, the different P forms have a differential role in the availability of P for crops that is directly related between the P form and the particle size fraction in which it is contained. The inclusion of pastures in a rotation keeps the levels of extractable or available phosphorus for the plants lower. However, this is the sequence that maintains the highest levels of moderately labile P, which would be feasible to be available during the cycle of the crop. Coincidentally this P is positively related to the P of the coarse fraction of the soil.

Keywords: crop rotations, no tillage, soil P fertility
Financial support: Comisión de Investigaciones Científicas Pcia Buenos Aires and Aapresid

(9965 - 3196) Impacts of soil exchangeable aluminium concentrations on acid upland New Zealand grasslands.

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New Zealand upland and dryland grazed grassland systems have historically relied heavily on sward legumes and forages to supply all nitrogen for pasture growth and to provide high quality feed for the grazing livestock. However, most of these contemporary grassland systems fail to grow persistent legumes, due to low soil fertility in combination with short growing seasons with hot dry summers. As such, increases in legume production and persistence is urgently required for improved productivity and sustainability of these grassland farming systems. Historically, fertiliser (single superphosphate) inputs to these farms has often been adequate to maintain adequate pasture production. However, application of lime ($CaCO_3$) to ameliorate natural and ongoing soil acidity in the long term has often been too expensive for farmers, and these grasslands are now acidic. The level of acidity is such that the commonly associated soil exchangeable aluminium (Al) concentrations are above 3 mg / kg soil. Such concentrations are toxic to most grassland and forage legumes and so is very likely to be a major factor contributing to low legume presence in upland and dryland grassland in New Zealand. This paper presents a cache of ongoing research conducted but the Soil Science and Dryland Pastures Research Groups at Lincoln University which aims at improving our understanding and amelioration of soil Al toxicity issue towards better legume abundance, productivity and sustainability in grazed grasslands. Issues explored in the paper will include drivers of soil Al concentrations at a catchment scale, our ability to measure bioavailable Al in soils of different properties, whether we can understand plant / Al interactions at the micro-rhizosphere scale and if 'Al-tolerant' legume species have a place as a new technology in these grassland farming systems. Data from several of our research projects will be presented to support this discussion and also to present some direction for future research in this field.

Keywords: Soil, aluminium toxicity, grassland, legumes, soil fertility
Financial support: New Zealand Merino, NZ Sustainable Farming Fund, Ballance Agrinutrients Ltd.

(7069 - 1525) Integrated Crop-Livestock Systems for Enhancing Soils and Water Quality in Northern Great Plains, USA

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Integrated crop-livestock systems (ICLSs) are beneficial in enhancing the soil health, however, limited research has been conducted in the

northern great plains (NGP) region of USA. The present study was conducted in the NGP to assess the impacts of ICLS on soil health parameters, greenhouse gas (GHG) fluxes, and soil water quality. The experiment was a randomized complete block design (RCBD) with 4 replications at the Brookings and Beresford sites, South Dakota. The treatments included cover crops and grazing. The cover crops had three levels: corn (*Zea mays* L.)-soybean (*Glycine max* L.)-oat (*Avena sativa* L.), corn-soybean-oat with broadleaf cover crops, and corn-soybean-oat with grass cover crops. The grazing treatment included grazing in the cover crop phase and un-grazing. Soil samples were collected from the 0-5 and 5-15 cm depths in 2016 and 2017. The measured soil health parameters included soil bulk density, soil organic carbon, total nitrogen, pH, water retention, urease and β-glucosidase enzyme activities, soil microbial biomass carbon and nitrogen, and soil cold and hot water carbon and nitrogen fractions. GHG samples were collected for 2016 and 2017 using the static chamber method. Carbon dioxides (CO_2), methane (CH_4), and nitrous oxide (N_2O) fluxes were weekly monitored. Soil water samples were collected using Piezometers after each heavy rainfall in 2017. Water ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, and ortho-phosphorus were analyzed. Data from this study showed that ICLS in short-term did not negatively impact the soils and environmental quality. However, if improper animal and nutrient practices are applied, ICLS could result in soil compaction, GHG emission increase, and groundwater pollution. These problems can be alleviated by using no-till practice, diversifying cropping systems, incorporating better forages, and improving grazing and nutrient management in the NGP.
Keywords: Integrated Crop-Livestock, Grazing, Soil and Water Quality, GHG Emissions, Northern Great Plains
Financial support: South Dakota State University

(3691 - 604) Long-term effects of organic and mineral fertilizers on soil organic carbon, soil properties and crop yields.

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Agroscope[1]

Easier access to synthetic fertilizers and specialization of farms led to the decrease in the use of manure on stockless farms and to the simplification of crop rotation. The removal of manure causes a well documented significant decline in the content of soil organic carbon (SOC). The techniques of soil conservation (straw restoration, green manure and reduced-tillage) are known for their positive effects on the storage of SOC. They could potentially compensate for the absence of manure. However, these techniques must be integrated in sound cultural systems and their effectiveness must be evaluated. The indirect effects of these techniques on other soil properties and crop yields should also be clarified. The effects of mineral fertilizers and organic amendments on soil properties, carbon (C) sequestration, and crop yields are studied in a 37-year field experiment, Phosphorus – Potassium (PK)-balanced design, in Switzerland. Treatments included a control (mineral fertilization) without nitrogen (N) fertilizers (*Min-N0*) and with optimal N (*Min-Nopt)* and five organic amendments [green manure (*Gm*), cereal straw (*Str*), fresh cattle manure in two doses 35 and 70 t ha^{-1} (*Ma35* and *Ma70*) and cattle slurry (*Slu*)] all receiving the same optimal N fertilization as *Min-Nopt*. All mineral and organic treatments received optimum P-K fertilization. Nitrogen fertilization (*Min-Nopt* vs. *Min-N0*) increased soil organic C (SOC), microbial activity and microporosity, but decreased pH, magnesium and macroporosity. All organic treatments with optimal mineral N resulted in higher SOC content compared to *Min-Nopt*, however these effects were significant only for the highest dose of manure. The organic amendments supplied 25 to 80 % additional C input to the soil compared to *Min-Nopt*, and their amendment-C retention coefficients ranged from 1.6 % (*Gm*) to 13.6 % (*Ma70*). Chemical, physical and biological soil properties were not or slightly significantly different among organic treatments. Nevertheless, soils fertilized with farmyard manure produced generally higher grain yield (up to 7.3%) compared to *Min-Nopt* while the opposite effect was noted for *Gm* (-2.2%) and *Str* (-5.2%) treatments due to their negative effect on N availability. In conclusion, *Gm* and *Str* treatments were as effectives as *Ma35* and *Slu* treatments to prevent soil degradation, but required higher chemical fertilizer to maintain crop yield.
Keywords: organic fertilizers, mineral fertilizers, soil organic carbon, soil properties, crop yields.
Financial support: Agroscope

(3834 - 885) Nutrient extraction by the biomass of *Eucalypts dunnii* Maiden grown on short rotation plantations for energy production

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The use of eucalypts grown on short rotation plantations is one alternative for energy production. Because all the components of the tree are harvested some questions arise: Can we call renewable energy the one in which all the components of the tree are removed from the soil every rotation of four year? What are the consequences from the nutrient cycling point of view? Energy production will vary depending on the number of trees per hectare? Because of this, the objectives of the research were: a) Quantify the nutrient concentration in different tree components of 4 years old *E. dunnii* plantations, b) Compare the magnitude of nutrient removals and energy yield in two initial planting densities, in two different sites. Trees were harvested, separated into: logs and the other tree components to estimate their nutrient content and potential energy production. There was no effect of the planting density on the biomass production per hectare, but owing to the higher proportion of wood in high planting density the production of energy was higher. Significant differences on nutrient concentrations in different tree components were observed, but were generally of similar magnitude between the two densities. The nutrient export made by forest biomass varies depending on the nutrient, tree component and the number of trees. Increasing planting density, shortening the cycle and essentially the extraction of the total biomass, compromises the sustainability of the system, particularly in low fertility soils.
Keywords: *Eucalyptus sp.*, forest biomass, short rotation woody plantations, nutrients export
Financial support: Universidad de la República/Facultad de Agronomía, INIA, Abengoa Energy Crops and UPM Forestal Oriental

(4070 - 525) Research for twenty years on biosolids and its use in agricultural soils of north Mexico.

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Treated wastewater in Republic of Mexico is about 106 m^3 s^{-1}; after water treatment, 660 thousand t $year^{-1}$ of biosolids (wet basis) are generated, which is increasing as population and use of water grows mainly in urban areas. Most of the efforts in research have focused on the use of biosolids as organic amendment in the north of the country. The objectives consist of compile the main results from two decades of agronomic research in the Juarez Valley, Chihuahua, analyze the progress to redirect studies and technological transference for farmers, and facilitate the adoption of biosolids recycling in agricultural production, but also, to increase people participation in urban and rural areas. Studies started in 1998, as parallel to activation of wastewater treatment plants in the region. First experiments were carried out at commercial level using big plots to test biosolids effectivity under saline soils cultivated with cotton, following an application program by farmers, and thus to initiate a reuse of this

organic material instead to continue sending them to the landfill of the city as disposal site. During the first ten years, the primary water treatment system used was producing lime stabilized biosolids, and recently the treatment plants use a secondary treatment system and are generating 105 thousand t $year^{-1}$ of digested biosolids. Most of the test plots were conducted using crops as forage sorghum, cotton, oat, wheat and ryegrass. In a parallel way, experiments were stablished to evaluate the nitrogen mineralization rates by using the cylinder technique. Incubation periods reached until six months in summer and winter seasons under field conditions. Ion exchange resins were installed inside cylinders filled with soils and biosolids at different rates to measure nitrate, ammonium, phosphorus, organic matter, alkalinity, and salinity for different soil types. Contribution of this research is considered strategic for soil scientists to continue analyzing better methods to promote organic residues in agricultural soils and increase food production at a global level.

Keywords: Sludges, organic matter, nitrogen mineralization, resins technique.

Financial support: USA, Environmental Protection Agency, COCEF-BDAN-UACJ, Project: Sustainable Program for sludges or biosolids disposal in agricultural soils.

(7918 - 2303) Runoff and soil loss at plot scale under different coffee managements in tropical conditions and a steep Ultisol, Costa Rica

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Soil erosion depends of different factors and crop management could make a positive and important effect changing soil cover and internal soil conditions that diminish soil erosion. The shade coffee systems have the advantage of good aerial coverage under high density plantation beside the extra soil coverage coming from coffee and shade trees branches. The effect of these conditions was measured over a 5 years period (2012 to 2016 period) on steep land (65%). Soil sediment loss, superficial runoff production and superficial soil moisture were measured using eight soil erosion plots (from 137 to 358 m^2). Soil erosion was measured at event scale, superficial runoff and rainfall at 10 min interval scale. The crop management treatments were: no renewal of mini-terraces, herbicide weed control, reduced pruning on shade trees and a control. Control plots had only once a year herbicide application (just prior harvest), mini terraces renewal, mechanical weed control and normal pruning (2-3 branches left). The dependent variables were: superficial soil runoff, sediment concentration, superficial soil water content (15 cm depth) and soil loss ratios (control plots as a baseline). The cumulative annual runoff of control plots was between 25 mm and 100 mm. Another effect on superficial soil change was renewal of mini terraces (handmade) which was applied to every treatment but the control. The year after the mini terraces were renewed the runoff and sediment concentration increased but after this period the trend was the contrary. Soil loss varied from 2012 to 2016 between 0.78 and 2.00 ton ha^{-1}. The annual sediment concentration was relatively constant (< 2.00 g l^{-1}) among all treatments during the five years with low temporal variation and a tendency to decrease in dry years. Rainfall distribution and accumulation pattern (over the year) besides previous superficial soil water content had an important effect on sediment and runoff production. The rainfall variability during the last 5 years (not normal compared with previous last 20 years records) caused a difficult data analysis looking for clear patterns. Herbicide treatment did not show a clear trend in any of the dependent variables. The shade tree reduced pruning treatment had a reduction on superficial runoff and sediment concentration. The latter treatment was the most consistent treatment in decreasing soil loss compared with other treatments.

Keywords: *soil erosion, runoff, shade coffee, mini-terraces, shade tree pruning*

Financial support: CIRAD, PCP, UCR.

(6569 - 2747) Soil Carbon and Nutrient Change after 11-years of a Short-Rotation Woody Crop Cycle

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Short-rotation woody crops (SRWC) for energy production have been investigated in 1-15 yr rotations in the Southeast USA since the 1970s. Lessons from managed pine plantations in the region that grow for ~25 yrs demonstrate a need for N and P inputs while K or Ca are only necessary with repeated harvest on specific sites. How such nutrient management knowledge from pine plantations translates to SRWC and to other species needs investigation. Here we report on soil C and nutrient changes after 11-years in the upper 1-m of soil under two cottonwood clones (*Populus deltoids;* clones ST66 and S7C15), sweetgum (*Liquidambar styraciflua*), sycamore (*Plantanus occidentalis*), and loblolly pine (*Pinus taeda*) in a USA Sandhills location. Treatments are control (*C*), fertilization (*F*), irrigation (*I*), and their combination (*IF*). Previously this research reported growth gains from *IF>F>I>C*, although at age 9, depending on species, *IF* did not always exceed *F* (e.g., sycamore or sweetgum) and *I* did not always exceed *C* (i.e., pine). Total growth gains from *C* to *IF* ranged from ~50% in pine to ~300% in cottonwood clone ST66 and maximal above+belowground net primary productivity was observed in pine at 33 Mg ha^{-1} yr^{-1}. At year 3 this increased growth was associated with limited declines in soil C in response to fertilization or irrigation with the exception of one cottonwood clone (ST66) showing a ~3 Mg-C ha^{-1} increase in the upper 30 cm of soil. Results reported here are unique in having repeated soil measurements over a decade and sampling through 1 m of soil. At year 11, *F* or *I* had not significantly affected soil C concentrations, but C declines observed from year 1 to 3 had stabilized in the upper two layers (0-15 and 15-30 cm). At depth (45-105 cm) soil C had increased possibly due to increasing root growth or decay of roots from the previous rotation. There was also some increase of N at depth but no significant effect of *F* or *I*. N accumulations were relatively small compared to the decade of N inputs. Fertilization increased P and K concentrations over 11-yrs. In contrast, Ca declined with time as liming only occurred at the start of the rotation. CEC declined with Ca declines despite some increase in C. SRWC management in this study did not alter soil C concentration over the 1-m profile but increased P and K. Nitrogen dynamics were consistent with pine plantations in that N demand is high, and despite high N inputs soil N increases are limited.

Keywords: Soil Carbon, Nutrient change, Short-rotation woody crops

Financial support:

(1022 - 1264) Soil chemical attributes and formation of biogenic aggregates associated to the application of animal waste

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Brazil stands out in the production of chicken and swine, generating a great amount of residue such as the chicken manure (CM) and swine liquid manure (SLM). The aim of the study was to evaluate the changes in soil chemical attributes associated to the application of CM and SLM and the formation of biogenic aggregates. The experimental area is located in Londrina, Paraná, Brazil, in a Ferralsol weathered from basalt and cultivated with annual crops. CM and SLM have been applied for 9 years in function of the demand of the crops for N or P (1 and 2 times the demand - 1X and 2X), a control that does not receive

organic waste was also evaluated. The samples were collected (0-10cm) and the aggregates separated visually (18-9mm) regarding its formation path (biogenic or physiogenic). The total organic carbon content (C) and the fractions humin (Hum), fulvic (FAF) and humic (FAH) acids, the pH, P-Mehlich-1 (P) and base saturation (V%) were determined. The data was evaluated by ANOVA and Tukey test at 5%. All the variables presented a significative effect of both the isolated factors. The averages of the biogenic and physiogenic aggregates were: C (40A and 36B g kg^{-1}); Hum (14A and 12B g kg^{-1}); FAH (7.4A and 6.7B g kg^{-1}); FAF (4.95A and 4.33B g kg^{-1}); pH (5.20A and 4.96B); P (102A and 42B mg kg^{-1}) and V% (78.5A and 73.1B %). In relation to the manure factor, the results for the Control, CM 1X, CM 2X, SLM 1X and SLM 2X were: C (24.7d, 43.5b, 48.3a, 32.6c and 40.8b g kg^{-1}); Hum (9.5c, 12.6b, 15.8a, 12.4b and 14.9a g kg^{-1}); FAH (3.5c, 8.9a, 9.3a, 6.3b and 7.3b g kg^{-1}); FAF (3.0c, 5.1a, 5.5a, 4.5b and 5.1a g kg^{-1}); pH (4.9c, 5.3ab, 5.4a, 4.8c and 5.0bc); P (16c, 38b, 107a, 75a and 123a mg kg^{-1}) and V% (73.1b, 79.9a, 83.6a, 69.0b and 73.4b %). The activity of the macrofauna and the consequent transformation and accumulation of organic compounds allowed the improvement of all the chemical attributes. The CM showed greater potential of improvement of the chemical attributes of the soil through the formation of biogenic aggregates in comparison to the SLM, which showed superiority only to the Control. The best results of CM, may be resulting from the higher amount of organic matter applied and the solid nature of the manure, which was an energy source to the macrofauna for a longer period than the SLM. The use of animal waste is an advantageous technique for the improvement of the chemical attributes of the soil through the formation of biogenic aggregates.

Keywords: animal waste; aggregation; soil fertility
Financial support: National Council for Scientific and Technological Development (CNPq)

(2491 - 1602) Soil Chemical Properties after Long-term Nitrogen and Phosphorus Fertilization of Grain Sorghum

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Inorganic fertilizers are routinely used to increase crop production, but there is limited information on the long-term effects on soil chemical properties, grain yield, and nutrient uptake. Nitrogen (N) and phosphorus (P) fertilizers were applied annually for 55 years to irrigated continuous grain sorghum (*Sorghum bicolor* L.) grown on a Ulysses silt loam (Aridic Haplustoll) in the central Great Plains of the United States. The study was conducted at the Kansas State University, Southwest Research-Extension Center near Tribune, Kansas. Treatments were a factorial of six N rates (0, 45, 89, 134, 179, and 224 kg ha^{-1}) and two P rates (0 and 20 kg P ha^{-1}). The treatments were broadcast applied in the spring and incorporated prior to planting of grain sorghum. The entire study was irrigated to minimize water stress. Soil samples were collected after 50 years of fertilization and analyzed for selected chemical properties. In the surface soil (0-15 cm), application of N to grain sorghum decreased pH, Ca, Na, Zn, and B while increasing NO_3, Mn, Fe, and soil organic matter (SOM) concentration. Fertilizer P increased soil test P, Zn, and SOM concentration with minimal effect on other chemical properties. Profile soil samples (300 cm depth) indicated movement of NO_3 to 300 cm at the higher N rates with P fertilization and at lower N rates without P fertilization. Over the long-term, application of a combination of N and P fertilizers on irrigated continuous grain sorghum were better than either applied separately for enhancing crop production, maintaining or enhancing soil properties (when applied at rates not too exceed crop requirements), and minimizing environmental risk from nitrate leaching.

Keywords: long-term fertilization, soil test P, nitrate leaching,
Financial support:

(5049 - 2703) Soil fertility dynamic of ten land use systems in the Peruvian Amazon

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Shifting cultivation has become the main reason for soil degradation in the tropical rainforest. It causes the deterioration of soil properties and the alteration of natural recycling process, resulting in the loss of productivity. The objective of this study was to know the dynamics of soil fertility of ten traditional land use systems (LUS) in the Peruvian Amazonia. The research was conducted during the dry and wet seasons from 2010 to 2015 in Yurimaguas, Peru. The assessed LUS were two types of forest: primary and secondary forest; three agroforestry systems: multi-strata in a 10 %-clay soil (*Cedrelinga cateniformis* and *Centrosema macrocarpum*), multi-strata in a 4 %-clay soil, *Bertholletia excelsa* with *Coffea arabica*; three perennial crops: oil palm (*Elaeis guineensis*) with kudzu (*Pueraria phaseoloides*), palm heart (*Bactris gasipaes*), peach palm (*Bactris gasipaes*) with kudzu; two pasture systems: degraded pasture (native pasture with a predominance of *Axonopus compressus*) and improved pasture (*Centrosema macrocarpum* with *Brachiaria brizantha*). When analyzing seasonality, the soil organic matter (SOM) content decreased and the fulvic acids fraction increased during the wet season. Most of LUS had a slight increase of available phosphorus content, which was more significant in the fertilized systems (oil palm and peach palm). However, the available phosphorus level was low for all systems in both seasons. Throughout the study, the primary forest had the highest content of SOM and available phosphorus, and represented the largest carbon stock, followed by the palm heart, peach palm, improved pasture, and multi-strata agroforestry system in a 10 %-clay. In the wet season, the degraded pasture system showed the largest increase in the aluminum saturation percentage compared to dry season, while perennial cropping systems with their biodiversity and types of coverage- reduced it. In conclusion, LUS with a high content of residues improve soil fertility because they promote the nutrient recycling.

Keywords: nutrients, reciclying, SOM
Financial support: VLIR-UNALM

(1922 - 1534) Strategies to secure adequate nutritional status of high yielding corn and soybeans

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Fundação ABC[1]; IPNI Brazil Program[2]; LASC IPNI Program - Argentina[3]

Aiming to increase grain yields in well-managed crop systems, several strategies related to plant nutrition and stress alleviation have emerged. Therefore, there is a growing demand for evaluation of new technologies, mainly related to nutrients supply, root growth improvement and soil amendment. In order to compare different nutrient use strategies and their benefits to crop yield and nutrient budget, two trials were established in Ponta Grossa, Brazil, in 2014-2015 season, with treatments application and evaluation over the 2015-2016 and 2016-2017 seasons. Both trials have received the same treatments, and the difference among them was the sequence of crops (soybean – corn – soybean vs. corn – soybean – corn). The soil of the trial is a typical clay Oxisol in use for 30 years under a no-till soybean-oat-maize-wheat crop rotation system. Treatments were applied in a randomized block design, with three replications. A conventional fertilization strategy broadly used in the region (NPK and liming to acidity alleviation) was set as control. Alternative strategies (treatments) were: higher NPK rates, higher lime rate, gypsum application, foliar Cu, Zn and Mn application, and poultry litter

application (applied in 2016), as well as all strategies combined. Data compiled from the trials considered, for the three seasons: grain yield and macronutrients removal and budget. Over the period, soybean yield was not affected by any of the strategies. Corn yield was affected only by poultry litter application (5 t ha^{-1}). Treatments did not affect nutrient removals in any evaluated season. However, accumulated nutrient budget, which considered nutrients inputs (fertilization) and outputs (removal), indicated a positive balance when higher rates of NPK were applied. Considering grain yields (average of 4,500 kg ha^{-1} and 13,000 kg ha^{-1} for soybeans and corn, respectively); these results indicate that conventional fertilization is sufficient to sustain these yield levels. Nevertheless, higher yields are expected in the future and the study will continue for long-term evaluation.

Keywords: Agricultural intensification; nutrient use efficiency; nutrient uptake
Financial support: IPNI

(9153 - 1241) Sustainable Management of Soils Through the Use of Cover Crops to Aid Maize Production

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Cover crop use in the UK is gaining popularity yet the research undertaken to support their use and management in a UK climate is lacking when compared to other parts of the world. Published research, mainly conducted outside the UK has shown that cover crops can have many benefits which may include: improvement to soil structure, soil erosion control, nutrient cycling, soil water management, pest reduction and crop yield. To further the knowledge of cover crop use and their benefits in a UK context, trials were implemented in Cambridgeshire, UK on organo-mineral soils (≈25% organic matter). These highly fertile soils are used to grow high value field vegetables and salads with wheat and maize as break crops in an intensive rotation. Recognising the detetoriation of the soil resources, the farm business is researching sustainable soil management options in order to continue producing high value and quality crops. Cover crops between wheat and maize are one way of helping to address this soil management concern. Zero tilled cover crop mixtures were compared to an overwinter wheat stubble control to assess their potential to i) reduce soil compaction, ii) manage soil water and iii) aid nitrogen availability for the following maize crop. The two cover crop mixtures established were differentiated by their sensitivity to frost. These replicated treatments, with plots 24m wide, were managed at field scale (6ha) using readily available machinery, to ensure the practicalities and management of cover crops could be reproduced elsewhere on the farm. In the first year of trials the frost sensitive cover crop had a small but beneficial effect on soil strength at certain depths. Following a frost sensitive cover crop there was significantly greater soil moisture at 20 and 30cm depth. There were also significant differences between the treatments for nitrogen availability to the maize crop with frost sensitive cover crop > winter hardy cover crop > control. Maize yield was greater following the cover crop treatments but not significantly different to the control. The frost sensitive cover crop was deemed the most practical at farm scale and therefore has been taken forward for a second year of trials, which will be assessed using the same criteria as the first year. The research undertaken in Cambridgeshire, UK is similar to findings in other parts of the world with reported benefits to soil structure, nutrient cycling and soil water management.

Keywords: Cover Crops, Compaction, Water Management, Nitrogen
Financial support: Cranfield University and G's Growers Ltd

(9157 - 499) The effect of constructing fertile cultivated layer on soil physical properties and crop yield in black soil region in Northeast China

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Black soil region in Northeast China is one of important agricultural production areas. But plough pan created by unreasonable tillage in plough land, is a mainly limited factor for agriculture production in northeast black soil. The experiment was carried out to analyze the effect of constructing fertile cultivated layer on yield, soil physics, soil moisture and microbial quantity by using field experiments. The results showed that constructing fertile cultivated layer increased yields by forming deep cultivated layer. The practices applying straw and organic material into 20-35cm layer decreased bulk density by 9.88% and 6.20%, increased porosity by 9.58% and 6.02% and enhanced soil saturated hydraulic conductivity by 167.99% and 73.78%, compared with traditional tillage, which indicated that constructing fertile cultivated layer could improve aeration and water permeability, enhance infiltration of rainfall. Soil water moisture and water use efficiency under treatments with applying straw and organic material into plough pan were higher than traditional tillage, and a positive correlation between soil moisture in 0-35cm layer and emergency ratio was found. The increase of microbial quantity also was found in fertile cultivated layer construction attributed to employ organic matter into plough pan.

Keywords: Black soil; Constructing fertile cultivated layer; soil saturated hydraulic conductivity
Financial support: This work financially supported by the national Natural Science Foundation of China (41571219, 41671299), The National Research Program of China (2016YFD0200300, 2016YFD0300806)

(8774 - 1965) The effect of the timing of maize and clover residue applications to a soil on carbon and nitrogen cycles

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Organic matters such as plant residues are useful to fertilize degraded soils because they can provide nutrients and increase soil microbes. However, the amount of organic matters which can be used for soil improvement are limited in some area. Thus, we have to develop effective ways to improve soil fertility using organic matters. In this study, we used two types of plant residues, which have different composition and degradability, namely white clover (*Trifolium repens*) and maize (*Zea mays*). They were applied to a soil in different patterns. The soil was sampled from a grassland in Hokkaido, Japan. After 1 week of pre-incubation at WFPS = 60% and at 25°C, white clover (C), maize (M), and their mixture (Mix) was applied to the soil (equivalent of 3000 mg-C/kg soil). Then, the soils were further incubated for 2 weeks. After the 2 weeks, the soils were again received one of the three residues (C, M or Mix). Thus, in total six treatments were prepared (control (no residue), C-C, M-M, C-M, M-C, Mix-Mix; 1st addition-2nd addition). During the incubation, soil respiration was measured twice using a CO_2 laser. In addition, soil biomass carbon was measured using a chloroform fumigation method. To estimate nitrogen utilization ability, ^{15}N labeled urea was added to the soils at 2 weeks after the 2nd residue addition, and N_2O emission was measured by a N_2O laser. In results, after the 1st residue addition, soil respiration was relatively higher in C and Mix, when compared to M. However, there was no clear treatment differences after the 2nd residue addition. This trend may be derived from the difference of the degradability between white clover and maize. White clover may be decomposed immediately and increased soil respiration, on the other hand, maize was decomposed slowly and increased soil respiration later. Although soil respiration increased after residue addition, biomass carbon didn't increase significantly except for C-C. This indicates added carbon contained in plant residue was used for

metabolism of microbes and didn't accumulate in the soil as biomass. The N_2O emission was the highest in M-M. This may be because carbon from maize remained in soil for longer period than white clover. Thus, the remained carbon in M-M may be used after nitrogen addition and contributed to the N_2O emission. Overall, these basic information can be used to determine the patterns of applications for different plant residues to soils to control carbon and nitrogen cycles.
Keywords: residues, nitrous oxide, carbon cycle, nitrogen cycle, soil microbes
Financial support:

(7608 - 498) The impact of tillage depth and straw incorporation on crop yield and soil water supply in arable black soil

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Black soil is one of important arable soil in China, tillage depth and straw incorporation both impacted the agricultural production of black soil. The impact of tillage depth and straw incorporation depths on maize and soybean yield were considered based on a three-year field experiment which is a split block design. The main treatments included shallow cultivation within 0-15 cm (D15), medium-shallow cultivation within 0-20 cm (D20), deep cultivation within 0-35 cm (D35) and 0-50 cm (D50), secondary treatments included contrast and straw incorporation (+S). Yields of maize and soybean were increased along with the increase in cultivation depth, and obtained the greatest values of 8999 kg/hm^2 and 2424 kg/hm^2, respectively, suggesting that the cultivation depth was an important factor impacting crop yield. Straw incorporation within 0-15 cm (D15+S), 0-20 cm (D20+S), 0-35 cm (D35+S), 0-50 cm (D50+S) were added after each cultivation depth treatment was split. Comparison with corresponding no straw incorporation treatments, maize and soybean yields were decreased when cultivation depth was ≤ 20 cm, but were increased when cultivation depth was ≥35 cm, and obtained the greatest yield in D35+S treatments, which suggested that the depth of straw incorporation was key factor impacting the role of straw incorporation. Comparison with D15+S, soil water content in 0-15 cm soil layer, crop emergence rate and soil water supply under D20+S, D35+S and D50+S treatments were increased by 7.8%-12.6%, 11.4%-16.9% and 6.7%-10.4%, respectively, suggesting that above factors could regulate the role of straw incorporation. D50 and D50+S treatments increased maize and soybean yields, but increased also mechanical operation cost and was not in favor of soil water conservation. Therefore, combination of 0-35 cm cultivation depth and straw incorporation was recommended with the objectives of increasing crop yield and rainfall use efficiency in study site.
Keywords: Tillage depth; Crop yield; Soil water supply; Straw incorporation; Arable black soil
Financial support: This work financially supported by the national Natural Science Foundation of China (41571219, 41671299), The National Research Program of China (2016YFD0200300, 2016YFD0300806)

(6178 - 2188) Tree-row proximity did not induce an increase in soil biological and chemical fertility in two temperate alley-cropping agroforestry systems

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Alley-cropping agroforestry consists in tree rows alternating with crop alleys. Tree rows present a herbaceous vegetation up to 2 m width which is often excluded from alley-cropping studies, although it provides additional organic matter and contributes significantly to soil carbon storage (Cardinael et al. 2015). This herbaceous strip is a permanent trophic resource for soil organisms and could enhance soil fertility and soil biota. However, the spatial extent to which the effects of this strip are detectable remains unknown. Our study focused on soil macrofauna, soil microorganisms and soil organic matter in young temperate agroforestry systems. We hypothesized that 1) properties of the herbaceous vegetation located on the tree row vary with tree distance, thus affecting soil organisms; and 2) there is a gradient in soil chemical and biological characteristics in the cultivated alley along a transect perpendicular to the tree row. We sampled two 10 years-old wheat alley-cropping sites of South-West France at the beginning of spring in 2017. We defined four positions. Two positions were in the tree row, at 1m from the tree and at equal distance between two trees (TR2). Two other positions were on a transect going from TR2 to the center of the cultivated alley, at 1m from the tree row and in the middle of the cultivated alley. In each position, we measured the aerial and underground biomass of the vegetation and hand-sorted soil macrofauna. We determined soil microbial biomass carbon, nitrogen and phosphorus and respiration as well as soil organic carbon and nitrogen and available phosphorus. We found that herbaceous vegetation and soil organism biomass did not vary within the tree row contrary to our first hypothesis, perhaps because vegetation was sown and not spontaneous. There was no gradient according to tree row distance for any variable studied in agreement with Pardon et al. (2017). Soil organic carbon and available phosphorus were higher in the tree row than in the crop alley. Microbial biomass and respiration were higher in the tree row compared to the closest position in the crop alley only, indicating that tree-row proximity could negatively impact microorganism activity. Saprophagous macrofauna were also more abundant in the tree row, leading to the hypothesis that tree rows can be a refuge for soil fauna. The management of the vegetation under tree rows may impact soil fauna dynamics and movement at the interface with the cultivated alley.
Keywords: alley-cropping, tree-row, macrofauna, microorganisms, soil fertility
Financial support: Fondation de France, research unit Eco&Sols (INRA, Montpellier SupAgro, CIRAD, IRD)

(6318 - 3177) Water and Silicon Management on Improving Rice Productivity in Central Java, Indonesia

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Yield stagnation or even decline has been observed in some rice growing areas of Asia including Indonesia since the early 1980s. The challenges to improve rice productivity in Indonesia have been increasing recently due to nutrient depletion, water shortage issue and also increasing population and reduced arable area. On this present study, a research was conducted in area with water shortage issue to study the effect of water This experiment was conducted at experimental site of Indonesian Agricultural Environment Research Institute-IAERI, Jakenan, Central Java province, Indonesia. The experiment was designed as split plot in randomized complete block design with 4 replications. The main plot consists of three water management namely continuous flooding (CF), Intermittent (IT) and Aerobic rice (AR) as main plots. The sub plot was characterized by two treatments including Si+ and Si- (with and without Si fertilizer). The result showed that IT was significantly higher comparing to CF and AR for root and shoot weight and plant height. IT was higher up to 16 and 29% for root weight, 11 and 13% for shoot weight, 5 and 4% for plant height comparing to CF and AR respectively. On lodging resistance parameter, IT IT at 75 DAT increased by 70 and 13% comparing to CF and AR in Si+ treatments., and 75 and 31% to CF and AR in Si- treatment, respectively. More over on blast disease occurrence, the result showed that Si application gave significant effect ($p < 0.01$) on reducing leaf blast infection throughout the observation periods in all

water management. On neck blast infection, Si application gave significant effect ($p<0.01$) on reducing neck blast infection throughout the observation periods in all water management as well as it did for the leaf blast. The present study demonstrated that water management significantly increases yield compared to conventional flooding management. The highest yield was at IT management. This result could be related to a better root growth as occurred in IT which lead to improve plant growth parameter i.e shoot weight and plant height. This present result showed that, there is a potential to improve rice productivity and grain quality in water shortage area such as Central Java by practicing IT management combine with Si application.
Keywords: rice, water management, silicon
Financial support: Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture, Republic of Indonesia

(6589 - 381) Zeolite use for a sustainable agriculture in Argentina: what we know and what we do not know yet?.

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Scientific and technological knowledge gaps are serious constraints for the sustainable use of natural resources in developing countries. This work aims to update the state of the knowledge regarding zeolite use in Argentina. The main zeolite geological deposits under exploration are located in La Rioja Province (Paganzo formation) but newest prospects have been discovered over recent times in several provinces (e.g. Chubut, Mendoza and San Juan). Most of the zeolites available at local level have been classified as Heulandite/Clinoptilolite (HEU/CLI). The HEU/CLI concentration in sedimentary volcanic rocks is quite valuable, ranging from 20 to 90% (v/v). Accompanying the HEU/CLI, different minerals has been detected in local zeolite rocks like quartz, feldspar, mica, gypsum, carbonates, illites, smectites, among others. The potential use of zeolites in Argentina arises from the vast arid and semiarid surface (two third of the territory extension) where sandy poor fertility soils are dominants. In addition, a very interesting potential use can be highlighted for field crops and pastures in the Pampas (humid/sub-humid region) where zeolite would be applied in combination with organic wastes or N stabilizer of urea-ammonium containing fertilizers. Laboratory and greenhouse studies have performed in Argentina with promising results. Thus, our research showed that zeolites can be used to reduce ammonia volatilization and/or leaching N losses as wells as to increase easily plant available water up to 2-3 folds compared to natural soil. Under drought, zeolites application increased dry matter production by 30 to 60 %, reducing water consumption and hence, irrigation requirements. Besides, zeolites could increase N recovery when applications were done combined with cattle manure. Although a renewed interest on zeolite research can be observed, there are still huge fundamental and applied scientific knowledge to be addressed. Regional and sub-regional research is needed to address zeolite amending/fertilizing recommendation at field level. Furthermore, more research efforts should be done to integrate geological/petrography and agronomic studies focus on agriculture technological applications. For instance, research studies related to zeolite quality for different purposes are vacant, which are so important to address the efficient and effective zeolite use in agroecosystems.
Keywords: Heulandite; Clinoptilolite; Soil
Financial support: Tecnoagro SRL; University of Buenos Aires

C3.3.11 - Biochar for soil fertility management

(2958 - 364) Ameliorating Effects of Designer Biochars in a Hard-Setting Subsoil Layer: Soil Fertility and Plant Biomass

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Soils in the southeastern U.S. Coastal Plain region have meager soil fertility and frequently have compacted subsoil layers (E horizon). Designer biochar has gained global interest as an amendment to improve the fertility, chemical, and physical properties of degraded agricultural soils. We hypothesized that addition of different designer biochars in Norfolk soils with hard setting subsoil layer will have variable effects on soil fertility, biomass and nutrient uptake of winter wheat. Five different designer biochars were evaluated to improve soil fertility and enhance plant biomass and nutrient uptake in soils with hard-setting subsoil layer. Biochars were produced by pyrolysis at 500^{O}C from pine chips (*Pinus taeda*), poultry litter (*Gallus dometicus*) feedstock, hardwood, and as blends (50:50 and 80:20) of pine chip (PC): poultry litter (PL). Our results supported our hypothesis that addition of different designer biochars had variable effects on soil fertility, biomass and nutrient uptake of winter wheat. Higher nutrient availability was found after additions of biochars especially applications of 100% PL and 50:50 blend of PC and PL. On the average, applications of 100% PL and 50:50 blend of PC:PL had the greatest amount of soil total nitrogen with means of 1.94% and 1.44%, respectively. When compared with the control, 50:50 blend of PC:PL additions resulted in increase of 669% for P, 830% for K, 307% for Ca and 687% for Mg while application of 100% PL increased the concentration of extractable P, K, Ca, and Mg by 363%, 1349%, 152% and 363%, respectively. Our study also demonstrated the favorable and beneficial effects of different designer biochars on biomass productivity and nutrient uptake of winter wheat grown in Norfolk soils with hard setting subsoil layer. Application of 80:20 blends of PC and PL was found to be superior over other blends with the exception of PL because of its favorable effects on biomass productivity and nutrient uptake of winter wheat. Overall, our results showed promising significance for improving soil fertility and tilth of hard setting subsoil layer since biochars did improve the aboveground, belowground and total biomass of winter wheat.
Keywords: hard-setting soil, designer biochar, fertility, biomass, amelioration
Financial support:

(6732 - 1019) Anthropogenic charcoal-rich soils of the XIX century reveal that biochar leads to enhanced fertility and fodder quality of alpine grasslands

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Soil incorporation of charcoal (biochar) has been suggested as practice to sequester carbon, improve soil properties and crop yields but most studies have been done in the short term. Old anthropogenic charcoal-rich soils in the Alps enable to explore the long-term impact of charcoal addition to alpine grassland on seed germination, fertility and fodder nutritive value. A germination test and a growth experiment in pots with *Festuca nigrescens* Lam. and *Trifolium pratense* L. were performed using three different substrates: (1) control soil (i.e. sandy-loam brown acid soils with some podsolization); (2) charcoal hearth soil (i.e. charcoal-enriched anthropogenic soils derived from the carbonization of larch wood on flat terraces); and (3) control soil mixed with a fraction of fresh larch wood charcoal to reach the soil-charcoal ratio of 0.6. Both aged and fresh charcoal improved germination and markedly increased plant growth of the two plant species. The addition of fresh charcoal had an initial detrimental effect

that disappeared in the second and third growth cycles. Plant Nitrogen:Phosphorus ratio revealed that growth was N-limited in the anthropogenic soils and P-limited in the control and freshly amended soils demonstrating that biochar aging is critical to obtain a significant growth stimulation. Plant nutrient contents revealed improved fodder quality in both the charcoal amended soils. Despite the occurrence of limited toxic effects on seedlings, larch wood charcoal appears to have positive effects on fertility and fodder quality of alpine grasslands in the long-term.

Keywords: Biochar, Charcoal, Fertility, N:P ratio
Financial support:

(8766 - 590) Biochar and bacterial manure additions promote nitrogen uptake efficiency by decreasing fertilizer nitrogen loss and increasing soil bacterial abundance and diversity

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To improve the low nitrogen uptake efficiency of vegetable production systems in China is a great challenge. Addition of biochar and bacterial manure may be options for promoting soil nitrogen retention and optimizing soil microbial community. However, little information is available about the combined effects from biochar and bacterial manure addition on nitrogen uptake efficiency and soil bacterial community structure. Therefore, a pot experiment was conducted with pakchoi in continuous three seasons including four treatments: only Nitrogen (N), Nitrogen + Biochar (NBC), Nitrogen +bacterial manure (NBM), and Nitrogen + Biochar + bacterial manure (NBCM). ^{15}N fertilizer was used to trace the nitrogen uptake by plant and the mineral nitrogen left in soil. The PCR-amplified partial 16S rRNA genes in soil were sequenced after last pakchoi season. The results showed that nitrogen uptake efficiency was promoted from 34% (only nitrogen treatment) to over 45% (treatments with biochar and bacterial manure additions) with a significant increase in recovery efficiency of 15N. Compared to only nitrogen treatment, biochar and bacterial manure additions both increased the plant nitrogen uptake from fertilizer by 33%-50% and bacterial manure addition further increased the plant nitrogen uptake from soil mineralization by 32%. The fertilizer nitrogen loss in treatments with biochar or bacterial manure addition was decreased by 21%-26%. Both biochar and bacterial manure additions enriched the soil abundance of bacteroidetes and proteobacteria, and biochar further enriched the abundance of chloroflexi, planctomycetes in comparison with only nitrogen treatment. The combined effect from biochar and bacterial manure addition on microbial abundance was significant compared to bacterial manure treatment but was not significant compared to biochar addition treatment. In addition, both biochar and bacterial manure addition significantly increased soil bacterial diversity in terms of species richness (observed species, phylogenetic diversity and Chao 1 index) in comparison of only nitrogen treatment. It was concluded that biochar could provide great benefits to promoting nitrogen uptake efficiency together with a reduction of fertilizer nitrogen loss and the increases in soil bacterial abundance and diversity. The combination of bacterial manure could result in further promotion of the amount of nitrogen uptake by plant from soil mineralization and higher soil bacterial diversity.

Keywords: Biochar addition, Bacterial manure additions, Nitrogen uptake, Soil bacterial abundance and diversity
Financial support: National Key Research and Development Program of China (2016YFD0801101)

(5546 - 531) Biochar for long-term food security in smallholder farms in Kenya

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Application of biochar (BC) has been shown to increase soil fertility and mitigate climate change through soil carbon sequestration. However, little is known about the long-term effects on crop yield responses reported in the literature from shorter term trials. BC usually contains ash, which provides plant nutrients and has a liming effect. It is therefore probable that yield responses decline with time. To investigate this, we laid out meta-replicated field experiments in 2006, and three are still running at three sites in Kenya. Maize and soybeans are grown in rotation in a randomized block design at all sites. During 20 growing seasons (10 years) the positive effect on crop yield has been persistent after application of 10 kg BC m^{-2} during the first year of the experiment, both in combination with and without mineral fertilization. Increases in water holding capacity, pH and nutrient availability were probably the main drivers for the observed yield responses. In 2015, a series of new experiments were started in eastern, central and western Kenya for testing the effect of much lower amounts of BC on crop performance under maize monoculture. Application rates of BC in these experiments (0.1, 0.5 and 1.0 kg m^{-2}) were based on the amounts realistically produced in energy efficient gasifier stoves from local feedstocks available at smallholder farms that have limited alternative use, such as maize cobs, coconut shells or tree prunings. During the three (two in western Kenya) growing seasons after application, crop yields consistently increased with BC rates and the yield response did not decline with time. Crop yields were on average 2.9, 5.0 and 6.4 times higher, compared with the unfertilized control, after application of 0.1, 0.5 and 1.0 kg m^{-2} BC, respectively. Corresponding yield increases in the NPK-fertilized treatments were 1.5, 2.3 and 3.3 times those in fertilized plots without BC. Preliminary results from participatory field trials on 152 Kenyan smallholder farms seem to confirm our results from the controlled field experiments, i.e., consistent yield increases with application rates of BC. In conclusion, the yield enhancing effect of BC on smallholder Kenyan farms appears to be long-lasting, rather independent of feedstock, proportional to the amount of BC applied without a lower threshold for response. Soil application of locally produced BC is a promising management technique for increasing food security on smallholder farms in Kenya.

Keywords: organic resource management; agricultural intensification; tropical farming systems
Financial support: Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning (FORMAS), grant no. 942-2015-1648.

(6302 - 1445) Biochar impregnated with magnesium increases phosphorus adsorption with potential to be used as fertilizer

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Phosphorus (P) recovery from wastewater using biochar is an alternative to produce organomineral fertilizers with environmental benefits. However, addition of cations for biochar production is needed to enhance P retention. We aimed at studying the adsorption

and release of P in biochar enriched with magnesium (Mg^{2+}) and its potential as fertilizer. Biochars were produced from poultry litter (PLB), pig manure (PMB) and sewage sludge (SSB) and were impregnated with $MgCl_2$ solution. Biochars were characterized for pH, EC, moisture content, ash content, total nutrient content and SEM-EDS. Adsorption isotherms (0-300 mg L^{-1} P, 5.0 g L^{-1} adsorbent, initial pH 4.0) were studied and desorption using H_2O, Mehlich-1 and 2% citric acid at 300 mg L^{-1} P was also carried out. P concentrations at equilibrium solutions were determined by ICP-OES. A 21-day pot experiment was performed by applying 200 mg kg^{-1} P in 200 g of an Oxisol sample and using maize as crop. A negative control (without P application) and a positive control (200 mg kg^{-1} P of triple superphosphate - TSP) were also used. Plant height, stem diameter, shoot and root dry biomass and nutrient accumulation were determined in the plant samples, while pH, available P (Mehlich-1 and exchangeable resin) and available Mg were determined in the soil samples after cultivation. Impregnation of Mg^{2+} in all biochars caused an increase in pH, EC and moisture content. The Langmuir (R^2 = 0.94-0.99) model described the adsorption process better than the Freundlich model (R^2 = 0.74-0.99). Maximum adsorption capacities of P were 34.5 mg g^{-1} for PLB, 35.6 mg g^{-1} for PMB and 28.1 mg g^{-1} for SSB. The Langmuir affinity coefficient (*Kl*) was five times higher for PMB when compared to PLB and SSB. Desorption of P in H_2O were 1.3%, 2.0% and 0.7%, in Mehlich-1 were 28.6%, 36.3% and 2.2% and in 2% citric acid were 27.2%, 34.3% and 8.7% for PLB, PMB and SSB, respectively. Biochars impregnated with Mg^{2+} promoted greater plant growth and accumulation of P, Mg, Ca, S, Cu e Mn in maize plants as compared to TSP, confirming its potential as fertilizer. The biochar treatments also increased soil pH and available P and Mg as compared to TSP, which is a positive residual effect. Sample PMB showed the highest adsorption and desorption capacity. In conclusion, biochars impregnated with Mg^{2+} have the capacity to recover P from solution and release it to the soil, and act as a biochar based fertilizer.

Keywords: P recycling, phosphate, organomineral
Financial support: CAPES, CNPq (Grant 404076/2016-5), FAPEMIG (Grant CAG APQ 00484-14), UFLA

(1429 - 2388) Effect of biochar and nitrogen on wheat yield and soil quality

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A pot experiment was conducted to investigate the effect of biochar and nitrogen on wheat yield and soil quality at the Department of Soil and Environmental Sciences, The University of Agriculture Peshawar during winter 2016-17. The experiment was laid out in completely randomized design with three replications. During the experiment four biochar levels (5, 10, 15 and 20 ton ha^{-1}) and three nitrogen levels were used (60, 90, and 120 kg ha^{-1}). The results showed that biochar and nitrogen increased yield components and soil fertility. Maximum plant height (83.6 cm), spike length (12.5 cm), number of grains $spike^{-1}$ (59.9), thousand grain weight (49.2 g), grain yield (51.4 g), biological yield (108.3 g), harvest index (48.3%), soil EC (0.21 dSm^{-1}), soil organic matter (1.31 %), soil total nitrogen (1.6 mg/kg) and soil saturation percentage (47.62 %), was recorded in plants treated with biochar at 20 t ha^{-1}. Biochar increased soil pH (7.97) and reduced bulk density (1.07 g/cm-3) over control. Pots that were incorporated with 120 kg ha^{-1}nitrogrn produced promising result by improving both the plant as well as the soil parameters that results in maximum plant height (81.1 cm), number of spike length (11.6 cm), number of grains $spike^{-1}$ (54.4), thousand grain weight (45.1 g), grain yield (43.3 g), biological yield (102.9 g), harvest index (41.0%), soil EC (0.21 dSm^{-1}), soil organic matter (1.26 %), soil total nitrogen (1.3 mg/kg) and soil saturation percentage (42.01%). Application of nitrogen increased soil pH (7.91) and reduced bulk density (1.07 g/cm^{-3}) over control. Biochar was negatively correlated with soil bulk density (R2= 0.923) while positively correlated with soil pH (R2= 0.944), soil EC (R2= 0.923), soil organic matter (R2= 0.7415), soil total nitrogen (R2= 0.9287) and saturation percentage (R2= 0.973).These results suggested that biochar application at 20 ton ha^{-1} with the combination of nitrogen at 120 kg ha^{-1}have a great influence on soil fertility and significantly increased occur in the productivity of wheat and thus these levels of biochar and nitrogen were recommended.

Keywords: Biochar, Nitrogen, Wheat yield, Soil Quality
Financial support: British Society of Soil Science

(6040 - 1545) Eucalyptus biochar soil fertility and corn yield on a long term field experiment

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Eucalyptus wood char is a renewable energy source produced by partial wood carbonization on mud ovens close to the plantation areas, and is an important alternative to mineral char mainly in the metallurgy industry. This process generates a black solid by-product, the wood biochar (WB), collect after many char batches production, form the bottom of the ovens. Most studies with biochar occur under controlled environments. The field experimentation makes it possible to obtain more concrete data about its effects long term either in soil and agricultural production, over time. This research is being developed at Agronomic Institute (IAC), Campinas/SP, in a clayey oxisoil with six doses of WB: Control, without WB; 10, 20, 30, 40 and 50 Mg ha^{-1} WB, which were applied on April 2016. The pH_{H2O} (1:10) of WB is 7.5. The WB doses used in the experimentation corresponds up to 25 Mg ha^{-1} of C; 1.4 Mg ha^{-1} Ca; 470 kg ha^{-1} of N; 75 kg ha^{-1} of P; 320 kg ha^{-1} of K and 65 kg ha^{-1} of Mg, at the 0-20 cm layer. NPK fertilization occurred in the corn planting, in line, below the seeds, on December 2017. The soil was collected in June 2017, after the harvest. Macronutrients, micronutrients and heavy metals contents were determinate in the diagnostic leaves of the plants as well as the shoots dry matter and corn yield. Soil organic matter (SOM), macro and micronutrients contents, pH and CEC were determinate in the soil. Nitrogen contents in the plants ranged from 28 to 30 g kg^{-1}; while P ranged from 1.8 to 2 g kg^{-1} and K from 19 to 20 g kg^{-1}. However no significative effects were identified for such elements in the diagnostic leaves. Furthermore, neither the corm yield nor the dry matter shoots were affected by the addition of WB to the soil. There was a small increase in the soil pH and CEC for the higher doses of WB, but also it were not significative. SOM did not increase with the WB applied doses, indicating that the increase of WB did not provide acceleration in SOM decomposition neither was mineralized. The results indicate that, after 14 months of soil application, WB aging in soil was not significant. In addition, the WB showed low neutralization power in soil, which is often with biochar application in tropical soils.

Keywords: by-product, soil organic matter, oxisol
Financial support: Capes

(6327 - 1210) Micron-scale pore structure of willow biochar modify soil moisture characteristics

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Pyrolysis has recently gained interest in the field of biomass conversion. In the agricultural context the solid end product called biochar has been used to improve soil structural properties and soil water holding capacity. However, the effects of biochar depend on the raw material from which biochar is derived as well as on the used processing technology and process conditions. Biochar may affect soil water retention in the direct or indirect way. Direct mechanism refers to water stored and held in the biochar pores while the indirect mechanism is related to soil-biochar-interactions (soil structure). In this work we focused on the direct mechanism, i.e. how micron-scale porosity of biochar contributing to storage of plant available water within the biochar particles. Willow (*Salix sp*) biochar was imaged with x-ray computed microtomography. The obtained images were quantitatively characterized by image analysis for specific surface area, porosity and pore-size distribution. The effect of biochar application on clay soil water retention was studied by conventional water retention curve approach. The results of image analysis indicated that micron-scale pores of willow biochar had bi-modal distribution with maxima at 50 and 10 µm (equivalent pore diameter). Observed changes in soil moisture characteristic curve indicated that biochar amendment increased soil porosity at pore size regimes close to 25 and 5 µm, which roughly correspond biochar pore size maxima multiplied by factor 0.5. In general, willow biochar modifies soil porosity and water holding capacity at the range relevant for plant water uptake. We anticipate that the approach presented is promising way forward in increasing understanding of biochar-water interactions. Establishment of relationship between biochar pore system and its specific effect on soil moisture characteristics facilitate development of tailored biochars aimed to enhance water use efficiency in agricultural soils.

Keywords: Key words: Biochar, X-ray tomography, image analysis, soil moisture characteristics
Financial support: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637020−MOBILE FLIP.

(6005 - 374) Nano biochar: Formation processes, carbon stability and colloidal behaviorNano biochar: Formation processes, carbon stability and colloidal behavior

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Nano biochar is increasingly receiving attention due to its specific environmental behavior (e.g., high mobility, strong adsorption towards contaminants) and potential risk. However, formation and characteristics of nano biochar, as well as its chemical and colloidal stability are largely unknown. Therefore, 16 types of biochars from charring peanut shell, cotton straw, Chinese medicine and furfural residues at 300, 400, 500, and 600 °C were used to investigate their release of nano biochar. Also, physicochemical properties, carbon stability, and colloidal processes of nano biochars were further examined. Our results revealed that the formation pathways of nano biochar included pore collapse and carbon matrix fracture during charring, structural breaking-up from grinding, and weathering and aging processes. Compared to graphitic component, amorphous carbon fraction in biochar was more readily converted into nanoscale fragments. Transmission electron microscope (TEM) and atomic force microscope (AFM) analyses displayed the irregular shape of nano biochars with lateral diameter of ~5–70 nm and profile thickness < 1.6 nm. The nano biochars were characterized with higher oxygen-containing groups and fewer aromatic units relative to the original bulk biochars, which can explain the lower carbon stability and better dispersibility of nano biochar in water. The negatively charged nano biochar could heteroaggregate with positively charged goethite or hematite particles via electrostatic attraction, while the heteroaggregation of nano biochar with montmorillonite or kaolinite did not occur. Spherical hematite particles and rod-shaped goethite showed the peak heteroaggregation at the nano biochar concentrations of 0.5-2.5, and 3.0–12.5 mg C/L, respectively, which was mainly resulted from the difference in heteroaggregation configuration. Individual hematite particles aggregated with nano biochar through bridging. Individual or homoaggregated goethite particles formed interlaced heteroaggregates with nano biochar, thus shielding a large proportion of positive sites on goethite and causing stronger heteroaggregation than hematite-nano biochar. These findings are useful for better understanding the environmental behavior and fate of nano biochar in soil and water.

Keywords: nano biochar; properties; carbon stability; colloid stability; heteroaggregation
Financial support: Natural Science Foundation of China (41503093, 41325013), and USDA NIFA McIntire-Stennis Program (MAS 00028).

(9440 - 729) Opportunities for biochar use in low-input agricultural systems

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Agricultural production systems have become highly dependent on chemical products and technological inputs resulting in ecosystem degradation on a massive scale. To minimize external fertilizer inputs, use of biochar that can be obtained from locally available farm materials could substitute or complement the use of synthetic products. Wide differences in nutrient availability exist between biochar produced from plant- and animal-based materials (feedstocks). For example, phosphorus (P) concentrations in mixed hard woods biochar is <2000 mg P kg^{-1} while in poultry litter biochar it is >30 000 mg P kg^{-1}. It is therefore difficult to adopt a "one-size-fits-all" recommendation. In addition, availability of nutrients from a given biochar at the same rate of application is highly dependent on the soil type. Tropical soils with high P retention properties will likely need a higher amount of a biochar to maintain soil fertility. Biochar produced from mixed feedstocks would be an option to reduce the amount of biochar to be land-applied to maintain soil fertility. For example, both plant- and animal-based "waste products" are often available in agroforestry systems in many parts of the world. Another option would be adding biochar to compost prior to composting. The relatively small quantities of biochar needed for application to nursery beds and pots, both commercial and small-scale nurseries, could also benefit from biochar use. Spot application of biochar in planting pits of trees is yet another, relatively unexplored opportunity. Further, biochar's high water-holding capacity could be advantageous in arid and semi-arid regions. Developing appropriate techniques for use of biochar will be a win-win situation in terms of yield increase and waste disposal for smallholder farmers particularly in developing countries.

Keywords: feedstocks, nutrient availability, nursery beds, phosphorus, tropical soils
Financial support: Support from USDA Hatch Funds for various analyses in the study is greatly appreciated

C3.3.12 - Sustainable land management in rural basins belonging to the south cone of Latin America

(5035 - 1339) Impact of agricultural rotations on environmental indicators in different areas of the Argentine Republic

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Land use and the agricultural production structure in Argentina have experienced important changes in recent decades. Extensive crops, specially soybean monoculture, expanded by replacing other activities. Land use changes impacted on soil quality in different areas of the country. The objective of this study is to determine the effect of different crop rotations on environmental indicators and their productivity. The study was based on data from farm field records (yields, rotations, edaphic parameters, etc.) of ten agricultural regions corresponding to 3.7 million hectares. Farm fields were categorized according to the proportion of grass crops in rotation: <20% of grasses, 20-40% of grasses, 40-60% of grasses and more than 60% of grasses. A System of Environmental Indicators developed by CREA (Regional Consortium of Agricultural Experimentation) was used as a tool to estimate three indicators of interest: GHGs emissions; soil phosphorus balance and soil organic matter balance. These indicators were compared according to the proportion of grass crops in the rotation. It was observed, in all the regions, that the increasing proportion of grasses in rotational planning tends to minimize the GHG emissions, mainly associated with an improvement in the soil organic matter content, that counterbalance the greater emissions due to the use of fertilizers. It was also observed that the fields with at least 40% of grasses in the rotation have better soil phosphorus balances. In summary, it could be verified that there is a positive association between rotations with greater participation of grasses and environmental indicators.

Keywords: soil quality, environmental indicators, crop rotation; sustainability

Financial support: Agricultural Crop rotations Project and Environmental Area (R&D) AACREA

(6606 - 1321) Land use change, soil degradation and water erosion: converting grasslands to croplands in the Rolling Pampa (Argentina).

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One third of Argentina is affected by water erosion and, to a lesser extent, by wind erosion. Recently the area and rate of these processes grew significantly. The main reasons are overgrazing, deforestation, land use change and inadequate cropping practices. We analyzed the effect of grasslands conversion into croplands, particularly its impact on some fragile hydrohalomorphic lowlands belonging to an 865 km^2 basin, characteristic of the Rolling Pampa. Firstly, we used GIS, remote sensing and USLE to measure the increment of the surface devoted to annual cropping between 1987 and 2015 for the whole basin and to estimate its effect on water erosion and sediment yield. Then, we selected and studied the soil properties of a pilot site located on the fragile lowlands belonging to the alluvial plain of this basin, which shifted its land use from livestock to grain production recently. We assessed changes in physical, chemical and biological soil properties compared to a control plot. With rainfall simulations, we studied runoff and its quality, emphasizing on physical (sediments) and chemical (phosphorus, glyphosate and AMPA) yield. Then, we selected some soil properties that were sensitive to land use change in this lowland: bulk density (BD), aggregate stability (AS) and soil organic carbon (SOC) and used them as indicators of the state of degradation for other similar situations corresponding to the basin´s alluvial plain. For that purpose, we compared paired crop and grasslands plots in the rest of this alluvial plain. During the period 1987-2015, annual crops area expanded over 26% of the whole basin, and currently occupies 80% of its surface. Water erosion estimates increased from 3.6 to 4.4 t ha^{-1} yr^{-1}, while sediment yield increased by almost 22,000 t yr^{-1} (31%). Regarding the fragile alluvial plain, SOC and AS decreased significantly because of the agricultural expansion (SOC: 13.2 g kg^{-1} in agriculture vs. 19.2 g kg^{-1} in livestock, AS: 1.95 mm in agriculture vs. 3.06 mm in livestock). BD increased from 1.17 g cm^{-3} in livestock to 1.24 g cm^{-3} in agriculture. Microbial biodiversity also decreased significantly. Rainfall simulation experiments showed that contribution of sediments and glyphosate to the stream water from these lowlands increased significantly. However, we did not detect AMPA in runoff water and the phosphorus levels did not show significant differences between crops and grassland plots.

Keywords: Basin; Agriculture; Indicators; Pollution.

Financial support: Universidad de Buenos Aires, Argentina. Project Number 20020130100709BA

(3084 - 2013) Monitoring of sediment yield and erosion modelling in a large no-till agricultural catchment in southern Brazil

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Erosion processes can be exacerbated when inappropriate soil conservation practices are implemented. In Brazil, little data is available to quantify the impact of conservation practices on erosion processes in agricultural catchments. This study aims to quantify the impact of different conservation measures on soil erosion and sediment dynamics in an agricultural catchment under no-till in southern Brazil, and to simulate conservation scenarios using a model calibrated with sediment data measured at the catchment outlet. Monitoring was carried out in a large agricultural catchment (800 km^2) of southern Brazil affected by extensive soil erosion and runoff despite the widespread use of no-till. Rainfall, river water discharges and suspended sediment concentrations were monitored during a five-year period (2011–2015). The WaTEM/SEDEM model was then calibrated. Four scenarios including a business-as-usual scenario and the implementation of alternative conservation strategies were simulated, and their impact on erosion, sediment deposition and sediment yield was quantified. All four scenarios were simulated twice, using either rainfall measured during a dry year or during a humid year. All the scenarios including alternative conservation measures drastically reduced erosion and sediment yields, with reductions reaching up to 400% when compared to the BAU scenario. The implementation of mechanical conservation measures such as crop levelling and terracing had the highest impact on soil erosion, and the most effective scenario included the implementation of crop rotation, crop levelling, terracing and the creation of forest protected areas. Model simulations indicated that no-till on its own has a low impact on erosion processes and that additional measures increasing the vegetation cover/density of the soil are necessary to significantly reduce sediment transfers in these agricultural areas. The simulations also demonstrate that during wet years, erosion processes increase on average by 33.9% for all scenarios. This study demonstrates that soil losses due to erosion processes remain significant and unsustainable in agricultural catchments of southern Brazil. Soil erosion is exacerbated by the lack of information provided to the farmers and the use of isolated conservation measures not coordinated at catchment scale. Farmers' and local communities' awareness should be raised to reduce soil degradation and sediment transfer to river systems.

Keywords: Soil Conservation; No-till; Connectivity; WaTEM/SEDEM model; Terraces.

Financial support: CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

(7152 - 1178) Multitemporal variability of land use and soil and its influence on surface temperature determined by remote sensing

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Land Surface Temperature (LST) is an important parameters for evaluating soil surface energy. Knowledge of the LST provides information about surface equilibrium and spatial variations, such as land use and cover changes (LULC) and LST distribution. Thus, the objective of this work was to evaluate alterations of surface temperature due to land use and soil variation, detected by a 30 years satellite time series Landsat images. The study area is located Piracicaba, region Brazil (2620 Km²). We collect Landsat images from 1985 to 2015. We did a supervised classification (maximum-likelihood), separated in five classes: agriculture, bared soil, straw, forest, water, and pasture. In addition, LST was estimated using inversion of Plank's function in the thermal band, with a correcting for land surface emissivity. As results, through the years the LULC we observe that the agriculture areas had an increase of 94320 hectares (35%), and forest had a decreased about of 5000 hectares (2%). Furthermore, the LST is correlated with the climate, in seasons with higher temperature and precipitation presented higher LST. Also, areas with bared soil had higher LST (average 28,5ºC), followed pasture (27,4º) and straw (26,7º). In specific of soil proprieties, areas with clay soils presented higher value compared with sandy, however, the temperature of clay soils is more constant between different seasons. Nevertheless, we observed in general, that the LST had an increase of 5ºC on the period of this study (22ºC to 27ºC), probably because of the damage of natural areas and increase of anthropic activity. Therefore, LST is influence according to the LULC, and it could be considered an important parameter about soil quality.

Keywords: Land use and cover, land surface temperature, remote sensing, degradation, climate.
Financial support: FAPESP: 2016/24794-4

C3.5 - Soil Degradation control, remediation and reclamation

C3.5.1 - Behavior and regulation of radionuclides in soil-plant system: Long term countermeasure for the renovation of agriculture

(3645 - 2725) Agricultural countermeasure against nuclear disaster

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Seven years after Nuclear Power Plant accident in Fukushima, Japan, various countermeasures regarding contaminated soil removal, huge amount of potassium application, etc. have been developed and thoroughly carried out. When looking back the initial impact especially on agriculture, we have met a lot of difficulties to decide the initiation of agriculture. The topics are 1) Environmental monitoring of plant in emergency, 2) Monitoring of food in emergency, 3) Restriction area of cultivation based on radioactivity of food, 4) Restriction are of cultivation based on external radiation, 5) Countermeasure to mitigate radioactive cesium transfer from soil to plant, 6) Countermeasure to reduce soil radioactivity by physical treatment, 7) Secure food safety by monitoring and all bags inspection, 8) Present situation of monitoring results of food produced in Fukushima, and 9) Final goal. The table shows the result of monitoring survey and all bags inspection of rice bag after 2011 in Fukushima prefecture. Initial quick decision and subsequent countermeasures succeeded to produce sufficiently low radioactivity in the brown rice. We have no report about exceeding the standard value since 2015.

Keywords: Radioactive Cs, FDNPP, decontamination, potassium application, inspection of radioactivity
Financial support:

(8855 - 3238) Thyroid Diseases as a Complex Natural and Technogenic Geochemical Problem and Approaches Towards Their Effective Prevention and Elimination

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In conditions of the virgin biosphere (before the anthropogenic impact) there has been developed a mechanism which provided ideal conditions for existence of all the species presented by a system of ecological niches. *Homo sapience* appeared to be the only species who acquired the ability to survive and colonize practically all the world due to his intelligence. However, the mankind had to pay for this by endemic diseases arising first due to colonization of the ambient areas with natural deficiency or excess of the particular elements, and then due to industrialization accompanied by anthropogenic contamination. Therefore, modern biogeochemical provinces provoking endemic diseases are characterized by two-layer structure formed by anthropogenic contamination overlaying the natural geochemical heterogeneity. The hypothesis has been tested by analysis of the situation within the areas subjected to the Chernobyl accident where the zones of ecological catastrophe were formed by isotopes of the same element – iodine (natural stable ^{127}I and radioactive ^{131}I). Analysis of superposition of the fields of these elements allowed development of a technique to evaluate the risk of thyroid cancer as a reaction to combined negative impact of iodine deficiency and radioiodine fallout in the form of a risk map. Obtained results have shown that the developed approach is universal and may be applied as GIS technology for solution of the problems related to endemic diseases of geochemical origin.

Keywords: endemic diseases
Financial support:

C3.5.2 - Native metallophytes from mine spoils as a potential source for phytoremediation

(5091 - 453) Arbuscular mycorrhizas differentially alter uptake dynamics under toxic soil concentrations of Cd and Zn in *Populus trichocarpa*.

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Metal inputs in terrestrial ecosystems are highly concerning due their toxicity to biota. Among soil remediation techniques, Phytoremediation - the use of plants to remove, sequester or stabilize soil contaminants - is considered to be less harmful to the environment. Alternatives to enhance Phytoremediation efficiency are the use of tree species with metal-accumulating capacity (such as Poplars) and mycorrhizal symbiosis associations as a way of increasing plant growth and tolerance to metal toxicity. We aimed to investigate some of the mechanisms by which mycorrhizal fungi can promote tolerance in poplars under Cd and Zn stress. *Populus trichocarpa* cv Trichobel cuttings were grown for seven weeks in soil contaminated by Cd (81 mg kg^{-1}) or Zn (300 mg kg^{-1}) with or without inoculation by an arbuscular mycorrhizal fungus (*Rhizophagus irregularis*). Growth parameters, transpiration, metal accumulation (leaves, stems and roots) and root colonisation were assessed. The expression of genes involved in metal transport (*PtHMA4, PtMTP1, PtZIP1* and *PtNramp3*) and chelation (*PtMT2a, PtMt2b* and *PCS1*) were quantified by qPCR in roots and leaves. The metallothionein gene *PtMT2b* was used for heterologous expression in yeasts under Cd and Zn stress. *P. trichocarpa* was highly tolerant to both Cd and Zn, and growth was not different from non-contaminated Control. Mycorrhizal symbiosis did not affect plant biomass, but increased Zn concentrations by 32 and

37% in leaves (1.2 g kg^{-1} Zn) and roots (1.1 g kg^{-1} Zn), respectively. Cd overall uptake was not affected by mycorrhization, however shoots accumulated 41% less Cd when compared to non-mycorrhizal treatments, indicating a strong restriction in translocation. Differential expression was observed in most genes, except *PCS1* and *PtNramp3*. *PtHMA4* and *PtMTP1* were down-regulated in roots due to Cd exposure, while *PtMT2b* was highly up-regulated by mycorrhizal symbiosis regardless of Cd addition, which may be linked to the restriction of Cd transport in all mycorrhizal plants. Gene expression patterns and heterologous expression in yeasts will be discussed along with their implications in biotechnology and phytoremediation processes.

Keywords: arbuscular mycorrhizal fungi, gene expression, heavy metals in soil, heterologous expression, phytoremediation, phytotoxicity.

Financial support: CAPES (project: 13462/13-0)

(4745 - 1262) *Dicranopteris dichotoma*: a rare earth elements (REEs), aluminum (Al) and silicon (Si) hyperaccumulator

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Dicranopteris dicthotoma (*D.d*) is a fern widely distributed in Southern China and is well known as a rare earth elements (REEs) hyperaccumulator, which could accumulate up to 3000 mg kg^{-1} (dry matter) in its leaves. As a pioneer plant of ion-adsorption rare earth mine tailings, *D.d* has a potential for agromining of REEs on these sites. Previous work showed that *D.d* accumulated also Al and Si, suggesting that it could also be an Al and Si hyperaccumulator. Researchers found that in Al & Si hyperaccumulators, Al and Si formed aluminum silicate in the leaves rather than compounds complexed by organic acids. As REEs and Al show similarities in geochemical behavior, can REEs act like Al and form REEs silicates in the leaves? In this work, we sampled *D.d* leaves of young, meddle age and matuure from ion-adsorption rare earth mine tailings, high and low REEs concentration background (Dingnan, Southern China), in order to determine the REEs, Al and Si concentrations, and their speciation in *D.d* leaves during the plant growth. Freeze-dried mature leaves were extracted by different pH of water (pH=1, 3, 5, 9, 11, 13) (leaves/water=1:100, m/v). Results showed that REEs, Al and Si concentrations in the leaves increased with age. The concentration of REEs, Al and Si in the mature leaves reached 2750±842, 5950±1610 and 12000±4020 mg kg^{-1} respectively, as the Si/Ca ratio (m/m) was 4.24±0.79 in mature leaves, confirming that *D.d* is a REEs, Al and Si hyperaccumulator. The Si/(Al+REEs) (mol/mol) ratio was 1.1±0.62 for middle-aged leaves and 1.9±0.38 for mature leaves respectively. Al/REEs (mol/mol) was 14.1±4.4 for middle leaves and 11.6±2.9 for mature leaves respectively. The REEs, Al and Si extraction pattern of *D.d* leaves were consistent to that of aluminum silicate (Al_2SiO_5) (Al), aluminum silicate and silica (SiO_2) mixture (Si). As found in an Al & Si hyperaccumulator *Faramea marginata*, we speculated that REEs, Al and Si formed $(Al+REEs)_2SiO_5 \cdot nSiO_2$ (n=1 for middle leaves and n=3 for mature leaves). Al and REEs showed similar pattern in the extracts, further confirming that REEs, Al and Si existed as $(Al+REEs)_2SiO_5 \cdot nSiO_2$ in *D.d* leaves. While more direct evidences are needed in the next, this is the first report that *D.d* is a REEs, Al and Si hyperaccumulator, which may fix these elements as $(Al+REEs)_2SiO_5 \cdot nSiO_2$ in its leaves.

Keywords: *Dicranopteris dichotoma*, rare earth elements (REEs), aluminum (Al), silicon (Si), hyperaccumulator

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(7901 - 510) Effect of Pb mining activities on soil properties, heavy metal levels and plant uptake in two communities of Ebonyi State, Nigeria

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We evaluated the effect of mining on soil Pb, Cd, Zn and Fe in active and abandoned Lead (Pb) mines in Enyigba and Isiagu villages of Ebonyi state, South East Nigeria. Triplicate soil samples were collected from the centre of each mine pit; and at distances of 20m, 40m and 2 km away from the mines. Mean soil Pb in active mines were significantly higher than acceptable limits being 73.0 and 52.4 mg/kg at Isiagu and Enyigba respectively, but remained within normal levels in abandoned mine soils (9.16 mg/kg) and in farm lands situated 2 km away from the mine pits. Cadmium levels at Enyigba (15.16 mg/kg), Isiagu (1.499mg/kg) and the abandoned mine (1.308mg/kg) all exceeded acceptable soil Cd levels nearly ten times over. Overall, soil zinc and iron levels were normal. Okra planted in soils collected from inside the mines gave either zero germination or poor germination followed by rapid death of seedlings. Plants grown in soils taken from 20 and 40 meters away from mines exhibited stunted growth, yellowing of leaves, and zero flowering in Isiagu and Enyigba soils. On the other hand, Okra grown in abandoned mine pits and adjacent farm lands exhibited relatively good growth, flowering and fruiting. There was significant Pb uptake by Okra as shown by whole plant analysis at 12 weeks of growth, being 15.4 and 5.0 mg/kg in Isiagu and Enyigba mine soils respectively. Okra uptake of iron, cadmium and zinc were however not significant. The study showed that soil metal levels around the mines of Enyigba and Isiagu villages pose a risk to the inhabitants of the mining communities, as growing crops in such areas may take up toxic levels of heavy metals into their edible portions. Further risk to human health may also arise from the stagnant water in mine pits which the villagers use for bathing and laundry, analysis of which showed significantly high metal levels.

Keywords: Pb mining, heavy metals, soil contamination, plant uptake

Financial support:

(7517 - 815) Hyperaccumulator identified from native weed species and its hyperaccumulative mechanism

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Phytoremediation is a promising technology for remedying contaminated soils by heavy metals. As two important mechanisms of phytoremediation, phytoextraction can permanently remove heavy metals from polluted site mainly using hyperaccumulators. Phytostabilization can reduce ecological risk of wind and water erosion of heavy metals, in particular, safely gain agricultural products (without heavy metal pollution) through planting excluder crops in polluted soil. However, seldom hyperaccumulators and excluder crops were found till now. In this study, pot culture, small scale experiment, sample analyzing experiment in polluted site and pilot experiment were used to identify hyperaccumulative plant and excluder crop and to explore remediative mechanisms and strengthening measurements. 66 weed species in 22 families were tested to identify Cd, Pb, Cu and Zn hyperaccumulator. After that, 50 cultivars of rice were determined the potential to Cd accumulation. We also tested the effection of some chelators and fertilizers on these remediative plants phytoremediating Cd contaminated soil. The main results

include: 1). 4 characteristics that critical concentration, translation, tolerance and accumulation coefficient are indispensable properties of hyperaccumulators and hyperaccumulator can also be found in unpolluted site; 2). *Solanum nigrum* L., *Rorippa globosa* (Turcz.) Thell. and *Bidens pilosa* L. (3 weed plants) were Cd hyperaccumulators with higher remediation potential; 3). Shendao 4 is Cd excluder rice which can be safely. Co-planting hyperaccumulator and low accumulation crop experiments in contaminated soils were completed and gained good results. 4). Though some chaletors can significantly improve phytoextraction efficiency, the adoption of modernization agriculture technology will be a short cut to the commercial apply of phytoremediation to heavy metals.

Keywords: phytoextraction; hyperaccumulator; excluder crop; safe production

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(9744 - 1854) Influence of fly ash application and mycorrhiza inoculation on heavy metals availability and survival of different Acacia species in heavy metal contaminated soils from Selebi-Phikwe, Botswana

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To develop a site-specific phytoremediation strategies for the abandoned and active mine areas in Botswana, several experiments are being conducted to identify suitable plant species coupled with beneficial soil organisms and amendments that will re-engineer the rhizosphere to enhance plants capability to rehabilitate heavy metals contamination. Several acacia species were screened for growth and survival in heavy metal contaminated soils amended with fly ash from coal power plant and mycorrhiza inoculants. Results showed that the both fly ash and mycorrhiza enhanced the survival and growth of different acacia species seedlings. Fly ash application had increased the pH of soil and decreased availability of heavy metals based on sequential extraction. Mycorrhiza inoculation successfully colonized the roots of acacia species and enhance growth and survival of acacia. Improvement of growth and survival due to FA amendments and mycorrhiza inoculation could be attributed to decreased metal uptake hence lower toxicity. Mycorrhiza also enhanced nutrient uptake by plants resulting to improvement of growth. The combined application of FA and mycorrhiza inoculation could improve the revegetation process of heavy metals contaminated ecosystems degraded by mining activities.

Keywords: Acacia sp., Fly ash amendments, heavy metal availability, mycorrhiza inoculation

Financial support: BIUST

(6749 - 2561) Native species of ultramafic massif of Barro Alto, GO, Brazil, can successfully be used to revegetate Ni mine spoil heaps

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Ultramafic soils of Barro Alto, GO, Brazil, are rich in Fe, Mg and some heavy metals, such as Cr, Ni, and Co, that are potentially toxic to most plants. Despite these limiting conditions, many plant species develop naturally in those areas and are therefore strong candidates for reclamation of environments degraded by Ni mining. After Ni mining, high heaps of sterile materials are generated in the landscape, which are usually re-vegetated using *Brachiaria* (grass) and *Mucuna* and *Crotalaria* (leguminous). Our goal was to develop a protocol to replace those exotic species by native ones, more adapted to these extreme soil conditions. Studies carried out in an area of intact vegetation considered that the rusticity of those plant species is associated to the relevant contribution of the rhizosphere-associated microbiota, such as growth promoting bacteria and arbuscular mycorrhizal fungi, and to the physiological mechanisms of adaptation to high levels of metals in soils and plant tissues. Floristic surveys identified about 200 plant species and a seed collection schedule was constructed for most of them. Differences in Ni-bioavailability of the soil affected the distribution of botanical families, and DNA-genomic findings marked significant genetic differences among plants of same species. The elements content in plant tissues growing on Ni-rich soil showed high levels of Mg, Fe, Mn, and some accumulate > 1,000 mg Ni kg^{-1} in D.M. Characterization of soils from mine spoil heaps showed strong chemical and physical heterogeneity, originated from distinct mineralogy. There were negligible contents of O.M., low levels of Ca, P, K and high bioavailability of Mn, and Cr^{6+}, element potentially toxic to the environment. That information was important in the definition of strategies to re-vegetate the spoil heaps and to select Ni-hyperaccumulator plants for use in metal bioremediation processes. About 20 native herbaceous-shrubs species were selected due to their characteristics of great abundance, to the ability to colonize altered environments, and to tolerate or accumulate high amounts of toxic elements. Methodologies were developed for the propagation of the selected species for planting in the field conditions. All of this information made up a satisfactory protocol to re-vegetate mine spoils heaps, using native species in ultramafic soils, allowing the substitution of exotic species commonly present in the seed cocktails used by mining companies in that process.

Keywords: Brazilian ultramafic flora survey; Metallophytes seedling propagation; Ni-hyperaccumulators; permanent green cover; re-vegetation protocol

Financial support: The authors thank the institutions Embrapa, Anglo American Brazil and Eliseu Alves Foundation for financial and administrative support to the project, and the Ministério do Meio Ambiente (MMA) for the authorizations granted to perform this study.

(4188 - 630) Phytoremediation of Chilean copper mine tailings with *Atriplex halimus*, adding humic substances and magnetite.

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Mine tailings in Chile, as an important source of trace metals, affects large surfaces of soils and water bodies, visualizing to phytoremediation as the most sustainable strategy. After their germination in mine tailings, *Atriplex halimus* seedlings were disposed in pots containing mine tailings, humic substances and/or magnetite (720 kg ha^{-1} and 180 kg ha^{-1}, respectively) to evaluate copper (Cu) and cadmium (Cd) plant uptake, during 180 days. We observe significant increase, in relation to a control only with mine tailings, of Cu and Cd at the aerial plant tissues, while in roots there were no differences between the treatments. Aerial part reached concentrations of 62.6 mg kg^{-1} of Cu and 0.175 mg kg^{-1} of Cd. The transport index of metals to the leaf increased with the amendments applications, responding to the halophytic character of this species. The plants growth was continuous and did not show toxicity symptoms, however the Cu exceeded the normal levels found in

plants (5-30 mg kg^{-1}). The results indicate that the humic substances and magnetite, enhanced their chelating effect in these mining tailings, contributing to the metals be absorbed by the plants, which is desirable for the phytoremediation strategy.
Keywords: soil recovery; metal bioavailability; organic matter.
Financial support: Regular FONDECYT Grant 1150513; ACM170002, CONICYT, Chile.

(9864 - 1759) Rare earth elements fractionation in soil-plant system during phytoextraction of ionic REEs mine tailings using *Phytolacca americana* L.

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The widespread use of Rare Earth Elements (REEs) has resulted in localized soil pollution in China. It was reported that *Phytolacca americana* L., a high-biomass REE hyperaccumulating plant, has a potential for REE phyto-extraction. However, the effects of the remediation practices (amendments, plant development) on the soil properties and the REE transfer in the soil-solution-plant system during the phytoextraction of mine tailings are still poorly understood. In this study, *P. americana* was grown on an ionic REEs mine tailing in Dingnan county, Jiangxi province, China to assess REE fate in the soil-plant system under such conditions. Three treatments were carried out: bare tailings (B), tailings amended with organic matter (BA), amended tailings planted with *P. americana* (BAPA). The properties of the soils and soil solutions of B, BA, and of the rhizosphere and bulk soils of BAPA (BAPA-R and BAPA-B respectively) were tested. In addition, the REEs distribution in the soil-plant system was estimated. The results showed that *P. americana* could successfully grow on the amended mine tailing. The concentrations of Al, Ca, P, S in the rhizosphere soil of *P. americana* significantly increased from 15.5% to 21.2%, 0.02% to 0.1%, 0.01% to 0.04% and 0.02% to 0.04% compared to the bare tailings respectively. Compared to the bare tailings, the total contents of organic carbon and nitrogen in the soil solution collected in *P. americana* rhizosphere were significantly higher, and the pH increased from 5.4 to 6.3. However, the total REEs concentrations in the soil solution collected in *P. americana* rhizosphere were lower compared to the ones in the bare tailing. The concentration of total REEs in the roots of *P. americana* ranged from 200 mg kg^{-1} to 600 mg kg^{-1}, while in the leaves it reached 2512 mg kg^{-1}. In this soil-plant system, the ratios of light REEs (LREEs, from La to Eu) to heavy REEs (HREEs, from Gd to Lu) ($\sum$LREE/$\sum$HREE) during the transfers from soil solution to roots, roots to stem and stem to leaves were 6.25, 0.35 and 0.41 respectively. In conclusion, the soil solution in the rhizosphere of P. *americana* was enriched in HREEs. Light REEs were more likely to be absorbed and stored in the roots of *P. americana* while HREEs were preferentially transport to the shoots. This induced an LREEs enrichment in roots and a HREEs enrichment in shoots of *P. americana*.
Keywords: rare earth element, phytoremediaton, Phytolacca americana L
Financial support: This work was supported by National Natural Science Foundation of China (NSFC) under Grant No. 41771343; Fundamental Research Funds for the Central Universities - Soil evolution on ionic REE mine tailings No. 17lgpy90.

C3.5.3 - Frontier of soil quality evaluation after remediation of contaminated field

(3418 - 1768) Changes in soil properties during phytostabilization of Rare Earth Elements mine tailings using ramie (*Boehmeria nivea*)

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Rare earth elements (REEs) are strategic resources due to their wide application in many high-tech products. China is the biggest country for REE mining and production in the world. The growing mining activities have led to severe ecological damages (*e.g.* erosion of tailings, loss of vegetation and biodiversity), and accumulation and pollution of REEs in the surrounding area, which poses a potential threat to local environment and public health. In the ionic REE mine areas of Southern China, phytostabilization of mine tailings can be considered as a cost-effective means to limit soil erosion and lower the mobility and spread of REEs. The fiber plant ramie (*Boehmeria nivea*), is known for its high biomass, vigorous root growth, and heavy metal tolerance. Therefore, it could be a good candidate for the phytostabilization of ionic REE mine tailings and the production of fibers of economic value. This work was conducted to investigate the effects of the combination of soil amendments and growth of ramie on soil tailing properties, focusing particularly on root activity effects. A demonstration base was set up on a former REEs mining site in Dingnan county, Jiangxi province, China. Three treatments were carried out including bare tailings (B), amended tailings (BA), amended tailings planted with ramie (BAR). For each treatment, five plots (2×2 m) were set up. The amendments (mixture of organic wastes) were mixed in the first soil 10 cm. The physicochemical properties of the bulk soils in B, BA, BAR, and rhizosphere soil in BAR were characterized after 4 months following plant installation. Results showed that the phytostabilization process increased slightly soil pH, electrical conductivity, organic carbon content and C:N ratio. Also, an increase in extractable Fe, K, Mg, and Mn, and a decrease in extractable Al in soils, especially in rhizosphere soil were recorded. The available REE content was reduced by the addition of amendments. The rhizospheric processes also tended to reduce the availability of REEs, but showed no significant effects. In conclusion, the phytostabilisation strategy adopted here for ionic REE mine tailings produces significant changes in soil properties favorable for plant growth. Ramie might be an appropriate material for REE phytostabilization. Further studies are necessary to better understand the mechanisms of phytostabilization on REE mine tailings.
Keywords: rare earth element; ramie; phytostabilization;
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(1827 - 3149) Contents of Heavy Metals in Urban Soils: evaluation at São Bartolomeu and Joventino Silva Parks in Salvador, Bahia, Brazil

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To stablish whether a particular area has a soil with potential contamination to human health and to ecosystems, it is fundamental to know the content of contaminants and their characters. In the

present work it was analyzed the content of Aluminium (Al), Barium (Ba), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn) in soils of São Bartolomeu Park and Joventino Silva Park, in the city of Salvador, Brazil. The samples were collected in areas that receive most of visitors and where they have direct contact with the soil, including playgrounds. To stablish the content of heavy metals it was used the EPA Method 3051A and an inductively coupled plasma atomic emission spectrometry (ICP AES). To associate the heavy metal content identified with the soil quality parameters, it was used the rate guide determined by the Brazilian Resolution CONAMA nº 420/2009 for residential areas, since there are not regional quality reference values. The analysis concluded that the soils examined did not present levels of heavy metals above the Investigation Value, which content could affect human health, that there was a content of Ba above the Prevention Value in a thicket at São Bartolomeu Park and in a lawn at Joventino Silva Park, and Cr above the Prevention Value in a floodplain at São Bartolomeu Park, which value defines the limit the soil can maintain its main functions. It was also identified a positive correlation between clay and metals, indicating that the highest the level of clay is the biggest is the availability of some metals. Although the origin of the hevy metals is uncertain, the Cr was associated to atmospheric deposition of materials liberated by automobiles, and the absence of contents above de Investigation Value may be explained because there are not industrial land use near both parks.

Keywords: quality reference values; public parks; contamination
Financial support:

(6104 - 1953) Evaluating soil quality and food safety for the rural soils with anthropogenic and geogenic heavy metals after in-situ stabilization

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In-situ stabilization is a remediation technology which is able to reduce bioavailability of soil heavy metals with application of amendments, such as lime, compost, phosphate rock, red mud, and other industrial by-products. In comparison with chemical extraction, dilution or mixing, in-situ stabilization is more efficient and cost-effective and has less impacts on the ecological functions of the soil. In order to evaluate the performance of in-situ stabilization method, Taiwan Environment Protection Administration (TEPA) conducted pot or field experiments for different types of contaminated soils. Cu, Zn, Cr and Ni exists in the soils not only from anthropogenic but also geogenic sources, such as industrial wastewater discharge and soils derived from serpentinite with high background levels of Cr and Ni. In anthropogenic soils, the pH was significantly raised after lime and oyster shell application, the availability of Cu, Zn and Ni in soil was reduced remarkably, and Zn and Ni concentrations in brown rice were lower than the control (blank). Furthermore, the rice yield and quality in the two cropping seasons were also not affected by the metals. The accumulation of heavy metals in brown rice tended to a maximum (Cu 10 mg/kg, Zn 30 mg/kg, Ni 15 mg/kg, and Cr 1.0 mg/kg), corresponding to the levels of these metals in general market rice of Taiwan. Therefore, this study recognized the metals existed in the rural soils but the above mentioned management controlled the minimal uptake of these metals, demonstrating a high level of food safety. The pot experiment for the serpentinitic soils showed applying lime or compost decreased soil Cr and Ni bioavailability (extracted by 0.1 N HCl or 0.005 M DTPA) compared to control treatment. Ni concentration in the brown rice was in the range of 0.5 to 1.5 mg/kg, while ranged from 1.0 to 1.5 mg/kg in corn. By calculating the tolerable upper intake level of Cr and Ni of rice, it showed that rice produced from these sites was safe for eating because the intake of Cr and Ni was lower than reference values. We concluded that in-situ stabilization method had no adverse effect on soil quality and crop productivity, and ensured the food safety both in anthropologic and geogenic heavy metals-contaminated sites, which could be regarded as a promising remediation technology for heavy metals-contaminated rural soils.

Keywords: heavy metals contaminated, in-situ stabilization, soil quality, food safety
Financial support: The project “Investigation on Background Characteristics of Parent Materials of Farmland Soils (2)” and “Evaluation of Management Strategies and Remediation Technologies for Farmlands Contaminated with Heavy Metals” were funded by Taiwan EPA.

(8925 - 602) Evaluation of Cd Immobilization Effects in a Polluted Wetland Soil after Stabilization with Calcium Polysulphide

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Stabilization has been widely and successfully applied in the remediation of the heavy metal-polluted soils due to its economic efficiency and environmental compatibility. Calcium polysulphide (CaS_x), also called lime sulphur, is a common soil bactericide and insecticide which has been widely applied in prevention and eradication of plant diseases and insect pests in agricultural production. In this study, different dosages of CaS_x were used as the amendment to investigate their effects on the immobilizing of Cd in a wetland soil by pot experiment. In addition to chemical analysis (pH and bioavailable Cd concentration), soil enzyme activities, microbial carbon utilization capacity, metabolic and community diversity were used to assess dynamic changes of soil environmental quality and toxicity of Cd as a consequence of ameliorant dosing. As soon as CaS_x amended, soil pH increased significantly compared to the unamended control (CK), and then declined slowly to the level lower than CK. Diethylenetriamine pentaacetic acid (DTPA) extractable Cd concentration was adopted to characterize the bioavailability of Cd in the soil. The CaS_x dose-dependent effect was observed that with increasing CaS_x dosage, the immobilizing efficient decreased. Soil urease and catalase activity assay and Biolog EcoPlate assay indicate that the addition of CaS_x at the early stage significantly inhibited soil microbial activities. But to the mid and late stage, the inhibition effects were alleviated, and the microbial activities could be recovered in 1% and 2% CaS_x treatments. Moreover, with increasing incubation time, microbial community diversity and richness were significantly recovered in 1% and 2% CaS_x treatments compared to the CK. No considerable changes were observed in the 5% CaS_x treatment. Conclusively, 1% of CaS_x amendment is an efficient and safe dosage for the stabilization of Cd contaminated wetland soil. This study contributes to the development of *in situ* remediation ameliorants and technologies for the heavy metal polluted wetland soils.

Keywords: Calcium polysulfide; Bioavailability; Stabilization; Soil Enzymes; Soil Microbial diversity
Financial support: National Key R&D Program of China (2016YFE0106400), National High Technology Research and Development Program (2012AA06A204-4, 2013AA06A211-4)

(6400 - 1364) Investigation of potentially contaminated industrial sites in Serbia

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Investigation of potentially contaminated industrial sites in Serbia is a part of the GEF-funded project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" implemented by United Nations Environment Programme (UN Environment) in close cooperation with the Ministry of Environmental Protection and Serbian Environmental Protection Agency (SEPA) in the period 2015-2018. In the first phase of the Project, 39 potentially contaminated industrial sites have been selected in accordance with project criteria from the database managed by the SEPA. Data and information on previous land use, type of industry, surface area, type and quantity of hazardous substances at the location and on the surrounding area, soil and groundwater quality, as well as geological, pedological and hydrological features were collected from previous studies and though numerous consultations. Collected data are sorted and transferred to digital format in order to complete a database of contaminated sites. Field missions to identified sites were conducted in the period September-December 2016 with the purpose to identify receptors of pollution and potential exposure routes, and to prepare and elaborate sampling programs. Following national and local consultations, field missions and meetings with operators/insolvency regulators, 32 operational and abandoned sites were selected for further investigation. In 2017, 264 soil samples were collected and undergone physical-chemical analysis, analysis of heavy metals content and specific pollutants such as: TPHs, PAHs, PCBs, cyanides, pesticides etc.. The expected result of the project is to compile a list of prioritized sites for clean-up and remediation. To support this process, a preliminary assessment of the risks to human health and the environment was performed by applying EEA's PRA.MS model, using the Source-Pathway-Receptor paradigm in the design of the conceptual model, where contaminated soil or waste disposed on/into soil represents a source. Application of PRA.MS model and development of Site Characterisation Plans for two abandoned industrial sites, suspected to be most contaminated, is supported by the Italian Ministry of Environment, Land and Sea through expert contribution of the Italian National Institute for Environmental Protection and Research (ISPRA).

Keywords: soil contamination, industrial site, PRA.MS, modeling
Financial support: UN Environment/GEF and Italian Ministry of Environment, Land and Sea

(7484 - 1794) Soil development in ion-adsorbed REE mine tailings to assess the sustainability of the reclamation

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Mining activities generate important ecosystem and soil degradation. Reclamation can use the processes of natural primary succession or pedological engineering to construct new soils fulfilling specific functions. More knowledge is needed about the links between soil-forming processes and the restoration of soil functions in order to assess the success and the sustainability of the reclamation. The exploitation of ion-adsorption type rare earth element (REE) deposits in South China by heap leaching has generated important environmental damages, such as water and farmland contamination, erosion and landslides. The mine tailings are sandy, compacted, with low concentrations in OM and nutrients and residual contents in REEs. Plants have difficulty to grow on such materials. The objective of this research is to better understand the soil-forming processes under the influence of the reclamation practices (addition of amendments and planting). Experimental plots were set up on a mine tailing abandoned since ten years in Ganzhou (Jiangxi province, China) to monitor the soil and plant development depending on different remediation strategies: - phytostabilization using low-cost perennial cover with grasses; - phytostabilization using fiber plants; - phytoextraction using REE accumulating plants. Thirteen treatments have been implemented including controls (bare and amended tailings) with 5 plots (2x2 m) per treatment. Amendments were mixed in the first 10 cm of tailings before planting. The surface bulk soil is monitored every six months for: total and $CaCl_2$-extractable major and REE concentrations, OM concentration, pH, CEC and exchangeable cations, bulk density and stability of aggregates. Profile development and microstructure using thin sections are described for controls and treatments with perennial cover. First results showed the formation of a crust layer at the surface, enriched in OM and heterogeneously distributed. Aggregates formed along the roots, especially in plots planted with grasses. The addition of amendments increased the soil pH, even if still acidic (pH< 5), the OM and nutrient contents and decreased the proportions of $CaCl_2$-extractable proportions of REEs and Al. The CEC remained low (2.5-3 $cmol^+ kg^{-1}$) but base saturation increased and exchangeable Al tended to decrease. Further analyses are in process to understand the processes (*e.g.* mineral and OM transformations, aggregation) controlling these changes and their evolution.

Keywords: mine tailings, phytoremediation, soil development, rare earth elements
Financial support: This work was supported by the National Natural Science Foundation of China (Grant No. 41771343) and the Fundamental Research Funds for the Central Universities. It is a contribution to the Sino-french Joint Laboratory ECOLAND.

(3746 - 517) Successful stories of soil remediation decision by health risk assessment approaching technology for As, Cr, Ni, Cu and Zn-contaminated rural soils in Taiwan

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Soil quality is defined as the capacity of a soil to maintain its functionality in agricultural ecosystem. Soil quality indexes (SQI) have been proposed as tools to quantify the effects of various soil properties on soil quality, which are most commonly used to assess the soil productivity and land suitability. However, few studies evaluated the soil quality change after soils were polluted or remediated. We compared the soil quality change of contaminated rural soils that attributed to irrigation water pollution of rural soils. The results of SQI values showed that the differences are owing to the high concentration of heavy metals in the surface soil. In Taiwan, most heavy metals-contaminated rural soils were remediated by dilution or excavation method to meet one target regulation value of rural soils of Taiwan (As 60, Cu 200, Cr 250, Ni 200 and Zn 600 mg/kg), which were cost-effective and had great impacts on the original soil properties. We should emphasize the necessity to regard the slightly contaminated soil as a natural resource. The major concerned issues of the contaminated rural soil sites are their food safety of pollutants. By establishing a health risk-based approaching method to decide the correspondent remediated method or management strategy is a new trend. In Taiwan, One big area (300 ha) of paddy soils were enriched in high As (100-500 mg/kg) in volcanic soils irrigated with high As concentration surface water in northern Taiwan and one big area (500

ha) rural soils with high As (>60 mg/kg) soils irrigated with high As content groundwater in south Taiwan. One big area (500 ha) of paddy soils were enriched in high Cr and Ni (>1000 mg/kg) of serpentine derived rural soils in eastern Taiwan. These metals (As, Cr and Ni) were low bioavailability in these types of soils and were not clearly accumulated in brown rice and vegetables grown in these regions. The health risk assessment of residents also showed no significant risk concerns, which indicated there were no need to conduct soil remediation. Eventually, the sustainable land use of soil were achieved for the communities by proper risk communication and management. Besides, big area (>500 ha) of paddy soils were enriched in high concentration of Cu and Zn (300-800 mg/kg) in contaminated rural soils for rice yields of Taiwan. In-situ stabilization method by low-cost soil amendments were advised to conduct with comprehensive health risk management.

Keywords: soil quality, heavy metals-contaminated rural soils, health risk assessment, soil remediation decision.

Financial support: The Soil and Groundwater Pollution Remediation Funds of Taiwan EPA.

C3.5.5 - Radionuclides in soils: pollution sources and sustainable remediation approaches

(9683 - 823) A simple method using rice seedlings to predict ^{137}Cs concentration in brown rice and to estimate appropriate amounts of potassium fertilizer for each paddy field

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Japanese government had restricted rice farming in the evacuation area (about 1,150 km^2) after the accident of the TEPCO's Fukushima Daiichi Nuclear Power Plant. Since the restriction had been lifted within 780 km^2 until April 2017, rice will be cultivated at the first time after the accident in this area. It would be helpful for farmers if radiocesium concentration in brown rice and appropriate amounts of potassium (K) fertilizer could be speculated before the first cultivation season. Radiocesium concentration in brown rice depends on both exchangeable K content and bioavailability of radiocesium in soil, but simple methods for evaluating bioavailability of radiocesium have not been established. In this study, we developed a simple method using rice seedlings to predict ^{137}Cs concentration in brown rice and to estimate appropriate amounts of K fertilizer. We conducted two experiments in this work. In the first experiment, correlation between ^{137}Cs concentration in brown rice grown in paddy fields and that in rice seedlings grown in a small container using soils from the corresponding paddy fields was analyzed. Radiocesium contaminated soils were collected from the total of eight paddy fields in Fukushima Prefecture, Japan, in 2016 and 2017 crop seasons before rice cultivation. The ^{137}Cs concentration in brown rice cultivated in these paddy fields without K fertilization was in the range from 1.6 to 137 Bq kg^{-1}. Seedlings were grown in a container filled with 80 g of each soil. The ^{137}Cs concentration in brown rice was positively and linearly correlated with that in seedlings (defined as bioextracted ^{137}Cs). The 95% prediction interval for ^{137}Cs concentration in brown rice was approximately ±50 Bq kg^{-1}. The result indicated that the upper 95% prediction interval of ^{137}Cs concentration in brown rice did not exceed the standard limit for grain (100 Bq kg^{-1}) when the bioextracted ^{137}Cs was less than 200 Bq kg^{-1}. In the second experiment, the effect of K application on the bioextracted ^{137}Cs was examined using one of the eight soils. The bioextracted ^{137}Cs of this soil was 360 Bq kg^{-1} in the first experiment. Potassium was applied to the soil at eight levels in the range from 0 to 60 mg-K_2O per 100 g soil before sowing. The bioextracted ^{137}Cs was significantly and negatively correlated with the amount of K application. Regression line indicated that the bioextracted ^{137}Cs would be less than 200 Bq kg^{-1} if more than 30 mg-K_2O per 100 g soil was applied.

Keywords: brown rice, paddy field, potassium application, radiocesium, rice seedling

Financial support: "Development of countermeasure technologies against radioactive materials for resumption of farming" project funded by the MAFF of Japan. Joint FAO/IAEA Programme on Nuclear Techniques in Food and Agriculture under CRP D1.50.15 on Response to Nuclear Emer

(3845 - 1842) Assessment of transfer risk of radiocesium in decontaminated agricultural land in Tomioka town, Fukushima prefecture, Japan

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After the Fukushima Daiichi nuclear power plant (FDNPP) accident in 2011, decontamination of agricultural land had been taken in highly contaminated areas in Fukushima prefecture except difficult-to-return zone. As a result, the total ^{137}Cs content in the soil surface was basically reduced to less than 5,000 Bq/kg. However, few studies have elucidated the transfer risk of ^{137}Cs from soil to plant on decontaminated field. Therefore, the objective of this study was to determine total and exchangeable ^{137}Cs content as well as plant-available K content of soil in a wide area of the decontaminated agricultural lands because they are reported as important indices to predict the ^{137}Cs transfer risk. In November 2016, 173 soil samples were collected from the plowed layer (0-15 cm depth) of decontaminated agricultural land in Tomioka town, Fukushima prefecture, Japan (N37°20', E141°00') located about 10 km south of the FDNPP. The total ^{137}Cs content in soils was determined by γ-ray spectrometry. Potassium in soils was extracted with 1 M CH_3COONH_4 and boiling 1 M HNO_3 to determine exchangeable K and boiling HNO_3 extractable K, respectively. Nonexchangeable K content was obtained by subtracting exchangeable K content from boiling HNO_3 extractable K content. For 32 samples which exceeded 2,000 Bq/kg in total ^{137}Cs content, exchangeable ^{137}Cs content in soils was also determined by γ-ray spectrometry. Total ^{137}Cs content in soils was on average 1,200±1,000 Bq/kg in the decontaminated fields which was much lower than total ^{137}Cs content before decontamination (>5,000 Bq/kg). The exchangeable K content was on average 172±74.2 mg/kg. Those of about 80% of soils were less than the recommended value by Fukushima prefecture (208 mg/kg) to reduce ^{137}Cs transfer from soil to plant. The exchangeable ^{137}Cs content was on average 260±150 Bq/kg (value range: 40 to 580 Bq/kg), which showed a negative correlation with nonexchangeable K content ($p<0.05$). This negative correlation indicated that ^{137}Cs was strongly adsorbed on the soil in association with nonexchangeable K, since nonexchangeable K was basically related to the specific adsorption site for Cs. In conclusion, in decontaminated agricultural land, 1) the exchangeable K content in soil should be increased for reducing transfer risk of ^{137}Cs and 2) the nonexchangeable K content can be a good index to select fields with

lower transfer risk of ^{137}Cs.

Keywords: Fukushima; radiocesium; decontamination; decontaminated farmland

Financial support: JSPS-KAKENHI-16H06188, Research grant from Tomioka town

(1216 - 2262) Integrated Nutrient Management in Remediation of Crude Oil Polluted Soils in Forest Ecological Zone of Delta State

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Experiment to remediate crude oil polluted soil using integrated nutrient management method was conducted in Teaching and Research Farm, College of Education, Agbor (forest ecological zone) located between latitude 6^{o} 15' North and longitude 6^{o} 12' East of Delta State. The study examined the practice of Integrated Nutrient method in the remediation of crude oil polluted soil. The soil was artificially polluted in the field with crude oil – bonny light - with specific gravity of 0.79, Integrated nutrient treatments were 300 kg NPK/ha + 10 t PM/ha, 300 kg NPK/ha + 10 t CD/ha, 300 kg NPK/ha + 10 t PD/ha, 250 kg NPK/ha + 10 t PD/ha + 10 t PM/ha, and 250 kg NPK/ha + 10 t PD/ha + 10 t PM/ha + 10 t CD/ha. The experiment was a randomized complete block design (RCBD) with ten treatments with three replications. SWAN-1 maize variety was planted at a distance of 25 cm x 75 cm. Each plot was 1.50 m x 3.75 m and the entire experiment area was 17.5 m x 13.25 m (231.88 m2). Results showed that application of integrated nutrient management in remediation of crude oil polluted soil offers an efficient and environmentally friendly way to treat contaminated soil and therefore may be a practicable choice in remediation of crude oil contaminated soils.

Keywords: Crude oil, integrated management, nutrient, remediation soil

Financial support:

(6808 - 562) Radioactivity in soils of the state of Rio de Janeiro, Brazil: radiological characterization, correlation with environmental conditions and Quality Reference Values

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A first large-scale systematic survey of radioactivity in soils of the state of Rio de Janeiro is presented. To encompass the main soil types and geological formations, surface soil samples were collected in preservation areas from all over the state, processed and analyzed by gamma spectrometry. A geographical information software (GIS) was used to produce distribution maps. The distribution pattern of the radionuclide and correlation with environmental factors were evaluated based on statistical methods. The concentration contents varied largely and the median values of ^{40}K, ^{226}Ra and ^{228}Ra were respectively 114 $Bq.kg^{-1}$, 32 $Bq.kg^{-1}$ and 74 $Bq.kg^{-1}$. The median value for ^{226}Ra was similar to the world median value for soils, the ^{40}K value was well below the worldwide value but that for ^{228}Ra exceeded the world median value. The intense weathering caused by the high rainfall rates and high temperatures may be responsible for the low levels of ^{40}K in the soils, of which the strongly acidic and clayey soils are markedly K-depleted. A soil from a high-grade metamorphic rock (granulite) presented the lowest ^{226}Ra (18 $Bq.kg^{-1}$) content, whereas the highest levels for ^{226}Ra (92 $Bq.kg^{-1}$) and ^{228}Ra (139 $Bq.kg^{-1}$) were observed in a young soil enriched in primary minerals (Leptsol). A lowland soil (Gleysol) showed the highest median of ^{40}K (301 $Bq.kg^{-1}$). Strongly acidic soils tended to present high amounts of ^{226}Ra and sandy soils tended to contain low levels of ^{228}Ra. The occurrence of fallout ^{137}Cs in soil samples of the Rio de Janeiro State was also investigated, its distribution pattern as well as their controlling factors were evaluated based on statistical methods for censored data set (with non-detected observations). The mean ^{137}Cs concentration of detected observations was 1.25 $Bq.kg^{-1}$, while for the censored data sets the mean value was 0.51 $Bq.kg^{-1}$. The Quality Reference Values (QRV) were estimated for each soil type. No influence of the rainfall index and soil pH on the Cs content in soil was observed. The external radiation dose indicates that the state has a background radiation level within the natural range. The data and information gathered in this study provide valuable information for geological and epidemiological studies, soil contamination managements and decision making process in case of soil contamination by agriculture practices and radioactive contamination by anthropogenic activities.

Keywords: radium, 40K, 137Cs, quality reference values, soil.

Financial support:

(2978 - 2838) Study on extraction and adsorption of cesium from contaminated soil in flexible container bag.

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A large amount of radioactive materials were diffused by the accident at Fukushima Daiichi nuclear power station (1F). Among the released radioactive materials, cesium-137 has serious issues because its amount was about 1.5×10^{16} Bq and its half-life is as long as about thirty years. Alternatively, it is well known to be difficult to remove the cesium from the soil which contains clay minerals since most of radioactive cesium is fixed in clay minerals such as vermiculite. The vermiculite is unevenly distributed in the soil of mountain area and along the coast in Fukushima prefecture. The stripped soil has also been left without disposing over seven years. For such a problem, in Fukushima, the stripping of surface soil is carried out so as to decontaminate the cesium from the contaminated soil. The collected contaminated soil is packed into flexible container bag and moved to the temporary storage space. The volume reduction of contaminated soil is conducted in the intermediate storage facility after the contaminated soil is passingly stored the temporary storage space. The Japanese Ministry of the Environment estimates that the amount of generated contaminated soil is about sixteen million m^3 to twenty two million m^3 after the volume reduction of the gathered one when all the soil in decontamination area of Fukushima are stripped. It is considered unrealistic to secure an intermediate storage facility in which the contaminated soils will be disposed over a long period of time. Therefore, the Japanese Ministry of the environment shows the guidelines that it is entertained to dispose the radioactive waste below eight thousand Bq/kg of radiation dose. In the present situation, it is extremely difficult to remove all the cesium from contaminated soil. However, the proposing and establishing a decontamination method that reduces the radiation dose of polluted soil in a flexible container bag to below eight thousand Bq/kg leads to volume reduction of the contaminated soil stored in the intermediate facility. Thus, in this study, the method in which only radioactive materials are collected from the contaminated soil in the flexible containers is proposed. The extraction of radioactive cesium from the soil is examined so as to check the performance and availability of the

proposed method. As a result, it is confirmed that is possible to collect a certain amount of cesium from the soil having a high cray content like vermiculite in which cesium is strongly fixed.
Keywords: Cesium; Vermiculite; Electrophoresis
Financial support: Nothing special

C3.5.6 - Biogeochemical fate of radiocesium in terrestrial environment: Advances after the Fukushima accident

(3632 - 3224) Mica in Asian dust as a natural amendment to increase soil ability to retain radiocesium

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Although mineral dusts are known to contribute greatly to marine and terrestrial biogeochemical cycles, their role in increasing the retention of radio-Cs in soil is less clear. Fine-mica, which is one of the main component of Asian dust, has a specific adsorption site for radio-Cs. Therefore, historical deposition of Asian dust may have rendered soils in Japan capable of retaining radio-Cs. This effect may be particularly important for volcanic-ash derived soils (Andosols) since they originally contain only small amounts of fine-mica. To test this hypothesis, we investigated 47 soils in volcanic ash-fall layers at four sites (Site 1, 2, 3, 4) with a different distance from volcanic crater of Mt. Aso, Japan, which is 10, 14, 16, and 32 km, respectively. Soils were collected from surface to the volcanic layer with 7.3 ka in Site 1 and 2, whereas from surface to the layer with 30 ka in Site 3 and 4. Ages of key layers were confirmed by tephrochronology and 14C dating method. Oxygen isotopic ratio (d18O) value of fine-quartz was used as a fingerprint of Asian dust in each volcanic layer. Average d18O value for fine-quartz from Site 3 and 4 was 16.0 ± 0.4‰, which was homogeneous and very close to those of fine-quartz in Gobi Desert, while clearly different from those of SiO2 in volcanic rocks. Fine-quartz and fine-mica contents were larger with increased distance from the volcanic crater and showed a linear relationship. Cumulative amount of fine-mica in the layers deposited during the last glacial period (i.e. 10 ka to 30 ka) was about five times larger than those deposited during the postglacial period (i.e. < 10 ka). These results clearly indicated that fine-mica in the volcanic ash-fall layers are mostly derived from Asian dust. Since radio-Cs adsorption experiment revealed that the ability to retain radio-Cs increased linearly as soils contained larger amount of fine-mica, we concluded that the inclusion rate of Asian dust to volcanic ash determine the ability to retain radio-Cs in volcanic-ash soils in Japan and probably any other soil influenced by these aeolian materials.
Keywords: Asian dust; oxygen isotopic analysis; radiocesium interception potential; volcanic-ash soils; x-ray diffraction analysis
Financial support: JSPS-Kakenhi (No 16H06188, 26252009).

(7599 - 1035) Mobility of radiocesium from specific sorption sites in agricultural soils in northeastern Japan

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The mobile fraction of radiocesium (RCs) in agricultural soils in Japan after the 2011 Fukushima accident has been often assessed by the so-called exchangeable RCs, which is extractable RCs with 1M NH_4OAc solution. However, mobility of RCs has not been well explained by only the exchangeable RCs concentration in soil, and it is not clear what fraction of RCs in soil is extracted. While RCs is sorbed on a specific sorption site of illitic clay minerals, of which sorption capacity has been often assessed by RCs interception potential (RIP), the relation between the exchangeable RCs and RIP is also unclear. In this study, the desorption behavior of RCs from the specific sorption site in various type of soils spiked with ^{137}Cs were investigated in a laboratory experiment and compared to the exchangeable RCs. Soil samples collected from arable fields in northeastern Japan were used in this study. The RIP was determined as follows; after carrier-free ^{137}Cs was spiked to a 1 g aliquot of each soil sample in a dialysis bag pre-equilibrated with 100 mL of 0.1 M $CaCl_2$ and 0.5 mM KCl solution, the bag was shaken for 5 d in the solution. RIP was calculated from solid–liquid distribution coefficient for ^{137}Cs. Then, the bag of soil was transferred into 100 mL of 1M NH_4OAc solution followed by shaking for 1 d. The ^{137}Cs desorbed into the 1 M NH_4OAc solution was measured, and its percentages in the ^{137}Cs absorbed in the soil samples were evaluated (NH_4-ext ^{137}Cs). For selected four soil samples, the bag of soil after the RIP measurement was shaken together with another bag of Cs selective adsorbent beads (Prussian blue), and the radioactivity in the adsorbent (reversible fraction) was successively measured for 7 d. The NH_4-ext ^{137}Cs varied in a wide range of 2-64% and were higher than the exchangeable RCs proportion to total one, showing that part of ^{137}Cs sorbed to soil in the RIP measurement condition is not extracted as the exchangeable RCs. The reversible fraction gradually increased during the experimental time. The proportion of the reversible fraction in sorbed ^{137}Cs in soil at 7 d were higher than NH_4-ext ^{137}Cs in vermiculitic soils but lower in allophanic and smectitic soils. The XRD analysis revealed that the extraction by the NH_4OAc solution induced interlayer collapse of vermiculite in the former soils. Those results show that a part of labile RCs can be fixed during the extraction, resulting underestimation of labile fraction by the exchangeable RCs.
Keywords: availability, radiocesium, RIP,
Financial support: Part of this study was performed under a contract with the government of Aomori Prefecture, Japan.

C3.6 - Salt-affected soils

D3.6.2 - Salinity mapping and modelling salinization processes

(8874 - 1173) Satellite and UAV thermography for soil salinity assessment

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Increased soil salinity is a significant agricultural problem that decreases yields for common agricultural crops. It is quite dynamic in time which makes timely soil salinity data crucial point in agricultural management. Remote sensing can provide necessary spatial and temporal resolution, but widely acknowledged methods and techniques for soil salinity monitoring using remote sensing are not present yet. The canopy temperature change is one of the stress indicators in plants. Its behaviour in response to salt stress on individual plant level is well studied, but its potential for landscape or field scale studies is not investigated yet. In our study, possibilities of satellite and UAV thermography for landscape and field scale soil

salinity assessment were studied. The performance of satellite thermography is compared with other approaches, like Normalised Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Optimized Soil Adjusted Vegetation Index (OSAVI) and Physiological Reflectance Index (PRI). The study areas were located in Uzbekistan, Australia, and the Netherlands. The diversity of the study areas allowed us to analyse behaviour of canopy temperature of different crops (wheat, cotton, barley, quinoa) grown in different conditions (rainfed and irrigated). MODIS and Landsat TM multiannual satellite images and UAV images were used. ANOVA was used to analyse relations between the soil salinity and canopy temperature and other remote sensing variables. Time series graphs were created to analyse the dynamics of the process. The results showed significant correlations between the soil salinity and canopy temperature on all study areas. The amplitude of canopy temperature difference between salinity classes varies for different crops, but the trend of temperature increase under increased soil salinity is present in all cases. Moreover, most widely used vegetation indices showed to be not useful for monitoring in case of salt tolerant plants like quinoa, because of the green biomass increase in response to soil salinity. The visual comparison of the soil salinity map and the canopy temperature map show similar spatial patterns. The strongest relation between the soil salinity and canopy temperature was usually observed at the end of a dry season and in the period of maximum crop development. Satellite thermography appeared to be a valuable approach to detect soil salinity under agricultural crops both at landscape and field scale.
Keywords: soil salinity, thermography, landsat, modis, UAV, vegetation indices
Financial support:

(1352 - 1118) Spatial Variability of Simulated Crop Yield with EPIC model in relation to Soil Salinity Predicted by Remote Sensing in Tarim River Basin/China

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The Tarim River Basin is the largest continental basin in China. The basin has an extreme desert climate characterized by low rain <50mm a^{-1} and high ET_p >3000mm a^{-1}. The Tarim River is the major water source of the oases along the northern rim of the Taklamakan Desert. Recently, the discharge into the River has been increasing steadily influenced by high melting rate of glaciers in the high mountains owing to temperature increase. The intensive cotton cultivation required excessive use of river water and saline shallow groundwater for irrigation. This enriched the soil with high amounts of salts leading to soil salinization owing to the arid climate and to absence of efficient drainage systems. The salinity effect can be clearly observed in cotton fields through vegetation-free patches or weak scattered vegetation pattern. Based on the negative effect of salinity on cotton plants, a regression model was developed from the correlation of NDVI of cotton vegetation with the corresponding soil salinity (EC_e: mS cm^{-1}) measured at several sites. According to this regression model, a salinity map (in grid format) was computed with GIS for the Aksu-Alar region in the upper reaches of the Tarim based on a NDVI map derived from Landsat-8 image captured during the maximum growth of cotton. After calibration and validation of EPIC model on field scale, a spatial estimation of cotton yield was conducted for Aksu-Alar using a combination grid map (100m*100m) comprising i.e. salinity map, soil map, climate data, and a standard field management as input data. The results showed that the spatial variation of simulated cotton yield correlated significantly with the variability of estimated soil salinity. The spatial simulated yields ranged from 0.48 to 6.17 t ha^{-1} with a mean value of 3.9 t ha^{-1}. The total sum of the simulated yield amounted to 652,000 t a^{-1} calculated for the whole agricultural area in Aksu–Alar (166,700 ha). The salinity threshold level (EC_t) was 11.3 mS cm^{-1}, whereas the decline of the simulated cotton yield (Y_d) for each unit of EC_e increase above EC_t was 3.1% (R^2 = 0.88). The comparison of the simulated yield with the derived yield from NDVI revealed significant correlation (R^2 = 0.57) calculated for all pixels in the grid (N = 166,700). The integration of EPIC with the remote sensing gives reliable quantitative estimation for large agricultural regions and can be an appropriate tool for reclamation planning and regional management of saline soils.
Keywords: EPIC, Cotton Simulation, Tarim Basin, NDVI
Financial support: SuMaRiO project: Federal Ministry of Education and Research of Germany

(6241 - 2278) Using image processing technics to map soil salinity in semi-arid region

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Soil salinization as result of natural or human-induced processes is a major environmental issue for agricultural sustainability, particularly in arid and semi-arid regions. The objective of this study was to evaluate the responsiveness of different remote sensing images to map soil salinity and to how the spatial resolution of satellite images influences this evaluation. The study was conducted at Baixo Açu irrigated perimeter, Rio Grande do Norte State, in a 2,500ha area under irrigated agricultural production systems. Image processing analysis for soil salinity mapping considered the use of LandSat 8 and Sentinel 2 remote sensing satellite constellations, respectively with 30 and 10 meters spatial resolution. Image scenes from both satellites covering the study area were preprocessed for radiometric corrections and atmospheric calibration. Soil reflectance responses were calculated to map surface state indicators of salinity at two spatial resolutions using the Brightness Index (BI), Normalized Difference Salinity Index (NDSI), and Salinity Index (SI). Forty-two topsoil samples (0–10 cm) were collected and analyzed for soil electrical conductivity using the paste extraction method. Partial least squares regressions were computed for correlations between salinity index responses and laboratory analysis, only showing a moderate relation for BI index from Sentinel images with second order polynomial regression (R^2=0.53). Visual field observations have shown negative influence on areas where the “Pirrixio” (*Blutaparon portulacoides*) was dominant, as opposite to previous considerations of this coverage being a salinity indicator. To compensate for spectral interference arising from surrounding vegetation covers, the correlation analysis was limited to seventeen sample points were bare soil pixels were characterized as exposed soils to a limit of 0.33 of the Normalized Difference Vegetation Index (NDVI). This approach has yield more significant correlations for BI and SI indices for both spatial resolutions. Results have shown that Sentinel 2 images have improved results for all indices, with the best correlation for BI (R^2=0.69). For all spectral indicators the spatial resolution has mostly influenced the potential of remote sensing for salinity mapping, in particular at locations with less “Pirrixio” coverage.
Keywords: soil salinity index, remote sensing, soil electrical conductivity.
Financial support:

D3.6.3 - Salinity management and remediation of salt-affected soils

(4080 - 1288) Assessment and management of saline and sodic soils in the eastern part of Georgia

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In Georgia, the agriculture sector faces numerous problems and challenges. An output is very low. Tough socio-economic conditions are closely linked to land degradation, being a significant ecological problem for Georgia, which is an agrarian country with limited agricultural land resources. The forms of land degradation are numerous and among those soil salinization is one of the issues. According to the recent data of the Ministry of Agriculture of Georgia, the low-yield agricultural lands occupy rather large areas. Saline and sodic soils account approximately 205 thousand hectares. The most of those salt-affected lands are favourable for agricultural production in terms of location, relief, sum of active temperatures, etc., and may have a significant input in agricultural production if their potential is used accordingly. The study was aimed to monitor the current status of salinity of soils from 1600 ha of arable land in the eastern part of Georgia and to assess the changes since 1965 when the last study was conducted. The results have shown some negative changes in soil properties caused by improper agricultural practices and use of saline groundwater for irrigation purpose. Those negative changes adversely affect agricultural productivity and reduce the income of farmers owning land in this area. The composed maps of salinity and sodicity of soils in the study area show their non-uniform spatial distribution, having natural and anthropogenic causes. Therefore, it requires a plot-based approach in order to apply a suitable and an economically feasible rehabilitation or adaptation measures to improve soils, increase crop diversity and amount and quality of agricultural products.

Keywords: soil salinity, soil sodicity, management of salt-affected soils
Financial support: The study was funded by the Scientific-Research Centre of Agriculture and the Ministry of Agriculture of Georgia

(7060 - 1656) Changes of soil salinity in Saemangeum reclaimed land with the passage of time

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Saemangeum is a reclaimed tidal land on the coast of the Yellow Sea in South Korea created by Saemangeum land reclaimation project. Through this project, 283km^2 of new land is to be reclaimed and 118km^2 of lake was created after the construction of sea dike connecting Gunsan and Buan on the west coast of Korea. In this study, we investigated soil physico-chemical properties of the Gwanghwal district in Saemangeum reclaimed land to obtain basic data for reasonable soil management and crop production of the Saemangeum reclaimed tidal land. The soil series of the Gwanghwal district was Munpo (coarse loamy, mixed, non-acidic, mesic family of Typic Fluvaquents) and soil property was sandy loam. Soil samples were collected from the sites spaced 200 meters apart from each other at soil depth 0 ~ 20cm and 20 ~ 40cm. Soil analysis results showed average soil EC was 14.5 dS m^{-1} in 2008, 6.5 dS m^{-1} in 2014 and 0.9 dS m^{-1} in 2017. The soil area below soil EC 4.7 dS m^{-1} (accepted as farmable soil salinity) was 25.0% in 2008, 54.3% in 2014 and 96.9% in 2017. Annual mean value of soil EC had been decreased rapidly over the years(2008 ~ 2017). The estimation equation for the soil EC was y = - 1.5756x + 14.6 (R^2 = 0.96) where, y=soil EC, x=elapsed years. It could be assumed that cultivation of most food crops be possible in the Saemangeum reclaimed tidal land before long.

Keywords: Reclaimed land, Saemangeum, Soil salinity
Financial support:

(3651 - 1771) Effects of biochar, fulvic acid and organic fertilizer on the improvement of barley yield and nitrogen use efficiency in a coastal saline soil of China

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Understanding soil amendment and fertilizer interaction is of great importance to improve crop yield and nitrogen use efficiency (NUE), especially for saline soil. The objective of this study was to investigate the effects of biochar, fulvic acid and organic fertilizer addition on barley yield and NUE. The treatments included the N0 (0 kg/ha), N1 (low, 150 kg/ha), N2 (moderate, 225 kg/ha) and N3 (high, 300 kg/ha) four nitrogen (N) plots, and the combinations of N1 and N2 as main plots and biochar (C), fulvic acid (H) and organic fertilizer (O) as sub-plots, each plot with three replicates. The plots were assigned to slight salinity level (EC1:5=0.61 ds/m). Application of soil amendments and N fertilizer significantly improved yield, with grain yield increases of 41%, 39% and 36% at the O+N2, N3, and C+N2, compared to the yield from control treatment, respectively. The highest total N uptake was obtained from N3 treatment with value of 192 kg/ha, then for the C+N2 and H+N2 treatments with values of 155 and 150 kg/ha, respectively. For a given N rate, the use of biochar and fulvic acid increased the agronomic efficiency (AE), apparent nitrogen recovery efficiency (ARE) and physiological efficiency (PE). The use of organic fertilizer increased AE and PE significantly but did not increase the ARE compared with the single N fertilizer treatment. The highest ARE, AE and PE at H+N1, O+N1 and O+N1 treatments with values of 45.9%, 6.1 kg/kg and 27.6 kg/kg. Our study demonstrates that the combination use of soil amendments and N fertilizer leads to greater barley yield, AE and PE than the single use of N fertilizer.

Keywords: Soil amendment, Biochar, Fulvic acid, Nitrogen use efficiency
Financial support: The authors are grateful for the funding provided by theNational Key Research and Development Program of China(2016YFD0200303, 2016YFC0501301)

(8977 - 1540) Effects of chemical amendments for sodic soil reclamation strategies in Puerto Rico

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High levels of soil exchangeable sodium (Na) cause structural changes that affect soil crusting, soil hydraulic conductivity, soil water availability, soil porosity and crop rooting extension restriction. The effects of amendment rates and sources were evaluated in laboratory microcosms and a field experiment in a Paso Seco soil (Fine, mixed, superactive, isohyperthermic Entic Udic Haplusterts) classified as sodic (exchangeable Na greater than 15%) in Guayama municipality, Puerto Rico. In the laboratory experiment the soil was amended with three gypsum sources (Agricultural Gypsum, Phusion® Gypsum, Reagent-grade Gypsum) and five levels (750, 1,500, 3,000, 6,000 and 12,000 mg/kg soil dry wt) of each of the amendments. Soils were packed in 60 mL microcosms and leached four times with 2.54 cm of water using a mechanical extractor in the laboratory. In the field experiment plots were amended with Agricultural Gypsum, Phusion®, and Sulfur (90%S), at a rate of 10,000 kg/ha. The laboratory experiment showed that leachate volume increased with increasing gypsum levels. Leachate pH decreased with increasing amendment rate and incremental leaching event. Leachate EC increased with

amendment rate and decreased with incremental leaching event. Improved leaching and leachate characteristics were observed at lower rates with Phusion® Gypsum. Leachate composition (Ca, Mg, Na) analysis of the soil amended with Phusion® Gypsum revealed that 73% of the exchangeable Na was removed in three leaching events reducing exchangeable Na to 4.73 cmolc/kg. In the field experiment soil hydraulic conductivity increased, aggregate stability improved, water dispersion under limited energy decreased, and tensile strength improved as a result of adding Agricultural Gypsum and Phusion®, but not the unamended and S amended soils. Gypsum amendment rates will be tested under commercial agricultural growing conditions.

Keywords: sodic soils, reclamation of sodic soils, gypsum amendment
Financial support: Cooperative agreement between Dow AgroSciences LLC and University of Puerto Rico.

(6345 - 1779) Effects of impoundment of the Three Gorges Reservoir on the dynamics of salt-water and soil salinity in the Yangtze River Estuary

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As the largest hydropower project in China, the impact of the Three Gorges Project (TGP) on the ecological environment along the river has aroused world attention and has been studied from various aspects. After the TGP was built up, the Three-Gorge Reservoir (TGR) seasonably adjusted runoff will cause great changes of hydrological regime in the lower reaches of the Yangtze River, especially the estuarine areas where seawater intrusion is strong and salt-water environment is complicated. Soil salt-water dynamics in this region will be greatly influenced under the storage process in response to the construction of TGP. In order to investigate the influence of the Three Gorges Reservoir（TGR） on salt-water dynamics in the Yangtze River Estuary (YRE), a field experiment was has been carried out since the year 1998, to monitor salt-water dynamics, and impact of the project on soil salt-water movement was assessed analyzed. Results showed that the reservoir outflow from the TGR was affected by its water storage speed, and runoff runoff at Datong station in the estuary was significantly correlated with the reservoir outflow. Decrease of runoff in October during typical impoundment years was greater than that of non-impoundment years, which revealed certain influence of the TGR impoundment process. Significant positive correlation was found between runoff at Datong station and the river water level in the estuary, and influence of the river runoff on the river water level delayed around 20 days in time. Similar conclusion was found patterns laws among the runoff, the water level and the river water salinity in the estuary. The dynamics of river salinity and runoff achieved the best synchronization in 10 to 20 days. A statistical model was established for predicting water salinity of the Yangtze River by using the data of the runoff and the water level in the estuary. Significant positive correlation between salinity of the river water and groundwater was also observed, while influence extent of the river water salinity

Keywords: Three Gorges Reservoir; Soil salt-water dynamics; the Yangtze River Estuary; impoundment process; Soil salinity
Financial support: Ecological and Environmental monitoring project (JJ[2016]-018) funded by the Executive Office of the Three Gorges Project Construction Committee of the State Council of China; the National Natural Science Foundation of China (No. 41701253)

(8254 - 282) Establishment of Sunflower and Maize on wet soils in the salt-affected coastal region of Bangladesh

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Intensification of crop production in coastal zones needs to manage soil water and salinity, scarcity of fresh water, waterlogging and poorly structured soil. In the coastal zone of Bangladesh, early sowing in the dry season is proposed to avoid severe salinity and drought stress during grain filling, but the best method for crop establishment and soil management on wet soils is not clear. Zero tillage (ZT), strip planting (SP), bed planting (BP), single pass shallow tillage (SPST) and double pass by two-wheel tractor (DP) were tested using the Versatile Multi-Crops Planters (VMP) for sunflower and maize establishment in 2016-17 on wet soils (Gravimetric soil water content was about 35% during sunflower and 28% during maize establishment) in early dry season. In both experiments, rice straw was applied about 5 t/ha as mulch for sunflower and maize, respectively. The emergence was faster and higher in SP (3.7 m^{-2} and 5.3 m^{-2} for sunflower and maize) and ZT (3.4 m^{-2} and 5.2 m^{-2} for sunflower and maize) and lower in BP (3.3 m^{-2} and 4.9 m^{-2} for sunflower and maize) in both experiments. However, subsequent plant growth and development was better in BP than the other four tillage treatments. BP maintained the highest soil water content at 0-7 cm depth in both experiments (Soil water varied from 35% to 25% for sunflower and 28% to 23% for maize), whereas soil water was the lowest in ZT (Soil water varied from 35% to 20% for sunflower and 28% to 18% for maize) and SP (Soil water varied from 35% to 21% for sunflower and 28% to 19% for maize throughout crop growth. Soil salinity ($EC_{1:5}$) was minimum in BP (Varied from 0.74 dS/m to 0.97 dS/m for sunflower and 0.59 dS/m to 0.81 dS/m for maize) while it was maximum in ZT (varied from 0.79 dS/m to 1.04 dS/m for sunflower and 0.72 dS/m to 0.86 dS/m for maize) and SP (varied from 0.75 dS/m to 1.01 dS/m for sunflower and 0.63 dS/m to 0.77 dS/m for maize) at 0-7 cm depth. Solute potential of soil solutions was more negative in ZT and SP compared to BP in both experiments. Yield was significantly higher in BP in both sunflower (3.6 t/ha) and maize (7.7 t/ha) and followed by DP and SPST over the ZT and SP. The results suggest bed planting has potential to conserve soil water and reduce soil salinity and maintained higher solute potential, while producing the maximum yield, but further research is needed to draw conclusion.

Keywords: Tillage practices, salinity, and waterlogging
Financial support: Australian Centre for International Agricultural Research

(4965 - 1752) Evaluation of sustainable irrigation regimes of mulched drip irrigation for cotton in an oasis of southern Xinjiang, China

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Water shortage and soil salinization have become the key factors constraining sustainable agriculture development in southern Xinjiang, China. Mulched drip irrigation during the growing season and flood irrigation during the fallow period, i.e., winter and spring irrigations, have been widely applied in southern Xinjiang for cotton production. Salt transport process under mulched drip irrigation was simulated by the advection-dispersion equation (ADE) and the mobile-immobile (MIM) models using COMSOL. Simulation results were compared with field observations conducted at Aksu, southern Xinjiang. The results indicated that the behavior of salt under mulched drip irrigation was better quantified by the MIM model than by the ADE model, especially at the region near the emitter. Subsequently, the simulation was extended to 10 years to evaluate the influence of the local irrigation pattern (including 350 mm-mulched drip irrigation,

150 mm-winter flood irrigation, and 150 mm-spring flood irrigation) on flied salinity distribution. And then, the salt changing pattern induced by different flood irrigation schemes for 10 years were further simulated. Results of the analyses suggested that winter or spring flood irrigation was of great importance for salt leaching from entire arable layer, especially for the severe saline soil. Nevertheless, the winter and spring flood irrigation amount was too large in the local irrigation pattern, and the averaged soil salt content of the 0–50 cm layer approximately maintained stability when the total flood irrigation amount was 200 mm. The proper flood irrigation amount and time could be adjusted modestly based on soil salinity conditions and the availability of freshwater resources. For the moderate or slight saline soil, the flood irrigation could be replaced by the drip irrigation after sowing in some years to alleviate the water shortage during the spring sowing period.
Keywords: Mulched drip irrigation; Flood irrigation; Cotton; Mobile-immobile model
Financial support:

(8031 - 1997) Experimental and Modeling Assessment of Salinity Leaching Efficiency in Soils

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Salinity leaching is necessary to sustain agricultural production in irrigated croplands. Improving salinity leaching efficiency not only conserves water, but also reduces groundwater contamination. The current leaching fraction (LF) and leaching requirement (LR) calculations are based on steady-state and one-dimensional (1D) approaches. Thus, they may not be applicable to drip (2D), micro-spray (3D) and partial-rootzone drying irrigation systems. Water application time and rate may also affect salinity leach, even if the same amount of water is applied. The aims of this study were to use computer models (HYDRUS-1D and 2D) and to conduct laboratory experiments to assess salinity leaching fractions under 1-D (to mimic sprinkler irrigation) and 2-D (drip irrigation), and to evaluate the effect of water application time and rate on salinity leaching efficiency. For simulations, the soil hydraulic and root water uptake parameters for HYDRUS were optimized by minimizing the residuals between measured and simulated water content data. Water application used the actual irrigation scheme in an almond orchard (same for all the three soil types) in Kern County, CA without considering precipitation. Model simulations showed that the soil salinity at the lower boundary reached steady-state in 3 years under 1D simulation, and the leaching fractions calculated both from D_{dw}/D_{iw} and from EC_{iw}/EC_{dw} were very close (0.06, 0.1, 0.065, respectively) for the clay, loam and sandy soils. However, simulation with HYDRUS-2D under the same conditions resulted in very different LFs: they were 0.241, 0.164, and 0.157, respectively, based on D_{dw}/D_{iw}; and 0.4, 0.452, 0.294, respectively, based on EC_{iw}/EC_{dw}, for the clay, loam and sandy soils. Therefore, the actual leaching fractions were much higher under drip irrigation (2D) than sprinkler irrigation (1D) when the same amount of water was applied. The AW/PET (applied water/potential evapotranspiration) was 1.06 (LF = 0.06) for both 1D and 2D, which is close to the LFs from HYDRUS-1D simulations, but is substantially lower than the LFs from HYDRU-2D simulations. Experimentally, packed columns were used to assess leaching efficacy under different water application time and rates. We conclude that LRs under drip or micro-sprinkler irrigation require further evaluation, and proper irrigation management can improve salinity leaching efficiency.
Keywords: Salinity, Leaching fraction, modeling
Financial support:

(8252 - 225) Reclamation of Saline Soils by Freezing Saline Water Irrigation

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Soil salinization and fresh water scarcity are major constrains for the development of agriculture in arid and semi-arid regions of the world. Usually saline soil areas have a large quantity of saline groundwater. Based on the natural freezing desalination of saline water in winter, we invented a new method to reclaim saline soil by freezing saline water irrigation in winter. In the monsoon regions with cold winter, saline groundwater is used for irrigation in winter, which will be frozen to ice. The saline ice melts gradually in spring and produced more than 50% slightly saline water and fresh water from 15g/L source water. Since meltwater at initial thawing stages contains more salts, infiltration of late-melted freshwater would wash out the deposited salts and create a desalinized soil surface layer. The results of soil columns experiments showed that in the top soil layers, water content was higher under salt-free ice treatment than under saline ice treatments. In the deeper soil layers, however, the saline ice treatments showed higher water content than the salt-free ice treatment. While infiltration of meltwater reduced the salt content of the surface layer of all the treatments, the desalting depths of the saline ice treatments were greater than that of the salt-free ice treatment. The field experiments indicated that after irrigation with the volume of 135-180 mm saline water (11-15g/L) in early to mid January (the air temperature <-5℃), the water frozen well on soil surface. After the infiltration of melted saline ice water in late February, the soil surface in 20cm depth desalinized greatly in which the soil salt content was less than 0.4%, while that of no irrigated land was more than 1.0%. To prevent the evaporation and salt accumulation on soil surface in spring season, soil salinity was further reduced by plastic film mulching. At sowing season in late April, the surface soil salt content was about 0.3%. The emergency rate of cotton was higher than 90%, while there was almost no emergency in control. Following rainfall in summer kept low soil surface salinity and crop growth. Based on above results, we designed an integrate management of saline soil by freezing saline water irrigation in winter and some models were also constructed. The application of this method had achieved good yield in cotton, sunflower, sorghum, sugar beet etc. in strongly coastal saline land.
Keywords: Saline soil, freezing saline water irrigation, reclamation
Financial support: STS program of Chinese Academy of Sciences (KFZD-SW-112)

(7259 - 2390) Reclamation of saline-sodic soil by growing plants in semiarid of Brazil

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Salinity is an environmental issue around the World. In Brazil, it happens on Northeast Region under semiarid climate. Chemical reclamation of these soils is an expensive practice and not always applied. Salt removal by plants is a feasible alternative as useful and low cost technology. Plant species as *Atriplex nummularia* have recognized efficiency in the recovery of salt affected soils, however it is not known in Brazil and the use of more accepted species may contribute to success of revegetation. This study aimed evaluates: *Mimosa caesalpiniifolia* Benth (Sabiá), *Leucaena leucocephala* (Lam.) de Wit (Leucena), *Azadirachta indica* A. Juss (Nim) and *Atriplex nummularia* L. (Atriplex) on revegetation of saline-sodic soil, isolated or in consortium. Plant growth was monitored in field for 18 months, as well as soil attributes. The experiment was performed in Serra Talhada (Pernambuco, Brazil) in four completely randomized blocks. The plants were grown isolated or in consortium, beyond a control

treatment: 1) Sabiá, 2) Leucena, 3) Nim, 4) Atriplex, 5) Sabiá/Atriplex, 6) Leucena/Atriplex, 7) Nim/Atriplex, 8) Control (without plant). Plant species responded differently to growth and soil recovery. Plant cultivation in all treatments promoted improvements on soil chemical quality. Soil salinity (EC) and exchangeable sodium percentage (ESP) were significantly reduced after 18 months of plant in the soil. Plant cultivation promoted significant reductions in EC values, with the exception of Sabiá growth alone. Atriplex treatment stands out from the other treatments used in a proportion of reduction twice higher than the consortiums Atriplex/Leucena, Atriplex/Nim and Atriplex/Sabiá, and it was three times more effective than the treatments Leucena and Nim, and four times in relation to Sabiá. Also the largest decrease in ESP was obtained at Atriplex treatment (28.21 to 9.69%), changing soil classification from sodic to not sodic. ESP was also reduced in treatments in which there was a consortium of species with Atriplex, or only with the other species, reinforcing the positive effect of revegetation management on soil quality. So *Atriplex nummularia, Azadirachta indica, Leucaena leucocephala and Mimosa caesalpiniifolia* can be recommended to phytoremediation of salt affected soils isolated or in consortium.

Keywords: Salt affected soils Phytoextraction Degraded soil
Financial support: FACEPE, CNPq, CAPES

(3327 - 415) Rehabilitation of saline-sodic soils using a rubble barrier and adding biochar or compost

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Soil degradation resulting from salinity and sodicity is a major environmental concern with severe negative effects on soil fertility and agricultural productivity in semiarid and costal regions around the world. The concentrations of soluble salts and sodium limit growth of most plants due to osmotic stress and toxicity. Additionally, the excess of exchangeable sodium reduces aeration and hydraulic conductivity. These conditions hinder the establishment of a plant cover that protects the soil from wind erosion, affecting also the air quality of nearby urban areas. An example of saline-sodic soils occurs in the former lake of Texcoco (FLT) in the basin of Mexico. Most of the soils in the FLT are too salty to be colonized by native or exotic halophytes and the exposed sediments are prone to wind erosion during the dry season. In the early seventies, strategies were implemented to reduce the emission of particulate matter into the atmosphere. However, the accomplishment of these activities is compromised due to the capillary rise of highly saline water that prevents the development of a plant cover. In this work we evaluate if the implementation of a barrier created with rubble and the addition of compost or biochar mitigate the salinization of the topsoil and allow the development of the native grass Distichlis spicata. For this, we evaluated the survival and cover of the grass, the pH, the electrical conductivity and the soil moisture in experimental plots with or without barrier in the FLT. Our preliminary analyzes indicate that the barrier decreases the salt content and humidity, but increases the pH, survival and cover of the grass. In addition, plant species with a lower salinity tolerance than D. spicata, such as Suaeda torreyana and Kochia scoparia, were mainly established in the experimental plots with barrier. In the case of the organic amendments, one year after their application, there are no significant differences between treatments.

Keywords: revegetation, saltgrass, organic amendments, pyrochar, hydrochar
Financial support:

(2506 - 3207) Response of *Solanum lycopersicum* L. cv. Chonto to halotolerant plant growth promoting bacteria isolated from Colombian saline springs

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The aim of this work was to evaluate the effect of halotolerant bacteria on the growth of tomato (*Solanum lycopersicum* L. cv. Chonto) under different saline conditions in photoautotrophic culture. *Lysobacter* OC7 (two strains), *Caenespirillum bisanense, Vibrio natriegens* and *Labrenzia aggregata* were isolated from different saline springs in Colombia. *Pseudomonas fluorescens* ATCC® BAA-477™ and *Azospirillum halopraeferens* ATCC® 43709™ were used as controls. The pure bacterial cultures were grown in Trypticas Soy Broth with 0.5%NaCl during 24h. The inocula concentration of each strain was 1 × 108 colony forming units mL–1 ($CFUml^{-1}$). The bacterial density was evaluated in seeds and roots of tomato sown on saline soil-sand mix (0%, 0.2%, 0.6% and 1% NaCl plus Murashige and Skoog media diluted 1:1). Sample were taken 1, 7 and 14 days after sowing-das. The chlorophyll concentration-SPAD, root length (radical elongation promotion index-PREP) and dry shoot weight-DSW were tested 14 das. Lysobacter OC7 populations were stable up to 14 days in the roots and the substrates amended with 0.6% of NaCl (9 $LogCFUg^{-1}$Root or substrate). These bacteria were effective to promote the growth of tomato under salinity up to 1% NaCl 7das. Lysobacter OC7 and C. bisanense showed the best effects on DSW, with average values of 4.86 g, 4.77 g and 4.53 g, respectively. The inoculated plants showed significantly higher values than the plants without bacterial inocula. In the PREP index, an effect of 35-40% was obtained in all the halotolerant strains highlighting a notorious effect in the two highest salinities evaluated over the inoculated controls Azospirillum halopraeferens and Pseudomonas fluorescens. The bacteria isolated from saline springs of Colombian Andes are potential inoculants and future tools for the amelioration of crop salinity stress.

Keywords: Halotolerant bacteria, Plant growth promoting bacteria, Tomato, saline springs
Financial support: Pontificia Universidad Javeriana

(8358 - 382) Saline water impact in hydrogel conditioned soil hydric retention

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In the face of the global water scarcity scenario, there is a need to maintain agricultural crops with the lowest water use possible. In this way, the hydrogels are an option due to their potential as a soil conditioner, increasing the water retention capacity and reducing the need for irrigation. Hydrogels consist of three-dimensional polymer chains that can retain significant amounts of water in their own structure. However, this retention can be compromised by the level of salts present in soils and irrigation water. Salinity, which is a common problem in semi-arid regions, can be a limiting factor for the use of hydrogels. In this study the objective was to evaluate the water retention and the quality of the leachate from soil with and without hydrogel and that was irrigated with saline water. The experiment was installed in a greenhouse of the Department of Soil Sciences of the Federal University of Ceará (Fortaleza, Ceará, Brazil). The soil used, sandy texture, was from the municipality of Pacajus (Ceará, Brazil). The experimental design was completely randomized with 4 replicates and in a 2x4 factorial scheme. The first treatment factor was related to hydrogel application (0 and 4.0 grams), and the second treatment factor was related to saline solutions with increasing values of electrical conductivity (0.5, 1.5, 3.0 e 4.5 dSm-1). The experimental units consisted of PVC columns 10 cm in diameter and 50 cm in length with the lower ends sealed with a lid and which had a hole for leachate collection. Corn (Zea mays) plants were sown in the columns, one plant per experimental unit being irrigated with the saline solutions that presented the electrical conductivities proposed in each

treatment. After irrigation, the volume of the leachate from each column was collected and measured. The following variables were determined: sodium (Na) and potassium (K) and Electric Conductivity (EC). There was greater drainage in the soil that did not contain hydrogel, but the one containing the polymer retained a significant amount of water, even when salinity increased in irrigation water. The soil with hydrogel also presented higher content of K and higher value of EC, but lower concentration of Na. In soil, the effects of salinity compromising water absorption by the hydrogel were not pronounced and the polymer assisted in the greater retention of water in the soil. However, the saline solution associated to the hydrogel promoted greater salinization of the soil.

Keywords: Hydrogels, Semi-arid regions, Water retention.
Financial support: Universidade Federal do Ceará, CAPES, Pibic CNPq, Pró-Integração nº 55/2013

(4601 - 1769) Scenario Simulation of Field Soil Water and Salt Balances Using SAHYSMOD for Salinity Management in a Coastal Salt-affected Agroecosystem

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Understanding water and salt balances in the salt-affected farming area is getting increasingly important because of the growing public interest in controlling salinization. An integrated spatial-agro-hydro-salinity model (SahysMod) was used to model field soil and groundwater salinity dynamics in a coastal rainfed farmland, and the calibration, error analysis, and sensitivity analysis were performed for SahysModmodel. Also, the potential influence of various field management practices on the soil water and salt balances was simulated using the calibrated model. Results indicated that a leaching efficiency ranging between 0.4 and 0.7 in the rootzone, hydraulic conductivity of 0.2 m/day and leaching efficiency of 1.2 in the aquifer produced model results best matching the measured data. Leaching efficiency of rootzone, hydraulic conductivity and leaching efficiency of aquifer were the most sensitive parameters for soil salinity, groundwater table and groundwater salinity, respectively. Rootzone soil salinity (ECe) generally decreased at an annual average rate of 2.2 dS/m under the existing conditions, and the decreasing rate of rootzone salinity ranged from 1.9 dS/m to 2.7 dS/m per year under the other scenarios. Practices including subsurface drainage system and plastic film mulching were suggested for managing soil salinity and stabilizing the groundwater table. Irrigation with brackish water in the dry season was not recommended since it increased soil and groundwater salinity in comparison with the existing conditions. It was concluded from the simulation results that subsurface drainage was the most high-efficient approach for salt leaching, whereas plastic film mulching was more economic and effective to control soil and groundwater salinization.

Keywords: scenario simulation; water and salt balances; SAHYSMOD; salt-affected agroecosystem
Financial support: the Innovation project of Institute of Soil Science, CAS (ISSASIP1633), the National Key Research and Development Program of China (2016YFC0501300, 2016YFD0200303)

(6899 - 2589) Use of EM-38 Soil Surveys in Forage Fields at a Saline Drainage Water Reuse Site to Calibrate a Hydro-salinity Model for Decision Support

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Soil salinity is a major factor affecting irrigated agriculture in the western San Joaquin Valley of California. Electromagnetic (EM)-38 soil salinity surveys were conducted at the San Joaquin River Improvement Project (SJRIP) facility managed by Panoche Drainage District (Los Banos, California, U.S.A.) which receives saline subsurface drainage water from 40,000 hectares of irrigated land. In the re-use facility, the drainage water is used to irrigate forages ('Jose' tall wheatgrass (*Thinopyrum ponticum* var. 'Jose') and alfalfa (*Medicago sativa*)) to reduce drainage discharge and salt loading into the San Joaquin River. In 2012, 2922 ha-m (29.2 M m^3) of saline drainage water was applied to 2080 ha of tall wheatgrass, alfalfa, and a small acreage of pistachios. The facility now has 2428 ha of land with ~30% of the reuse fields having subsurface drainage systems. In this project, salinity surveys were conducted in fall and spring of 2016 and 2017 using a Geonics EM38-MK2 in two alfalfa (ALF) and two tall wheatgrass (TWG) fields in the SJRIP to monitor soil salinity in response to the salinity (EC_w) of applied drainage water. The chosen fields were 28-36 hectares in size and the TWG fields were irrigated with higher salinity water as compared to the ALF fields. To convert the apparent electrical conductivity (EC_a) readings from the EM-38 to the established soil salinity measure (EC_e- electrical conductivity of the saturation paste extract), soil samples were taken at 12 locations in each field (0-120 cm depth, 30-cm increments), as directed by the ESAP software, and analyzed for pH, EC_e, gravimetric water content and saturation percentage. During the two years in which soil surveys were conducted, average EC_e obtained from the ground-truthing locations was 12.5 to 19.3 dS/m for tall wheatgrass (TWG) and 8.9 to 14.4 dS/m for alfalfa (ALF) fields. GIS maps were developed to depict the spatial variability of salts in the fields. Fields 13-1 (TWG) and 13-2 (ALF) with subsurface drainage systems had improved leaching, as most of the salt accumulation was found at the lower soil profile (120 – 150 cm). In contrast, in the undrained fields, 10-6 (TWG) and 13-6 (ALF), salt accumulation was greatest from 30-60 and 60-90 cm. Data from these EM-38 surveys were used to calibrate a computer model (CSUID) developed as a potential decision support tool to adjust salinity levels in applied irrigation water with the soil leaching requirements for sustainable forage production.

Keywords: saline irrigation, soil salinity mapping, EM-38, forage, reuse
Financial support: California Department of Water Resources, Prop 204 Agricultural Drainage program

D3.6.4 - Impact of land use change on soil and the environment in dry regions

(2932 - 1336) Soil salinization in Patagonian meadows with different grassland condition

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Patagonian meadows (locally named "mallines") are wetlands that develop in the lower parts of the landscape, were runoff water accumulates, and organic and humid soils appear, contrasting with the surrounding steppe. An internal soil moisture gradient generates different types of vegetation, dominated by *Juncus sp* in the lower/wetter areas and by *Festuca sp*. in higher/mesic ones. As meadows have a high primary productivity of forage value, they were heavily grazed mainly by sheep during the last century. Overgrazing causes a reduction of plant cover and an alteration of water dynamics with consequences on salt movement. We conducted this research to evaluate the effect of historical grazing on soil chemical properties of meadows of north Patagonia. We selected three meadows with similar characteristics within the "Sierras y Mesetas" area, where we identified zones with different vegetation conditions (good-G and regular-R) due to effects of historical grazing, in two types of vegetation (wet-W and mesic-M). Mean annual precipitation is 300 mm, concentrated in winter. As we expected that water table variations could influence salt dynamics, we took soil samples at 5 depth intervals (0-5, 5-15; 15-30, 30-60 and 60-90 cm) on three different dates (September and December 2016 and February 2017).

In the laboratory, soil pH and electrical conductivity-EC (soil suspension, 1:2.5) were determined. To analyze data, we performed an ANOVA with a factorial design for each vegetation type and depth interval, with vegetation condition and sample date as factors. No significant differences were found among sample dates in both pH and EC. Comparing R with G areas, W-meadows significantly increase soil pH up to 90 cm depth (on average 7.5±0.7 vs 8.5±0.5), and a significantly decrease EC at 0-5 cm and 30-60cm (0.7±0.1 vs 0.4±0.1 and 0.6±0.1 vs 0.35±0.3, respectively); in M-meadows, pH showed a lightly significant increase only at intermediate depths (5-60 cm, 8.8±0.2 vs 8.4±0.1 on average) and no differences in EC, although variability among data was very high. These data show a more significant effect of the vegetation condition on soil salinity in wet meadows than on mesic ones, where a process of sodification seems to be developing. Contradicting the expected, no differences in responses during the growing season were observed. Wet meadows, where water table fluctuations are higher, seem to be sensible areas to monitor degradation processes due to overgrazing.

Keywords: wet meadows, water dynamic, degradation, salinization
Financial support: INTA PNAgua 1133023

(1863 - 1394) The modern state of irrigated sodic soils in the south of Russia (Svetloyarsk irrigation system, Volgograd oblast)

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Agricultural lands are the main source of products for humans and strategically important economic resource. The national food security and related sectors of economy highly depend on their quality and condition. Due to social and economic situation, the significant reduction of irrigated lands occurred and many monitoring programs ceased in the late 1990s in the south of Russia. At present, there is the growing concern about the modern state of soils under uncontrolled anthropogenic pressure which favors the development of new monitoring programs and concepts based on the modern achievements and technologies. One of the promising technique for monitoring land resources is the remote sensing. The aim of our research is to study the current state of irrigated soils and their properties such as salinity, humus content and carbonates using ground truth and remote sensing data with Svetloyarsk irrigation system (Volgograd oblast) as a case study. The field studies were conducted in June-July of 2015 and 2016. The samples were collected from three transects and the random-regular grid. The square of the studied area is 130 ha. The crops are represented by cereals (wheat, barley) and perennial grasses (alfalfa). The high resolution space-borne Pleiades imagery (19.05.2015) was used. The maps of soil properties were compiled using RStudio. After 50-year irrigation, the following changes have been observed: 1) the area of irrigated lands as well as the specific water consumption for irrigation have decreased which resulted in the fall of water table below 3-5 meters; 2) the structure of agricultural use has changed, mainly due to the increase in the relative areas of the crops of winter cereals; 3) the soil cover has changed drastically due to the complete transformation of initial soil morphological and chemical properties: 4) the readily soluble salts have been washed from the upper to the second meter of soil profile; 5) the process of irrigation-induced accumulation of carbonates occurs at the top soil layer, which can be easily observed from the space as a patchy pattern; 6) the soils of the investigated area are characterized by a low content of humus. Thus, our research made it possible to obtain information on the current state of the soil cover of irrigated lands and propose the recommendations for the sustainable management of soils.

Keywords: irrigated soils, sodic soils, digital soil mapping, remote sensing data
Financial support: This study was supported by the Ministry of Finance of the Russian Federation

C4.1 - Soils and the Environment

C4.1.1 - Soil ecosystem services

(7174 - 1031) Development of a multi-functional land evaluation for dedicated bioenergy crops.

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The Queensland state government in Australia is seeking to help facilitate a sustainable bioenergy industry. A component of this is to identify areas across the state that could sustainably support the cultivation of bioenergy crops. The state however has almost fully utilised cropping land. Thus the potential of bioenergy crops in marginal areas needs to be assessed. In order to achieve this we have developed a Multi-functional land evaluation framework MFLE. This has been adapted from the framework classifying and quantifying the natural capital and ecosystem services of soil. A suite of functions critical to supporting a dedicated bioenergy crop enterprise have been modelled and mapped. The approach then aggregates these functions. The aggregations can be grouped in 4 broad themes, environmental services, production capacity, physical and infrastructure limitations and cultural constraints. Environmental services and production constraints were modelled with Agricultural Production Systems Simulator (APSIM). Soil parameter files were derived from Australia's contribution to the Global Soil Map initiative, the Soil and Landscape Grid of Australia (SLGA). A subset of locations at which to run the models were selected using a conditioned Latin Hypercube (cLHS). A spatial layer of each environmental or production function was then calculated using random forests. The spatial layers were then aggregated into their respective production or environmental scores using fuzzy spatial overlays. Physical, infrastructure and cultural constraints were characterised by a series of geospatial calculations. Example physical limitations account for access to markets and infrastructure. Cultural constraints are currently limited to displacement of food resources. A final overall suitability metric was then calculated through an overlay of all four themes. Final products will be made available as open data through publically consumable web services.

Keywords: Land evaluation, ecosystem services, bioenergy, Global Soil Map
Financial support: Queensland government bio-futures agenda

(9946 - 1980) From process understanding via soil functions to sustainable soil management – a systemic approach

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Fertile soils are central resources for the production of biomass and the provision of food, energy, and raw materials for different branches of industry. A growing world population and latest climate targets lead to an increasing demand for both, food and bio-energy, which requires preserving and improving the long-term productivity of soils as a bio-economic resource. At the same time, other soil functions and ecosystem services need to be maintained: filter for clean water, carbon sequestration, provision and recycling of nutrients, and habitat for biological activity. All these soil functions result from the interaction of a multitude of physical, chemical and biological processes that are not yet sufficiently understood. In addition, we lack understanding about the interplay between the socio-economic system and the soil system and how soil functions benefit human wellbeing. Hence, a solid and integrated assessment of soil quality requires the consideration of the ensemble of soil functions and its relation to soil management to finally be able to develop site-specific options for sustainable soil management and governance. We present an integrated modeling approach that investigates the influence of soil management on the ensemble of soil functions. It is based on the mechanistic relationships between soil functional attributes, each explained by a network of interacting processes as derived from scientific evidence. Soil functional attributes are applied as indicators for assessing the effect of distinct soil management options on soil functions. The connection to the socio-economic system is established using the Driver-Pressure-Impacts-States-Response (DPSIR) framework where our improved understanding about soil ecosystem processes is linked to ecosystem services and resource efficiency via the soil functional indicators.

Keywords: soil functions, ecosystem services, modeling, soil functional indicators
Financial support: BonaRes (Module B): BonaRes Centre for Soil Research, grant 031A608

(9613 - 455) Impact of tropical land-use intensification on soil ecosystem services

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Tropical agriculture has experienced a strong intensification in the last decades following the global demand for agricultural commodities. While provisioning ecosystem services (ES) provided by tropical ecosystems have raised rapidly, regulating and cultural ES are strongly affected. Oil palm cultivation is one of the land-use types where tradeoffs between ES are most prominent. On the one hand oil palm is the most efficient crop to produce oil per surface area and its net primary production (NPP) of surpasses by 50% the one of rainforest. On the other hand, soil C inputs are reduced by up to 90% in oil palm plantations as compared to rainforests because of the high proportion of harvested biomass and the C sequestered in wood biomass that is not available for decomposer food chain. Here, we address the impacts of such an imbalanced share of NPP in oil palm plantations between short-term human benefits and long-term ecosystem needs on soil functions and services. We synthetized data from two interdisciplinary projects: "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems" and "Oil Palm Adaptive Landscapes". We present the resistance or sensitivity to land-use change of indicators of regulating or supporting ES such as soil and ecosystem C storage, water regulation, nutrient availability, organic matter decomposition and soil microbial activity. We aim at demonstrating that the resistance of soil processes to soil degradation is subject to thresholds. Soil processes driven by microbes can be maintained at the expense of the soil resources accumulated in the past, leading to a depletion of stocks over time and a potential collapse of soil functions in tropical agroecosystems.

Keywords: Tropical ecosystems soil degradation agriculture sustainability tradeoffs land-use change
Financial support: German Research Foundation (sfb990), Swiss National Science Foundation (r4d)

(2553 - 2347) Quantification of soil services at the plot scale using modeling approach: A case study of a drained agricultural field affected by land-use change

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Soil agro-ecosystem services can be conceptualized as the "conditions and processes associated with soil that confer benefits to the society"; including the farmer who acts as the manager of agroecosystem. There is a need to develop methods and quantitative approaches based on measurable indicators to evaluate soil services. This study addresses

evaluation of soil services, combining a detailed field experiment with a modeling approach. Soil services identified directly in our study are related to the capacity of soil to (i) supply water required for plant growth and recharge blue water, (ii) release nutrient to plants, and (iii) maintain water quality, such as the ability of soil to filter organic and inorganic contaminants. To evaluate theses services, indicators reflecting changes over time were identified, such as available water capacity, soil-water balance for estimating groundwater and surface recharge, nitrogen retained in the top soil, pesticide dissipation in the top soil. The two-dimensional water flow and solute transport model Hydrus_2D is used to calculate indicators involved in the delivery of soil services. An experimental area of about 2 hectares drained agricultural soil is equipped at Saclay plateau (Essonne, France) offering prime opportunities to measure and monitor variables associated with soil and biotic interaction processes, that lead to the delivery of soil services from agro-ecosystems, and their response to land-use and management changes, in the context of strong urbanization pressures. Direct measurements is used to test Hydrus_2D. The field experiment is carried out in a tile drained silt loam Albeluvisol with a shallow water table trapped above an impermeable burrstone clay subsurface layer. Taking the advantage of working on pipe drained plots, a water sampling system is installed at the drain outlet collecting flow-proportional subsamples of the drainage water before it leaves the experimental area. Drain discharge rates, pesticides and nitrates concentrations in the drainage water samples are monitored in the leaching winter period. Simultaneously, measurements (e.g. soil water content, soil mineral content) are held in the soil profile in order to quantify water and transport solute processes in the soil. Finally, the model is used to simulate scenarios to assess the consequences of new managements practices of land-use changes (e.g. apply of organic waste compost, catch crops).

Keywords: Soil agro-ecosystem services, drained agricultural soil, field experiment, modeling approach

Financial support: Laboratoire d'Excellence BASC

(7145 - 314) Soil Security Assessment contributing to ecosystem service.

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Soil Security is a holistic soil assessment approach that think of soil as a multi-dimensional medium contributing to ecosystem services. Rather than traditional single dimensional assessment approaches such as land capability mapping that largely considers only soil and landscape biophysical attributes, the Soil Security concept considers social aspects, education, policy, legislation, current land use, condition and the soils natural and economic value to society. We use Tasmania as an example as its government is managing the ecosystem services where this is increased agricultural expansion through new irrigation schemes and multiple-use State managed production forests co-exists beside pristine World Heritage conservation land, a major drawcard of the economically important tourism industry. The application of Digital Soil Mapping and Assessment capacities in Tasmania to stimulate agricultural production and better target appropriate soil resource use has formed the foundational system that can enable the first efforts in quantifying and mapping Soil Security, in particular the five Soil Security dimensions (Capability, Condition, Capital, Codification and Connectivity). This forms a preliminary mapping product that demonstrates the feasibility of mapping the Soil Security concept. To provide a measure of overall soil security, it was necessary to separately assess the State's three major soil uses; Agriculture, Conservation and Forestry. These products will provide an indication of where different activities are sustainable or at risk, where more soil data is needed, and provide a tool to better plan for a State requiring optimal food and fibre production, without depleting its natural soil resources and impacting on the fragile ecosystems supporting environmental benefits and the tourism industry. From an international policy perspective, using the Sustainable Development Gaols (SDG's) this could be seen as an exemplar of the emerging tool for quantification of spatial soil security to effectively protect our soil resource in terms of food (SDG 2.4, 3.9) and water security (SDG 6.4, 6.6), biodiversity maintenance and safeguarding fragile ecosystems (SDG 15.3, 15.9). The following paper demonstrates why and how we might map Soil Security, describing a preliminary approach to mapping the separate dimensions; this approach could be adapted and applied elsewhere as an evaluation tool to identify soil threats relevant to current land use

Keywords: soil conditon, capability, natural capital, governance, soil health

Financial support:

(9537 - 2149) Using the DPSIR model in the Colombian policy for sustainable soil management: an ecosystem service approach

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Since the 1970s there has been interest from state institutions, academia and private sector for the protection of Colombian soils, which has been shown through various soil degradation maps and regulations for soil conservation. However, the country's soils degradation has increased significantly, restricting soil use and reducing the ecosystem services it provides. Though it is recognized that loss of soil quality has environmental, social and economic consequences, research has had little impact on environmental public policies, and in turn this has put constraints on the implementation of these policies. We argue that scientific knowledge should be a key input for the formulation and implementation of environmental policies in Colombia. One possibility is using the soil ecosystem service approach, which allows integration between science and policies, however this is complex and currently poorly understood. In recognizing the need for soil protection, in 2016, the Colombian government launched the national policy for the sustainable management of soils (PSMS). This policy aims to promote sustainable management of soil in a systemic context, in which land planning, risk management and the conservation of biodiversity, water and air converge to contribute to sustainable development and improve the livelihoods. The PSMS proposes to comprehensively address the complexity of soil quality, considering not only the soil origin and evolution, but also the need to improve the knowledge of soil ecosystem services. The PSMS has 6 strategies: i) institutional strengthening and harmonization of regulations and policies; ii) education, training and awareness; iii) strengthening of environmental and sectoral planning instruments; iv) soil quality monitoring; v) research, innovation and technology transfer; vi) preservation, restoration, and sustainable use of soil. Under this policy one expected outcome is generating key information about the limits of soil use. The PSMS uses the DPSIR indicator model (driving forces – pressure – state - impact - response) to understand specific relationships among the state of soil quality; the causes of soil degradation and contamination; and the actors that cause adverse impacts and those affected. During this process the actions that should be taken to promote soil conservation can be identified. This paper showcases the advantages and requirements for using the DPSIR model for the PSMS under an ecosystem service approach.

Keywords: ecosystem service assessment, soil quality, soil degradation, developing country

Financial support: Universidad Nacional de Colombia

C4.1.2 - Climate change and adaptation of soil functions

(6562 - 2109) A Decade of Nitrous Oxide Flux Measurements with Annual and Perennial Crop Rotations on the Canadian Prairies

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The magnitude and timing of nitrous oxide (N_2O) emissions from cropping systems depend on soil and meteorological conditions, as well as cropping and management decisions. We report here N_2O emissions in two cropping systems in southern Manitoba, Canada, for the years 2006-2016. The study site soil is a poorly drained clay, high in soil organic matter (3.2 g organic C kg^{-1}). A continuous annual cropping system was compared to a cropping system that included a 4-year perennial phase. N_2O emissions and NEP were determined using the flux-gradient approach with N_2O and CO_2 gradients measured with a tunable-diode laser analyser and momentum similarity theory and 3-D sonic anemometer-thermometer measurements to estimate transfer coefficients. Cumulative N_2O emissions among four adjacent 4-ha fields over the 10 years varied from 0.3 to 28 kg N_2O-N ha^{-1} y^{-1}, depending on annual crop (corn, faba, spring wheat, barley, rapeseed, soybean) and environmental conditions. Inclusion of the 4-year perennial alfalfa/grass phase lowered the range in emissions being 0.2 to 2 kg N_2O-N ha^{-1} y^{-1}. Emissions with the annual crops mostly occurred (>70%) in spring following planting and fertilizer N addition, whereas, emissions were equally distributed between soil thaw period in April, spring, and the remainder of year. Meteorological and associated soil conditions, management (agronomic practices), NEP and partitioned CO_2 exchanges (GPP, respiration) and harvest removals on thaw, and spring N_2O emissions were assessed using univariate and multivariate statistical approaches. Soil nitrate concentrations mostly influenced N_2O fluxes at thaw. Consistent occurrence of late spring rains induced fluxes from applied fertilizer N. In conclusion, management practices such as N fixing crops (alfalfa/grass, faba, soybean) reduced emissions while nitrate accumulation of fertilizer applied N and rainfall increased emissions from non-N fixing crops.

Keywords: annual, cropping, nitrous oxide, perennial, long-term
Financial support: Natural Sciences and Engineering Research Council of Canada, Canada's Agricultural Greenhouse Gas Program

(4910 - 1878) How does zero valent metals and metal-sulfate materials affect N2O emission and abundance of denitrifying bacteria gene (narG, nirK, nirS, norB, and nosZ) in arable soil?

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Denitrification is major production process to emit nitrous oxide(N2O) from arable soil. This process is a series of enzymatic reduction reactions from nitrate(NO3) to di-nitrogen gas(N2) and it can be proceeded entirely associated with microorganisms. The enzymes of each steps in dentrification required a diversity of metals cofactor such as Copper(Cu), Iron(Fe), Manganese(Mn), Molybdenum(Mo), Zinc(Zn). In addition, these metal functions electron donor to soil system with these applied to soil. However, the underlyin g reaction that cause each steps of denitrification promotion or suppression in variety of metal-amended soils are poorly understood. Therefore, we set up microcosms experiments using wet soil(70% for water filled pore space) to process mainly reaction of denitrification. Zero valent metal(Cu, Fe, Mn, Mo, Zn) and metal-sulfate(CuSO4, FeSO4, MnSO4, ZnSO4) were selected and mixed with the pretreated wet soil at the 0.01% (ww-1). Five soil microcosms were incubated for two days to quantify N2O and N2O+N2 fluxes using acetylene based methods(3, 6, 12, 24, 48h) and to investigate the impact of the metals on N2O emission and abundance of denitrifying bacteria (narG, nirK, nirS, norB, and nosZ). Ammonium ion(NH4+) and Nitrate ion(NO3-) contents were determined spectrophotometrical analysis to determine basically gross nitrification and NO3- consumption rates, To investigate each denitrifying bacteria analyses nucleic acids (DNA) extracted from frozen soil samples taken at each microcosms(3, 6, 12, 24, 48h) using quantitative polymerase chain reaction(qPCR). Ammonium contents did not change in all metals materials but NO3- contents dramatically decreased with applicating metals materials. Nitrous oxide emission significantly decreased by 30% with CuSO4 addition. In contrast, N2O emission significantly increased with FeSO4 addition. Other metal materials were no change amount of N2O emission compared to control. Then, we confirmed that change of denitrifier of each steps, CuSO4 makes nos Z(nitrous oxide reductase) abundance was greater than control because of using Cu as its cofactor. In FeSO4 treatment, abundance of all denitrifying bacteria gene(narG, nirK, nirS, and norB) improved except for nos Z since Fe was generally known as cofactor for NO3-, NO2-, NO reductase. These results highlight that nitrogen transformation especially denitrification was influenced by abundance of dinitrification reductase induced by application different metals.

Keywords: Denitrification, Denitrifier, Nitrous oxide(N_2O), Metal ions, Copper(Cu)
Financial support: This study was carried out with the support of "National Research Foundation of Korea (Project No. 2016R1C1B1013152)", Ministry of Science, ICT and Future Planning, Republic of Korea.

(3352 - 1626) Impact of climate on the mighty manganese soils of Graskop

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This study characterizes how climate change may alter the physical and chemical properties and the reaction kinetics of the extraordinary manganese soils found in Graskop, South Africa. Manganese-oxides govern many geochemical reactions due to their abundance and high reactivity. Despite their importance in cycling redox sensitive compounds in natural systems, much remains unknown about the reactivity of manganese-oxides formed under environmental conditions and how this may be altered by changes in local climates. In order to quantify how these manganese-oxides react under different conditions, soils were collected from Graskop, South Africa. Three soil profiles were excavated with a range of manganese concentrations. Each profile was further separated based on horizons, with some of the profiles containing over 20% manganese. Manganese nodules of various sizes are ubiquitous in these soils. The soil in each horizon was analyzed to determine the cation exchange capacity (CEC), point of zero charge (PZC), and pH. X-ray powder diffraction (XRD) was used to characterize the mineralogy of the crystalline material found in the clay fraction. Finally, a series of batch reactions were used to determine the capacity of these soils and nodules to oxidize arsenite into arsenate with simulated changes in climate. The conditions of the reaction were varied in order to elucidate how differing environments, such pH and temperature, will influence the oxidation reaction. Aliquots collected from these experiments were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Solid samples were analyzed at the Stanford Synchrotron Radiation Lightsource on beamline 4-3 to determine the changes in manganese oxidation state after reacting with arsenite under varying conditions. This study provides key insights to more fully understand the role of manganese-oxides in controlling redox sensitive reactions in the present and future environment.

Keywords: Manganese-oxides, Arsenic, Temperature, Nodules, Kinetics
Financial support: National Science Foundation Graduate Research Fellowship Program, Delaware Environmental Institute

(5190 - 809) Introduction of Impact Assessment and Adaptation with Crops on Climate Changes in Korea

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Since KMA (Korean Meteorology Administration) had announced climate change scenario based on RCP pathway in Korea, there were

many research activities to assess the impacts on agriculture including soil and crops, and to cope with their adaptation. In the basis of RCP8.5 climate scenario, Korean peninsula will be increased up to 6℃ with temperature and 20% with precipitation in 2100. We would introduce many research results about impact assessment of crop production, soil status changes in the future and development of adaptation techniques. At first, estimation of rice production based RCP8.5 scenarios have been simulated with parameters of present varieties and cultivation methods. Simulated rice production comparing with current production would be decreased 13.6% in 2040's, 22.2% 2060's, and 40.1% in 2090's. Potential production of Barley would be projected to increase gradually to the future, and safety region to winter cultivation extended to the north area. Potential production of soybean also estimated to increase up to 40% in 2060's comparing with average production in 2000's, while corn decrease up to 26% in 2090's. Even though the results of simulated soybean production would be estimated to increase their production in the future, there are many risk to secure their whole production. The assessment on risk of high temperature damages have been carried out about maize and soybean which would be grown summer times according to climate change scenarios. It is difficult to decide obvious diagnosis of high temperature damages at present, but risk of high temperature damages on maize and soybean at summer season will be predicted to rapidly rise from 2030's with RCP8.5 scenarios, especially when it is exposed high temperature at their flowering time. Though climate change scenarios predicted to increase about 20% of precipitation, frequency and intensities of drought in the future would be showed similar pattern with present, or more serious when soil water balance model(AFKAE0.5) was simulated on RCP8.5 scenarios. There were many studies to develop adaptation techniques against global warming and abnormal weather in Korea such as assessing crop damages against high and low temperature, drought, soil wet, heavy rain, and etc., moving cultivation periods of several crops, adjusting cropping system, and developing adaptive varieties of crops.

Keywords: climate change, impact assessment, adaptation, RCP scenarios, abnormal weather
Financial support:

(9137 - 2022) Investigation of the dry stress effect on the water consumption and the tree growth with the use of lysimeter

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Climate modeling projections for the next 100 years suggest that global annual temperatures will increase between 2 °C and 3 °C, when using medium severity scenarios (SRES B1 and A1B, IPCC 2007). Due to climate change, heat waves and drought are expected to increase in frequency and intensity in Central Europe. Thus, assessments of critical constraints of water supply in forest trees are needed to develop adequate forest adaptation measures. Therefore, forest hydrology research looks into the influence of differently structured forest on the soil water budget. The use of different types of lysimeters in this region has a tradition of more than 100 years. The Eberswalde lysimeters are excellently suitable for the complex investigations because of her size (100m² of surface and 5m of depth). The investigations are completed by the use of especially developed weighable lysimeters and an open field laboratory. Lysimeters are indispensable in investigations of water consumption of small forest trees of different origin in the face of increasingly limiting water resources arising from climate change. A main topic of the research is to investigate the water consumption, water stress and the growth of small trees at decreasing soil water resources. The ability of trees to adapt to climate change is still unexplained in the main. The investigation of their yield capacity under the conditions of drought and heat is a declared research objective. Main emphasis of the research consists in the investigation of cause and effect relationships under the conditions of different levels of drought on water consumption, radial growth and fine root dynamics of the trees. Young trees are more sensitive to dryness because their roots cannot reach the water content in deeper soil layers. The relationships between increasing soil water drying and evapotranspiration of young beeches and oaks are represented. We present a novel critical limit approach to soil water availability (SWA) for small trees based on the physiological plant water status. The critical limit of soil water availability (CL-SWA) represents the proportion of plant-available water within the variable effective rooting depth (ERD) that meets both the critical soil water potential at the lower limit of the ERD and the critical plant water status. The decrease of evapotranspiration is followed by the reduction of radial growth. The results are important to the sustainable forestry in "Future Forests".

Keywords: Climate change, sustainable forestry, weighable lysimeters, soil water resources, water stress
Financial support: For Sustainable forestry

(5685 - 2379) Near-infrared spectroscopy: an alternative tool to predict ^{13}C abundance and to improve Soil organic carbon dinamycs understanding.

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Climate change is presented today, as one of the biggest challenges for humanity. Results of its study, by scientists of different disciplines, have shown an increase in the temperature of atmosphere and oceans, which is mainly due to greenhouse gases (GHG) emissions.On the other hand, Soil Organic Carbon (SOC) represents one of the main reserves of Carbon (C) in terrestrial ecosystems. However, studies indicate that the exchange of SOC with the atmosphere can be very variable, thus raising the question about the role soil has as a source or reservoir of atmospheric CO_2. Therefore, understanding the dynamics of SOC and especially the process of C stabilization is crucial. Current studies show an interaction between climate and geochemical factors in this process and, on the other hand, the use of the ^{13}C isotope, as a very useful methodological approach for the understanding of this process. The determination of the abundance of ^{13}C by Isotopic-ratios mass spectroscopy of (IRMS) is a tested technique in soil organic matter turnover evaluation and in the C cycle. It has been shown that the variation of this isotope can be related to the changes that occur in the decomposition rate of SOC. Chile is a 'natural laboratory' that allows the study of these interactions, climate and geochemical factors, in the stabilization of C. Therefore, the proposal of this study covers a transect of more than 4000 km, with approximately 38 different sampling sites with three depths of the soil profile. Consequently, the number of samples that will be used in data collection is very high and so are their costs. Near Infrared Spectroscopy (NIRS) is presented as an alternative that does not require laborious preparation, is not destructive and does not generate waste or residues that could impact the environment in any way, which reduces the analysis costs. Under these conditions, implementing this methodology, NIRS, to predict stable isotopes of C in soils, is presented as a viable and economical alternative when researches consider wide transects and different depths of samples, increasing the complexity and costs of the analysis. Preliminary results of calibration of measured and predicted $\delta^{13}C$ values using the NIRS technique will be presented.

Keywords: NIRS, δ^{13}Carbon, Calibration, Carbon Stabilization, Geochemistry
Financial support: FONDECYT PROJECT 1161492

(2038 - 584) Soil C-sequestration and CO_2 fluxes under maize-based conservation agriculture systems in the Eastern Cape, South Africa

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Traditional farming methods deplete the soil of carbon and contribute to greenhouse gas emissions. We investigated conservation agriculture effects on C-sequestration and CO_2 flux from two agro ecologies in the Eastern Cape Province, South Africa. The field trials were laid in a split-split plot design. The main treatments were tillage: conventional (CT) and no tillage (NT). Crop rotations were the sub-treatments: maize (*Zea mays* L.)-fallow-maize (MFM), maize-fallow-soybean (*Glycine max* L.)-(MFS); maize-wheat (*Triticum aestivum* L.)-maize (MWM) and maize-wheat-soybean (MWS). There were two residue managements for each rotation: removal (R^-) and retention (R^+). Biomass production was higher at the semi-arid site, which had higher soil organic carbon (SOC), as compared to the sub-humid site. Biomass and carbon inputs for crop rotations were in the order: MWM > MWS > MFM > MFS. The MWM and MWS rotations as well as residue retention had greater levels of particulate organic. Residue retention was effective ($P<0.05$) in increasing SOC in the 0-5 cm depth at both sites. The CT had higher CO_2 flux than NT. While R^+ had higher CO_2 fluxes than R^-, but it resulted in greater C-sequestration in the soil. The mean CO_2 fluxes were significantly influenced by air temperature ($P<0.001$, $r^2 = 0.41$) and soil bulk density ($P<0.001$, $r^2 = 0.16$). The MWM and MWS rotations in conjunction with residue retention under NT, offer the greatest potential for biomass and carbon inputs, and consequently carbon sequestration in the Eastern Cape sub-humid and semi-arid agro ecologies.

Keywords: Crop residues, greenhouse gas emission, particulate organic matter, soil organic carbon, soil health.
Financial support:

C4.1.3 - Soil in the Anthropocene

(2255 - 468) Amazonian deforestation and soil biodiversity

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Clearance and perturbation of pristine Amazonian forests are one of the greatest threats to tropical biodiversity conservation in our times. A better understanding of how soil communities respond to Amazonian deforestation is crucially needed for policy interventions that effectively protect biodiversity and the essential ecosystem services it provides. We provide an assessment of the impact of deforestation and ecosystem conversion to arable land on soil biodiversity in Amazonia using a meta-analysis. We analysed 274 pairwise comparisons of soil biodiversity in Amazonian primary forests and sites under different stages of deforestation and land-use conversion – disturbed (wildfire and selective logging) and slash-and-burnt forests, established pastures and cropping systems. Overall, 60% and 51% of responses of soil macrofauna and microbial community attributes (i.e. abundance, biomass, richness and diversity indexes) to deforestation were negative, respectively. We found few mesofauna (such as micro-arthropods) and microfauna (such as protozoa and nematodes) studies, and those groups could not be analyzed. Macrofauna abundance and biomass were more vulnerable to the displacement of forests by pastures than by agricultural fields, while microbes showed the opposite pattern. Effects of Amazonian deforestation on soil macrofauna were more detrimental at sites with mean annual precipitation higher than 1,900 mm, and higher losses of soil microbes occurred in highly acidic soils (pH < 4.5). When organisms were grouped according to their trophic function, responses of predators, herbivores, and especially invertebrate decomposers were consistently negative for all community attributes, while responses of microbial decomposers were neutral. Limited geographic coverage, omission of meso- and microfauna, and low taxonomic resolution were main factors impairing generalizations from our analysis. Furthermore, few studies have assessed the impacts of within-forest disturbance (caused by wildfires and selective logging) on soil species in Amazonia, where logging operations rapidly expand across public lands and more frequent severe dry seasons are increasing the prevalence of wildfires. Future research is needed to tackle these knowledge gaps.

Keywords: land-use change, soil fauna, microorganisms, meta-analysis
Financial support: Office of the Vice President for Research, One Health Institute, and School of Global Environmental Sustainability at Colorado State University.

(2527 - 1114) Being a good 'soil farmer'? The uneasy relation between 'soil health' and 'good farming' in British agriculture.

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Farming is the area where soil-related impacts of the Anthropocene must be most urgently addressed. Farming movements such as soil conservation are seen as hopeful in this respect. This paper offers insights into the role soil science can play in this transition, and into the challenges associated with changing soil management in relation to farmer identities. In England agriculture is undergoing a 'soils renaissance'; issues of soil conservation and soil health, which have for decades been the purview of organic or alternative forms of farming are now becoming mainstream. Importantly, farmers are being encouraged by soil scientists and soil advisers to attend to soil health as a way of enhancing their farming business: taking care of one's soil is being strongly linked to farm profitability in both the short and the long term. In this presentation I will discuss some of the emerging convergences and tensions between practices of soil conservation and practices of 'good farming' (understood as practices aimed at the maintenance of a profitable farm business). I will suggest that the current conflation of 'soil health' with 'farm profitability' poses challenges to farmers who seek to situate soil conservation within their project of becoming 'good farmers', as maximizing soil health and maximizing farm profitability do not necessarily go hand in hand. As a result, farmers who engage in soil conservation seek to reconfigure the meanings of 'good farming' in order to accommodate soil conservation as a valuable practice. Furthermore, I will argue that the conflation of soil health with farm profitability puts the future of soil conservation in danger by glossing over the trade-offs between these objectives.

Keywords: soil, farming, knowledge, identity, productivity
Financial support: the Leverhulme Trust

(3930 - 2410) Policy Distortion, Farm Size, and the Overuse of Agricultural Chemicals in China

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Chinese farmers use excessive amounts of agricultural chemicals, leading to financial losses and serious local, regional and global pollution. Understanding the causes of these excessive usages is key for agricultural sustainability. Here, using data from rural household surveys in China and a cross-country comparison, we found that small farm size is a major cause of agricultural chemical overuse in China. Agricultural chemical use per hectare is strongly and negatively correlated with farm size, but only weakly correlated with crop mix and fertilizer to crop price ratio, suggesting that the influences of these other factors are not strong. While economic growth has been associated with increased farm sizes in other countries, in China this relationship has been distorted by land allocation policies and barriers to migration. Removing these distortions would decrease agricultural chemical use and environmental impact without compromising crop yield, whilst increasing rural income.

Keywords: Farm size; Fertilizer overuse; Food security; Economics; Sustainable development
Financial support: Discovery Early Career Researcher Award by the Australian Research Council; Australia-China Joint Research Centre – Healthy soils for sustainable food production and environmental quality;

National Natural Science Foundation of China

(7647 - 835) Research Development and Future Prospects on Soil Pollution and Remediation in China

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In the past 30 years, with the rapid development of social economy in China, large amounts of anthropogenic emissions of different types of pollutants have entered the soil environment through multiple pathways, causing soil pollution. The pressure on soil safety and health is increasing, and the social demand for the remediation of polluted soils is extremely urgent. In the 1970s, China soil environmental protection focused on preventing the pollution of agricultural soil in sewage irrigated areas. In the 1980s, significant progress was made in the research on pollution control of organochlorine pesticides and heavy metals. In the 1990s, the soil environmental background values on a national scale and its regional differentiation were determined. The National Soil Environmental Quality Standard was enacted in 1995 to provide a basis for soil environmental management and pollution prevention. Research on soil remediation and phytoremediation was also started in the mid-1990s. At the start of the 21st century, the National "973" Plan, National Natural Science Foundation of China, and the Knowledge Innovation Projects of Chinese Academy of Sciences funded research projects on the evolution of rules of soil environmental quality and soil remediation mechanisms. Remediation technologies for polluted soil were also included into the National "863 Plan". A national soil pollution survey and prevention project was carried out, and the soil pollution status at the national scale was mapped. These projects stimulated the nationwide development of scientific research and technology on soil pollution and remediation of HMs, POPs, petroleum hydrocarbons, and pesticide-contaminated soils. Meanwhile, to strengthen scientific and technical research, personnel training and innovation on soil environment and remediation, a group of key laboratories and engineering centers, enterprises and academic societies have been set up. Several national and international academic conferences on remediation of polluted soil were organized in China. In the future, it will be a matter of great urgency to strengthen soil environmental governance in China. We believe that the further implement of "China Action Plan for Soil Pollution Prevention and Control" and the "National Special Key Research and Development Program" will greatly improve the capacity for soil environmental governance and scientific decision-making, and effectively promote China's soil remediation industrial development.

Keywords: soil environment, soil pollution, soil remediation, research and development, China
Financial support: The current research was funded by the National Key R&D Program of China (2016YFE0106400) and the National Natural Science Foundation of China (41230858).

(2990 - 486) The importance of soil information in land use planning in the Sardinia region, Italy

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Considering the fact that soil preservation is essential for sustainability, soil protection has been highlighted as a key land use policy issue by many national and international institutions. Soil degradation processes are a consequence of human misuse and mismanagement of soil resources due to various economic activities. In Sardinia (Italy), agriculture, forestry, livestock production, industry, and urbanization have been identified as leading cause of soil degradation. Recognizing the need to design proper policies to achieve sustainability, the community of soil scientists of Sardinia produced, in recent decades and in collaboration with land managers and other actors, useful information in order to guide policy makers to implement the most efficient managements and strategies. One of the main results is the Regional Landscape Plan (RLP), issued in 2006, which establishes the directions for any land use planning in Sardinia and requires that pre-existing sectorial and local plans, as well as plans for protected areas, must be changed to comply with these directives. In the RLP and its updated versions, the soil is specifically considered one of the main landscape components. Indeed, in the RLP guidelines, issued in 2008, a soil survey of the whole communal territory is required (at the suggested reference scale of 1:10,000) while designing City Plans (in Italy, where municipalities are administrative divisions with a corporate status and endowed with a degree of self-government, land-use planning is coordinated at regional level but is largely a local issue). Moreover, Land Unit and Land Capability Classification maps are explicitly required, and the adoption of a single regional reference legend for these maps is strongly recommended. In this regard, a Land Unit and Soil Capability Map of four pilot areas of Sardinia has been recently produced. When drafting the City Plan, municipalities define the zoning of the agricultural areas in accordance with the agro-pedological characteristics and the soil capability, and consequently establish urban-building parameters for the realization of permitted interventions in the identified agricultural sub-areas. In the agricultural areas, to choose the most suitable crops, it is foreseen the use of the Land Suitability Classification. The Sardinian experience is presented as a possible example of a policy relevant approach to prevent or mitigate soil degradation, soil sealing, and soil grabbing.

Keywords: Land use planning; soil protection policy; Sardinia.
Financial support: RAS/FBS, Grant Number F72F16003080002

(1268 - 505) The Maya Anthropocene: Soils, Paleosols, and ancient Agriculture (but no Terra Preta) in the Maya Lowlands

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Millions of people lived and farmed across the carbonate lowlands of Mesoamerica for millennia, altering most of the region's soils. This paper explores these long-term Maya influences on soils in the central Maya Lowlands of Mexico, Belize, and Guatemala. We base this paper on numerous soil sequences studied over the past decades to understand soil formation, ancient Maya impacts on soils, and the region's ancient agroecosystems. The paper synthesizes many soil profiles from several soil catenas from hillslopes, with and without ancient agricultural terracing, and into depressions, including wetland field complexes to analyze the surface and buried soils and explore the range of ancient Maya uses and impacts on soils. We use traditional soil methods along with archaeological information to characterize these soils and their chemical and physical properties. The paper draws on a range of multiple proxies for past uses of soils in the surrounding landscape, including pollen, phytoliths, macrobotanical information, and isotope geochemistry. Well-dated depositional evidence from lakes, floodplains, sinkholes, and footslopes demonstrate that ancient Maya land uses accelerated erosion but not consistently over their long history or wide geography. We also show widespread ancient use of terraces, field walls, and wetland fields, which show the Maya conserved and enhanced soils and developed sustainable farming systems.

Keywords: Maya Lowlands, Soil Catenas, Erosion, Conservation, Anthrosols
Financial support: UT Austin

(5862 - 3186) Traditional Māori agriculture: kūmara (*Ipomoea batatas*) origin, soil amelioration techniques, and Māori kūmara systems in Aotearoa (New Zealand)

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The kūmara or sweet potato (*Ipomoea batatas*) is known to have originated in South America, where plant remains, either of kūmara or a close wild relative, have been dated at more than 8,000 years old. Bones of chickens (*Gallus gallus*), native to Asia, that predate European contact were found in Chile and their DNA had a distinct Polynesian signature. The kūmara and the bottle gourd (*Lagenaria siceraria*), both native to South America, have traditionally been grown throughout Polynesia for over 1,000 years and may have been introduced to East Polynesia and subsequently to New Zealand by early Māori in tandem. For millennia preceding the arrival of Europeans, agricultural soils of the Andes were amended with sources of organic matter, including charcoal, in order to increase soil aggregate stability and inversely decrease soil erodibiltiy. The discontinuation of traditional agricultural soil stewardship practices in the Peruvian Andes, including long-fallows and additions of organic wastes, has intensified soil loss via erosion. The kūmara was commonly grown throughout central Polynesia by 700 CE. When the Māori arrived in New Zealand before 1300 CE, they brought plants from Polynesia, including the kūmara, with them and together they spread across the islands of New Zealand over the subsequent centuries. Although the application of animal waste to agricultural soils was considered repugnant to the Māori, contamination of waterways with animal excrement was an even greater affront to Papa-tū-ā-nuku (the earth mother), that was to be avoided at all costs, including using the land as filtration media through which to clean runoff. The addition of ash and charcoal to agricultural soils, and resultant darkening, by Māori functioned to attract and hold relatively more solar radiation, thereby lengthening the growing season for kūmara. It has been suggested that kūmara grown in soils amended with wood ash are capable of being stored for longer periods of time than kūmara grown in unamended soils. Some anthropogenic soils created by Maori for the purpose of kūmara production contained vast amounts of charcoal, estimated to have required several hundred tons of biomass to have been combusted per acre of soil. Given the current evironmental challenges in New Zealand related to reducing surface water pollution from agricultural sources, there may be important lessons for current and future soil scientists to learn from the ancient agricultual practices of the Māori.

Keywords: Māori, kūmara, sweet potato, biochar, indigenous agriculture

Financial support: N/A

C4.1.4 - Soil as natural capital: Economic and legal dimensions of ecosystem services.

(2474 - 3054) Addressing the on-site costs of soil erosion: Modelling the economic aspects of our natural capital

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According to FAO statistics, 99.7% of the human food is coming from land. Soil erosion is the major threat to soil, removing organic matter and important nutrients, preventing vegetation growth and overall biodiversity. In particular, soil erosion changes the physical, chemical and biological soil characteristics causing a drop in potential agricultural productivity and raising concerns on food security especially in a context of growing world population . The consequences of soil erosion for the society might be severe. According to Kibblewhite et al. (2012), erosion affects 115 million ha in Europe which is around 12% of the total land area. The impact assessment included in the proposed Soil Thematic Strategy estimated the cost of soil degradation. Based on estimations done in 13 countries including the major Member States where erosion occurs, the cost of soil erosion was ranging from 0.7 to 14.0 Billion Euros. The cost of soil erosion can be substantive also outside the EU. In the end, soil erosion is perceived as potential threat to development: Land Degradation Neutrality (LDN) is included in the recent international policy agreements (UNCCD, UNFCCC, CBD) and is also highlighted in Sustainable Development Goals (SDGs). In this backgroundJoint Research Centre (JRC) proposed an economic assessment of soil erosion by water on-site effects. The main models employed are: the cost benefit analysis, the marker price of soils, the direct cost estimations, the replacement cost and the latest generation of Computable General Equilibrium (CGE) economic models. Those economic models are coupled with the Biophysical erosion model RUSLE2015 developed in JRC. The direct cost estimation takes into account also the prices of commodities and share of commodities in the severe eroded areas. According to this methodology, the total economic loss in agricultural productivity of European Union due to severe erosion is around 1,257 million euros which is about 0.43% of the total agricultural GDP in the EU (estimated to 292,320 million Euros). In case we employ the General Equilibrium (CGE) economic model, the agricultural production loss due to soil erosion is about 0.12% in the EU-28 resulting in a loss of about 295.7 million Euros in the agricultural sector. In monetary terms, the crop productivity loss is 4 times higher than the loss in agricultural sector and 8 times higher the GDP loss. This is due to endogenous adjustments or adaptations in the economic system.

Keywords: soil erosion; modelling; economic costs ; Computable General Equilibrium direct cost estimation; land degradation

Financial support:

(7372 - 552) Effect of Nefzaoua oasis degradation in livelihood and food security: farmer's perception

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Oasis agrosystems have always played an important role in the development of arid and semi-arid areas and the settlement of humans in these areas. However, these agrosystem are under several natural and anthropogenic threats of degradation. This research aims to identify the farmers perceptions on the degradation in oasis agrosystems, its impacts on the farmers' livelihoods and the factors that may hinder the farmers decisions of adopting sustainable management practices. The case study was carried out in Nefzaoua oasis southern Tunisia. 180 semi-structured surveys were conducted with the farmers. The results indicated that farmers are aware of the on going degradation process of the oasis; they acknowledged water scarcity, soil salinity, followed by biodiversity loss as the most noticeable signs of degradation. According to them, the naturally salinized water resources, topography of the oasis, and climate change were the most common natural drivers of degradation. The anthropogenic drivers such as illicit drilling of groundwater, illicit expansion of date palm plantations, and excessive use of chemical fertilizers. The socio-economic drivers of degradation were concentrated on the oasis employment, farmers economic status, and market competition. Most of farmers have strongly agreed that public policies and regulations could have contributed to oasis degradation; the most rated drivers were lack of subsidies, ignorance of the state to oasis problems and technical incompatibility of the implemented projects by the state. The oasis degradation has resulted in reduction of oasis productivity and deterioration of the farmers' livelihoods. The practices adopted by farmers were limited to use of organic matter amendments, and wind breakers to limit effects of degradation. The main factors hindering the farmers from adopting sustainable management practices were lack of financial resources, governmental policies, lack of knowledge, and uncertainty about the effectiveness of the practices they adopt. To alleviate degradation of the oasis, farmers as main actors should be involved in the process. This demands commitment by farmers to adopt sustainable practices. The state should intervene through capacity building programs for the farmers and policies that encourage sustainable development of the oasis and enhance active

engagement of the farmers in the decision-making process regarding oasis management.
Keywords: Farmers' perception, oasis agrosystems, degradation, sustainability, date palm, Nefzaoua oasis, Tunisia
Financial support:

(4634 - 1369) European Soil Partnership: a Regional Cooperation to Develop Soil Policies and Achieve the SDGs in Europe and Central Asia

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Developing soil policies is an unavoidable stage prior to any implementation of soil protection measures. All countries will have to deal with the national and transboundary effects of soil degradation in order to ensure the sustainability of essential ecosystem services provided by soils. In this context, the FAO has established a multilateral initiative Global Soil Partnership (GSP) whose activities are covering the entire globe with the mission to facilitate and contribute to the exchange of knowledge and technologies related to soils. Moreover, region-specific aspects for implementation are considered and strengthened through regional soil partnerships for actions addressing various local approaches, cultural specificities and regional priorities. The core tasks of the regional partnerships are to enable cooperation and knowledge transfer within the region while being able to match the regional knowledge about the state of soils, its proper management (good practices), and actions for awareness raising and research. The European Soil Partnership (ESP) has been established in October 2013. Given its very large geographic extent, covering all Europe and part of Asia, for a total of 40 countries, the establishment of sub-regional soil partnerships was encouraged, and Eurasian Sub-regional Soil Partnership (EASP) was launched in November 2013. More recently, in November 2017, the Alpine Soil Partnership was set up as a regional and territory specific initiative that will promote soil protection and land management in the Alpine region. According to the "FAO- The Status of the World's Soil Resources Report", the following threats in Europe were identified as the prominent ones: soil sealing, salinisation and pollution. In this respect, the ESP established its implementation plan according to the main priorities, also identified by the 2012 European Commission - Soil Thematic Strategy (STS). The EASP has operated autonomously and established its specific Implementation plan with the respect to the priorities of 13 member countries, focusing on areas affected by soil salinity. The ESP has taken a role as an umbrella network covering 40 countries and has encouraged the establishment of goals that would benefit the ecosystem services while keeping stable socioeconomic and politically relevant issues in the region.
Keywords: Europe; regional soil partnership; soil policy; regional cooperation, ecosystem services
Financial support:

C4.1.5 - Carbon sequestration potential of soils

(4276 - 2987) Defining and Predicting the Organic Carbon Sequestration Potential of Soils

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Soil organic carbon (SOC) sequestration is recognised as a potentially significant option to off-set the rise in global atmospheric carbon dioxide (CO_2) concentrations. It is widely accepted that a soil's potential to sustainably sequester C is finite and dependent on its capacity to stabilise SOC, although this theory has been challenged. The stabilisation of SOC has been attributed to several mechanisms, but the formation of organo-mineral complexes in the fine fraction (silt and clay) is generally regarded as quantitatively most important. The SOC associated with the fine fraction has been found to be relatively resistant to changes in management and is characterised by long turnover times. The maximum concentration of SOC in the fine fraction has been used to define the SOC stabilisation capacity of soil. The difference between the stabilisation capacity and the current SOC concentration in the fine fraction has been termed the saturation deficit. The SOC sequestration potential of a land area (i.e. t C/ha or Mt C for a defined region) can be estimated as a function of the SOC saturation deficit and bulk density of its specific soils and their associated land areas. This paper will review recent advances in defining and predicting the soil C stabilisation capacity and sequestration potential of soils. We will also discuss some efforts to define the vulnerability of soil organic C to loss. Finally this review will outline some current research efforts to increase SOC sequestration in agricultural soils with a particular focus on case studies from New Zealand pastoral farming systems.
Keywords: soil organic carbon, sequestration, carbon stabilisation, soil organic matter
Financial support: New Zealand Agricultural Greenhouse Gas Research Centre

(2178 - 2715) Land use change effects on soil carbon stock in Caatinga biome over time.

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The conversion from natural ecosystems to conventional agricultural systems promotes a decline of soil carbon (C) content and contributes to the emission of greenhouse gases. The native vegetation of the semiarid northeastern Brazil, known as Caatinga, has been continuously replaced by extensive livestock farming and itinerant agriculture. Once few numbers of published studies confirm the real impact of these land uses on soil C stocks in this Brazilian biome, this research aims to evaluate the effects of the conversion from native vegetation to cultivated and grazing areas on C stocks in Brazilian semi-arid soils over time (2-90 years). Soils were sampled in areas of Caatinga vegetation (time 0) and in 17 other areas, in the states of Alagoas and Paraíba, with different times of land use change: from native vegetation to cultivated areas converted 2, 11, 12, 15, 19, 20, 30, 38, 40, 47, 50 and 90 years ago and to pasture converted 4, 6, 10, 20 and 30 years ago, at depths of 0-10, 10-20, 20-30 and 30-50 cm. Soil attributes analyzed were bulk density and total organic C concentration for determination of C stock as described by Sisti et al. (2004). Regarding the soil profiles, there was no difference between C stocks referring to time 0 and 2. C stocked declined in the cultivated areas implanted in previously Caatinga land from 2 to 20 years ago, ranging between 89.06 and 31.03 Mg C/ha, respectively. It means a C loss rate of 3.22 Mg C/ha/year. Otherwise, cultivated areas that were converted in time interval of 20-50 years ago returned to add C in the soil, reaching 71.69 Mg C/ha (accumulation rate was 1.35 Mg C/ha/year), except by the area converted 47 years ago (49.78 Mg C/ha).

Cultivated area converted 90 years ago did not follow the accumulation pattern (44.5 Mg C/ha). As for the areas where pastures took place, there was continuous loss in the soil C stored at times from 4 to 10 years, 86.84 and 67.87 Mg C/ha, respectively. It corresponds a C loss rate of 3.16 Mg C/ha/year. On the other hand, there was a slight increase in the C stored in the soil between the years 10 and 30, reaching in the last year 74.77 Mg C/ha, which is equivalent to a C gain of 0.35 Mg C/ha/year. The results show that both uses cause significant alterations in the amount of C stored on semi-arid soils. C loss rates were similar in the 2 uses (~3.2 Mg C/ha/year), meanwhile C accumulation rate was lower in pastures areas than those turned into crop systems.

Keywords: Semi-arid, soil organic carbon storage, vegetation cover change.
Financial support: BID, Embrapa, CNPq

(8662 - 213) Methodological discrepancies in the IPCC-based assessments of organic carbon stock changes in agricultural soils and their offsetting potential

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Reduction of greenhouse gas (GHG) assessment uncertainties and improvement in the quantification of sinks and offsetting mechanisms are a global necessity for the development of appropriate mitigation measures aimed at keeping global temperature <2^{O}C. In order to meet these objectives precise, verifiable estimations of soil organic carbon (SOC) and its variation at field scales is required. Annex-I countries mostly use the Tier-1 default methodology for GHG inventory and SOC quantification due to lack of spatially explicit activity data and reference/baseline information. Thus, improved methodologies, as well as data collection and sharing, and standardized sampling and modelling techniques are needed for accurate assessments. For SOC measurements, land use (LU)/soil type-specific and consistent sampling protocols (e.g., method and timing of sampling) are required. This includes a consideration of other factors (e.g., soil moisture and carbon) that influence soil mass and volume, and thereby reporting, of SOC by 'mass by volume' on an equal soil mass basis, in a defined but adjustable soil layer. For estimations of SOC density/stock (SOCρ/s) changes across key agricultural LUs, managements and inputs, the Intergovernmental Panel on Climate Change (IPCC) proposes a proportional (%) approach, as a SOCρ change factor (DCF). Coupled with higher spatial resolution databases, GIS approaches and two-phase modelling, the IPCC DCFs overestimated the annual rate of SOCρ changes for organo-mineral and organic soils by 42-156% compared to mineral soils. Based on the SOCρ in mineral soils, a depth-specific fractional approach was adopted to minimise any overestimation. This resulted in a SOCρ change for the four LUs combined, over 25 years, of 0.23, 0.42 and 0.53 t C ha^{-1} yr^{-1} for the 0-10, 0-30 and 0-100 cm layers. The corresponding national agricultural SOCs for Ireland in 2006 were 316, 838 and 1679 Tg. The long-term projections resulted in a carbon sink of 1.24, 3.09 and 5.48 Tg C yr^{-1}, respectively, demonstrating the potential to offset 24, 59 and 106% of the total GHGs emitted from Irish agriculture. These findings suggest the replacement of the apportioning approach, by a LU, management and depth-specific 'mass by area' approach for more precise estimations. This will also require the disaggregation of soil types, improvement of models and the calculation of country-specific DCFs for upscaling to regional/international level.

Keywords: Soil organic carbon, measurement and modelling, IPCC approaches, SOC stocks and its changes, Offsetting GHGs.
Financial support: Environmental Protection Agency (EPA), and Department of Agriculture, Food and the Marine (DAFM), Ireland.

(9928 - 3210) Soil carbon stock change after land use change from forest to cropland in Japan

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In National Greenhouse Gas Inventory Report of Japan (NIR), soil carbon (C) stock change factors derived from average soil C stock of forest and cropland are currently used in calculating soil C stock change caused by land use change between forest and cropland. This can cause problem because data is derived from multipoint soil survey of each land use, not derived from soils actually experienced land use change. Under this situation, the average C stock of forest soils is lower than cropland which is not consistent with our common sense that forest soils are more C-rich than cropland soils. We therefore conducted soil survey of paired adjacent soils with- and without- land use change from forest to cropland (i. e. a soil experienced land use change from forest to cropland and an adjacent soil remained forest unchanged) for developing a country-specific soil C stock change factor for land use change from forest to cropland in Japan. Soil survey sites were selected based on point data of previous field survey on ARD (afforestation, reforestation and deforestation), aerial photographs or satellite images of the past to present and field survey including interview to land owners. We sampled 17 pairs of soils, with 6 replications, to the depth of 30 cm for cropland and 40 or 50 cm for forest soils so that "mass equivalent" calculation method could be applied. We adjusted the depth of forest soils for calculating C stock so that soil mass of forest to a certain depth would be equivalent to the soil mass (0-30 cm) of cropland in each pair. Average soil C stock change factor of 17 pairs of data was 1.07 when we did not adjust the depth indicating 7% increase in soil C stock (0-30cm) after land use change from forest to cropland. Soil C stock change factor calculated by "mass equivalent" method resulted in 0.82 indicating 18% decrease after land use change from forest to cropland. We are still accumulating data to develop representative factors which can be used in NIR.

Keywords: Land use change, soil organic carbon, equivalent soil mass, forest, cropland
Financial support: Environment Research and Technology Development Fund (2-1601) of the Ministry of the Environment, Japan

(1810 - 1304) Soil carbon storage potential in tropical croplands: revisiting boundary lines and drivers

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Increasing soil organic carbon (C) stocks allows climate change mitigation and adaptation as well as food security enhancement, as promoted by the 4P1000 initiative. However the levels of soil C storage potential, the feasibility to fulfill this potential, and the temporal dimension of soil C storage are still discussed. In this study we aimed to evaluate, in tropical soils, soil C saturation levels, soil C accumulation rates that can be expected in croplands when improved practices are adopted, and what are the determinants of the soil C dynamics. We reviewed tropical literature dealing with i) soil C distribution across particle size fractions and ii) soil C stocks measurements after the modification of management practices in cultivated soils, e.g. tillage reduction, rotation changes, or fertilizer addition. In the first dataset, the

theoretical maximum amount of C stabilized in fine fractions of soils (<20 µm) was evaluated with quantile regression and analyzed according to land use. C saturation deficits were analyzed in cultivated soils that experienced land use change or change in management practices. In the second dataset, we calculated soil C accumulation rates (ΔSOC) and analyzed their determinants through random forest regression and analyses of variance. C saturation levels of tropical soils were lower than previous assessments at global scales. The upper limit of C contents differed according to land uses. This upper limit defined effective stabilization capacity, with lower levels for cropland soils compared to grassland and forest soils. Changing management practices did not allow C contents to reach saturation levels in croplands. Using a C saturation curve defined only with cropland data rather than with global data gave a lower C storage potential but surely attainable. After changes in management practices, the average of ΔSOC was 0.41 ± 0.03 Mg ha^{-1} yr^{-1} for an experiment duration of 13.6 ± 0.6 years. The strongest predictors of these changes were the amounts of C inputs and the experiment duration. Soil and climate characteristics did not influence ΔSOC. The conversion rate of C inputs was 8.2 ± 2 %. Given the huge competition for residues management in many tropical farms, climate change mitigation through improved management practices could be overrated. However, increasing soil organic inputs is still a relevant objective, as C associated to coarser fraction of soils also contributes to food security and adaptation to climate change.

Keywords: soil organic carbon; tropical; soil carbon saturation; carbon stocks; cropland management

Financial support: Ecobio Department, IRD, France

(7028 - 1400) Soil Organic Carbon stocks assessment, an emergency for environmental and agricultural policies. A case study from Amazonia (French Guiana).

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In South America, as throughout the world, tropical soils are characterized by a great variability of carbon stocks, Cs, ranging from less than 26 MgC.ha^{-1} to more than 300 MgC.ha^{-1} (0-0.3 m). Some areas, such as the Amazonian coast, have some of the highest Cs levels (251-300 MgC.ha^{-1}). But, the Amazonia is subject to strong development issues that induce much diversified changes in land management and agricultural practices. However, it takes several years to measure Cs changes and to evaluate good practices that are beneficial for C sequestration in soils. This time needed is not compatible with the emergency of policies that must propose soil management alternatives. Unfortunately, the future of these soils stays, for this moment, unknown. We observe a too low density of sites studied and a lack of results in the med-long term resulting from rigorous experimental designs. Thus, it's still difficult to limit the uncertainties associated with determining the carbon stock of these soils before deforestation. Therefore, this case study focuses, in a first stage, on 35 forested sites that have to be cleared by 2030 (French Guiana; Guiana Shield). We aims to spatialize and limit uncertainties of Cs determination. We applied the French soil quality monitoring network (RMQS) method (www.gissol.fr), sampled soils to one-meter deep and measured C and N concentrations and bulk densities. The amplitude of the depths sampled varied between 0-0.3 m in Fluvisols and 0-1 m for many Ferralsols. The amplitude of Cs were from 25.9 to 298.8 MgC.ha^{-1}. The Ferralsols data analysis showed that those with free vertical drainage presented the highest Cs (median 204.5 MgC.ha^{-1}). There was also an effect of the parent material of soils, and as soon as we considered the sandy rocks and basic detrital series (median 78.8 MgC.ha^{-1}). The relationships between pedological factors and C concentration and stock were detailed. Our approach using soil database (250 sites and 14,000 km^2 mapped area), and modelling in two steps scales is presented. These results also question on strategies needed to support local public policies preserving better the most sensitive areas and low agronomic potential areas such as sandy soils.

Keywords: SOC, Equatorial climate, Forest soils, Land use management, Fertility.

Financial support: ADEME, AFD, IRD

(7867 - 537) The 4 per 1000 goal and soil carbon storage under agroforestry and conservation agriculture systems in sub-Saharan Africa

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The 4‰ Initiative launched by the French government at COP21 in Paris in December 2015 aspires to increase global soil organic carbon (SOC) stocks at a rate of 0.4% per year. We conducted a systematic literature review on SOC storage under agroforestry and conservation agriculture systems in sub-Saharan Africa, where we reported 66 and 33 cases for both systems, respectively. The results showed that SOC storage rates were significantly higher than 4‰ yr^{-1} in fallows and in multistrata agroforestry systems (p-value = 0.0001 and 0.0178, respectively), but not in alley cropping and parklands systems. For conservation agriculture, only SOC storage rates in the system with all three principles applied, i.e. no- or minimum tillage combined with crop residue retention and intercropping or rotation, were significantly higher than 4‰ yr^{-1} (p-value = 0.0438). The data showed very large variability in SOC storage rates as the result of various factors, including previous land-use history, experimental set up and approach used to determine SOC storage, depth of soil sampling, soil type, type of cropping/agroforestry system and management, and duration of the experiment. SOC storage rates significantly decreased with time in the agroforestry systems (p-value = 0.0328). Our review clearly highlighted the scarcity of good quality data on SOC stocks in sub-Saharan Africa. We argue that there is a potential for SOC storage in agricultural soils of sub-Saharan Africa given the large areas of SOC-depleted soils, as illustrated by soil fertility gradients observed on smallholder farms. Low SOC levels are to a great extent the result of limited resources of most smallholder farmers in sub-Saharan Africa. The 4‰ initiative has to be implemented on the grounds of the positive impact on crop productivity rather than on climate change mitigation. The efficiency in doing so will depend on the specific situations and will need economic support to smallholder farmers.

Keywords: carbon sequestration, soil, sub-Saharan Africa, agroforestry, conservation agriculture

Financial support: French agricultural research and international cooperation organization (CIRAD)CGIAR Resear

C4.2 – Soils, food security and human healtth

C4.1.1 – Soil and human health

(8368 - 478) A New Index for the Determination of Soil Health

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Soil is the thin veneer of material that covers much of the Earth's surface. This fragile terrestrial skin is frequently less than a meter thick, yet it is absolutely essential for human life. Soil has been described as the most

complicated biomaterial on the planet due, in part, to the vast populations of microorganisms that are responsible for the biogeochemical cycling of critical nutrients. We therefore hypothesize that the metabolic status of the soil microbial community provides an overall index of soil health, which is key for agricultural yields and remediation efforts. Here, we describe a new concept for evaluating the metabolic status of soil microbial populations by determining the ratio of microbial cellular adenosine monophosphate (cAMP) to adenosine triphosphate (cATP), also termed the AMP Index or AMP_i. This ratio can be used to assess the metabolic status of a given microbial populations. A low AMP_i value indicates the active metabolism of available nutrients by microorganisms; conversely, an increase in the AMP Index signifies enhanced stress levels due to greater levels of microbial dormancy. AMP_i values of less than 0.1 suggest little to no metabolic stress, while an index of 10 or greater is demonstrative of high stress conditions that may eventuate in dormancy, or even cell death. In this study, the protocol of a kit provided by LuminUltra was modified to allow determination of soil community concentrations of cATP and cAMP in real-time (less than 10 minutes). Using this new protocol, AMP indices were determined for 5 different soil types subjected to adverse environmental conditions (specifically, extreme heat and low soil moisture content), followed by exposure conditions favorable for microbiological activity including adequate soil moisture, mesophilic temperatures, and the addition of readily-assimilated nutrients. The data generated indicate that the AMP Index was capable of discerning between favorable and unfavorable soil conditions and overall soil health. This new index of soil microbial health has potential applications for the assessment of soil quality, and can provide guidance to farmers and home owners with respect to water use requirements and nutrient management. Conversely, it may also be employed to evaluate the adverse effects of organic or inorganic soil contaminants on soil health, and thus aid in soil remediation.

Keywords: soil health index
Financial support: National Science Foundation

(2170 - 2072) Arsenic and Cadmium in Rice: Interactions Between Soil Management and Human Health

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Arsenic (As) uptake by rice affects grain yield and may affect human health upon contaminated grain consumption. It is therefore important to understand how soil management influences As release and plant-uptake. Arsenic mobility in soil and consequent plant uptake can be mitigated by increasing soil redox potential thorough water management, but this practice may increase the mobility and plant uptake of cadmium (Cd), another potent human toxin. Here, we will explore how soils can be managed to simultaneously decrease both As and Cd in rice grain thereby lessening the risk to human health through a combination of silica and water management. We will show that soil silica mangement affects the loclization and speciation of As in rice grain with consequent impacts on human health. When combined with water management, soil silica addition can be used to decrease the health risks of As and Cd due to rice grain consumption.

Keywords: redox potential, rice paddies, water management, silica
Financial support: US National Science Foundation and the US National Institute of Food and Agriculture

(6103 - 386) Assessment of potential health risk due to consumption of vegetables grown near a copper smelter in central Chile

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Intake of trace elements through consumption of vegetables is a subject of great concern due to potential health issues, which may be aggravated in mining areas. Particularly, the Puchuncavi valley in central Chile has been exposed to emissions from Ventanas copper smelter, thus, agricultural practices in this area may imply human health risk. In consequence, this study aimed to (1) compare concentrations of trace elements (TE) (As, Cd, Cu, Pb and Zn) in edible parts of vegetables grown near Ventanas smelter and areas without mining influence, and (2) to compare the potential human health risk associated to the consumption of these vegetables grown in both areas, through determination of hazard quotient (HQ). Consumption habits of the studied population were extracted primarily from official data given by the Health Ministry of Chile, and age-group scenarios were set as children under 6 years and people of 6 years old and older. Concentrations of TE in vegetables (lettuce, chard, cabbage, potato, carrot and beetroot) were in most cases higher in mining areas than in control areas. This difference was most pronounced for leafy vegetables, being As and Cu the TE of concern. Specifically, As concentration in lettuce and chard had the highest differences between areas, with 3.7 and 2.7 fold higher in mining areas than in control areas, respectively. Additionally, Cu concentration in chard and cabbage were 2.8 and 1.6 fold higher in mining area, respectively. However, Cd and Pb in underground vegetables were the TE of concern for human health, because their HQ values were above 1 for Cd in mining area and for Pb in both areas. Consequently, we recommend limiting the consumption of carrot and potato in children under 6 years old in the studied area.

Keywords: Hazard quotient, arsenic, cadmium, copper, lead, health risk
Financial support: FONDECYT project 1160018

(1960 - 377) Bio-fortification of crops with micro- minerals for human and animal health

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Micro-mineral deficiencies are common world-wide and about half of the world's population suffers with their deficiencies, especially selenium (Se) zinc (Zn) and iron (Fe), because of their low availability in soils and thus low dietary intake of these minerals. Biofortification of staple food crops with micronutrients by using agronomic and genetic breeding tools is a cost-effective and sustainable approach. This presentation will provide an overview of the agronomic and genetic approaches used for biofortification of food and feed crops to enhance the concentration of desired minerals. Field trials conducted in Balkan countries and elsewhere show positive biofortification of Zn and Se and in some cases also of Fe in the edible parts of winter wheat and maize crops and that foliar application of Zn and Se fertilizers was more effective than their soil application. Severe deficiency of Se in cows and sheep was observed in all Balkan countries and the need for bio-fortification of both food and feed crops with Se but also with Zn was felt. The consumption of biofortified food elevated the level of minerals in blood leading to positive health effects. Biofortified maize silage showed positive effect on In vitro digestibility of Zn and Fe and their availability to dairy cows

Keywords: Animal and human health, bioforticiation, food and feed crops, micro-minerals, iron, selenium and zinc
Financial support: I am EC member of IUSS and will be supported by IUSS

(5229 - 2541) Biofortified Lentil on poor fertility soils: An inexpensive source of Zn nutrition for developing countries

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Insufficient zinc (Zn) intake is a chronic health risk factor in many developing countries including Pakistan. Cereal grains low in Zn content are considered a major cause of Zn malnutrition in human population

groups greatly reliant on cereal grains for daily calorie intake. Zinc biofortification of major food crops may be an attractive, sustainable and economical solution to the problem of human Zn deficiency. Lentil (Lens culinaris L.) is a pulse crop that is considered to be the "poor man's protein" and also has the potential to serve as a source of Zn. A series research studies were undertaken to assess the potential of agronomic Zn biofortification strategies for lentil grown in under contrasting soil conditions ranging brown and black soils of Saskatchewan, Canada to alkaline calcareous soils of Punjab, Pakistan. These studies were undertaken because lentil is an important crop in both these regions and there was need to asses the response to lentil to agronomic biofortification strategies under varying agro-climatic conditions. In the Saskatchewan trials, Zn fertilizer application significantly influenced grain yield of lentil varieties and the effect was soil dependent. A significant increase in grain yield over the control was observed from application of Zn on some low organic matter, high pH Brown Chernozem soils, whereas a decrease in grain yield over control was observed in other soils such as a Black Chernozem of high organic matter content and low (<7) pH. An increase of ~20% in Zn concentration over control was observed when supplied with 5 kg Zn ha^{-1} on a loamy textured low organic matter Brown Chernozem soil. In the Punjab trials, up to 30% increase in Zn concentration and 24% increase in grain yield was observed. The higher response in Punjab trials may be attributed to low fertility of calcareous soils. The trials suggested there is a potential of improving bioavailable Zn and yield of lentil crop by agronomic Zn application.

Keywords: lentil; agronimc biofotification; calcareous soil
Financial support: ADF and NSERC Canada, Higher Education Commission Pakistan

(4184 - 1806) Chromium contamination and potential health risk implications at abandoned and in-service tanning sludge storage sites

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Chronic exposure to Cr at elevated concentrations poses a potential health risk. This study aimed to assess Cr pollution levels and health risks of Cr(VI) in six tanning sludge storage sites (four abandoned sites with conventional processes and two in-service sites with Cr-less/free new tanning technologies). A three-pathway health risk assessment (i.e. particle inhalation, oral ingestion, and dermal contact) was carried out for tanning sludge-Cr contaminated soils. Results showed that total Cr content in soils from abandoned sites ranged from 0.31 to 36.9 g kg^{-1}, with a median of 16.8 g kg^{-1}, and two in-service sites had only 2.81 g kg^{-1} of Cr in soil averagely. High Cr(VI) levels were also detected in abandoned sites, and soil Cr contents exceeded the quality standards for residential and green land in China (0.40 g kg^{-1}), Canada (0.38 g kg^{-1}) and Holland (0.06 g kg^{-1}). It was beyond the acceptable level for both hazard quotient (HQ) (1) and carcinogenic risk (CR) (1×10^{-4}) posed by Cr(VI) via each exposure route in abandoned sites. In contrast, there were no potential risks except dermal contact in-service sites. The overall hazard index (HI) and total CR of Cr(VI) via three routes at all the investigated sites exceeded both recommended thresholds, indicating great non-carcinogenic and carcinogenic health risks. Further, the contribution of dermal contact to health risks accounted for 98.6%.Therefore, remediation amendment actions should be performed in these sites before land development.

Keywords: soil Cr and Cr(VI), tanning sludge storage sites, chronic exposure, hazard index, cancer risk
Financial support: National Natural Science Foundation of China (No. 41703073, 41225004), Special Fund of Environmental Protection Research for Public Welfare of China (No. 201509037)

(2443 - 827) Diversity of herbaceous plants and bacterial communities regulates soil resistome across forest biomes

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Antibiotic resistance is ancient and prevalent in natural ecosystems and evolved long before utilization of synthetic antibiotics started, but factors influencing the large-scale distribution patterns of natural antibiotic resistance genes (ARGs) remain largely unknown. Here, a continental-scale investigation over 4000 km was performed to profile soil ARGs, plant communities, and bacterial communities from 300 quadrats across five forest biomes with minimal human impact. We detected diverse and abundant ARGs in forests, including over 160 genes conferring resistance to eight major categories of antibiotics. The diversity of ARGs was strongly and positively correlated with diversity of bacteria, herbaceous plants, and mobile genetic elements (MGEs). ARG composition was strongly correlated with the taxonomic structure of bacteria and herbs. Consistent with this strong correlation, structural equation modelling demonstrated that the positive effects of bacterial and herb communities on ARG patterns were maintained even when simultaneously accounting for multiple drivers (climate, spatial predictors and edaphic factors). These findings suggest a paradigm that the interactions between aboveground and belowground communities shape the large-scale distribution of soil resistomes, providing new knowledge for tackling the emerging environmental antibiotic resistance.

Keywords: Antibiotic resistance; forest soils; public health
Financial support: Chinese Academy of Sciences (XDB15020200) and Australian Research Council (DP170103628, DE150100870).

(8349 - 2317) Respiratory bioaccessibility of potentially harmful elements in Brazilian urban soils

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Human beings living in urban centres with heavy traffic and industrial activities, such as steel, metallurgy etc. can be exposed to potentially harmful elements (PHE) daily. Atmospheric pollution, for example, can bring particulate materials on the soil, and these materials might be introduced in humans by inhalation. Soil samples were collected in three Brazilian regions: Piracicaba and Apiaí, in the State of São Paulo, and Santo Amaro, state of Bahia, Brazil. Samples were collected in parks, gardens, recreation areas in residential districts in Piracicaba and Santo Amaro. In the latter city, a sample was collected in old facilities of a metallurgic. On the other hand, samples from Apiaí were collected in an old area of lead slag deposit. The samples were collected in the 0 to 5 cm-layer and sieved at 10 µm. In this study, the respiratory bioaccessibility fraction of urban soils contaminated with As, Cd, Cu, Pb and Zn was assessed. To simulate lung fluid, an artificial lysosomal fluid (ALF) solution was prepared. The ALF solution (pH 4.5) simulates the intracellular conditions in the lungs and extracts higher concentrations of metals than other solutions, i.e., Gamble Solution (pH 7.3). ALF solution is a complex medium with high concentration of organic complexing agents and low pH, which may have contributed to the dissolution of these elements. The pseudototal PHE contents and bioaccessible fraction of the soils covered a wide range of values. The ratio bioaccessible to pseudototal contents ranged from 13 to 100% for As; 58 to 98% for Cd; 21 to 89% for Cu; 49 to 100% for Pb and; 41 to 84% for Zn. The bioaccessibility of PHE was high for some samples and may be correlated to particle size and mineralogy and to different forms of metals and other elements in soil. The average bioaccessible fraction of the elements decreased in the order of Pb = Cd> As> Zn> Cu. The order, however, changed when the samples were separated by sites (Piracicaba, Apiaí and Santo Amaro). In Piracicaba, the order among the

elements was: Cd> Pb> Zn> Cu> As, while in Apiaí: Pb> Cd> Zn> As = Cu and in Santo Amaro: As = Pb> Cd> Zn> Cu. A high positive correlation was observed among the pseudototal and the bioaccessible contents (R^2> 0.9, p <0.05). There are few studies focusing on the relationship between urban soils and human health in Brazil, giving rise to the need for more detailed investigations on the interaction between soil solution transfer and respiratory systems.

Keywords: Artificial lysosomal fluid; soil pollution; human health.
Financial support: São Paulo Research Foundation (FAPESP), Project # 16/24483-9

(8216 - 3026) Selenium in soils of Serbia in relation to animal and human health

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In Serbia as well as in many other countries, the concentration of Se in soil is low (0.024-0.45 µg g^{-1}), which affects level of Se in feed and food plants and consequently animal and human health. Se is more available for plants in alkaline soils but in some soils e.g. in Northern Serbia low total Se concentration is factor limiting plant uptake despite favourable conditions for its availability. Se in feed and food plants is very important for normal animals and humans metabolisms. However, in most of the feed plants from different areas in Serbia, Se concentrations were below the minimal required Se concentration in animal feed.The lowest concentration of Se in blood and plasma GPx activities has been reported for animals without Se supplementation. Furthermore, the symptoms of Se deficiency e.g. White Muscle Disease, retained placenta, is well known in the region, particularly for young animals dominantly grazing on pasture. Although Se supplementation of animals has had positive results, high variation in Se concentration between animals supplemented with Se reflects different farm management including different types and amounts of Se supplementation used. Additionally, difficulties in general Se supplementation of animal always brings potential risk of Se toxicity due to overdose, which has been occasionally documented in the region. As a result of Se supplementation of animal feed, human daily intake has been improved in Serbia; it is currently estimated to be 40.9 µg Se day^{-1} but this amount is still inadequate as adequate Se dietary intake ranges 50-200 µg day^{-1}. Corresponding low plasma Se (70 ng Se ml^{-1}) was measured in people in Serbia, while different studies in UK and USA showed that 130-150 ng Se ml^{-1} are concentrations related to minimal mortality. Se in wheat in Serbia is so low that if people were fed exclusively with wheat, their daily requirements for Se would not be met. Agronomic biofortification through Se fertilization of soil and plant has to be considered as safer way to enhance the Se status of feed and fodder crops and subsequently of animals and humans, with possibly less problems related to overdosing. Our results from several field experiments showed that e.g. for wheat foliar Se applications were more effective in increasing Se than soil application, although both, Se foliar- and soil-fertilization increased Se concentration in grains from 2.6- to 4.6-fold. Positive effects of Se fertilization of feed crops are also got.

Keywords: selenium, bioavailability, deficiency, feed and food plants, daily intake
Financial support:

(8011 - 606) Soil and human health: A pursuit of patterns

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On a broad level, humans function with simple requirements of food, shelter, and water. So do soils and the ecosystems they support. Humans interacting with their environment can alter their own health and functional capabilities – we also have great influence on the health of our soils, upon which we depend for nutritious food, abundant raw materials for shelter, and fresh and clean water. The patterns of health for soil and humans are becoming increasingly expressed, and often share similar designs. Consider soil health – a seminal indicator is the breath of soil itself. Like us, soil is living and therefore breathes – the more it breathes, the more it needs to be fed – the more it is fed, the more work it can do. Soil that has been fed a robust diet of crop diversity and kept intact with conservation tillage works hard to provide sufficient nitrogen to crops. This presentation explores a variety of patterns that have emerged in the description of functioning soils and human health.

Keywords: Soil biological activity; nutrient cycling; ecosystem functioning
Financial support: USDA - Agricultural Research Service

(5929 - 2542) Soil and the human microbiome

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Soils are by far the largest global pool of microorganisms and at the same time the habitat for humans, offering space for living, production and locomotion. Moreover, soils produce food and fibre and are filtering rain water for the provision of drinking water resources. Since 2007 soils are coming into the focus of biomedical research within the Human Microbiome Project (HMP), that aims at the sequencing of all microbes (eukaryotes, archaea, bacteria, and viruses) inhabiting human body sites. Similarly the TerraGenome network facilitates activities that will increase our knowledge and understanding of the soil metagenome. Recent data show that specific compositions of the human microbial community are associated with human health and disease. Meanwhile, HMP has become a major field of biomedical research, targeting in particular the intestinal microbial community, which turned out to play a major role in human health and disease (Blum, H.E., 2017). This intestinal microbial community represents a microbial ecosystem, principally comparable to the soil microbial ecosystem, from which it has originally developed. Looking at the entire ecological systems, the human body can therefore be regarded as an extended genome, and the question arises, whether still today a local or regional functional relationship between both systems exists, for example by human exposure to different soil microbiological environments. As human activities are changing the distribution and abundance of soil microorganisms, e.g. by the spread of antibiotics to soils, the resultant changes in microbial ecosystems will not only affect biogeochemical cycles driven by microbial activity, but also feed back on human health. Indeed, it was found that pollution-induced shifts in natural soil bacterial community, like in PAH-polluted areas, can contribute to the prevalence of chronic diseases. This has lead to the formulation of a novel altered environmental microbiome hypothesis as a potential explanation for the complex relationship between human health and the soil environment (Parajuli, A., 2017).

Keywords: human health; intestine; metagenome; environment
Financial support:

(5571 - 665) Soil carbon storage and climate change

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Soil organic matter contains about 58% organic C, which performs essential physical, chemical and biological functions in soil. It also provides a large storage of organic C (1550 Giga tonnes to 1 m depth and 2500 Giga tonnes to 2 m depth), which exceeds the combined C pools of the atmosphere (860 Giga tonnes) and vegetation (≈ 600 Giga tonnes). Therefore, the soil organic C (SOC) pool is an important component of the terrestrial C cycle. Over the long-term, the amount of SOC storage is in steady state with C inputs and C outputs. Both C inputs and C outputs

are affected by climate change both directly by increasing temperature and changing precipitation, and indirectly by increasing CO_2 concentration in the atmosphere (so-called 'CO_2 fertilisation'), and through atmospheric deposition of reactive nitrogen (ammonia and oxides of nitrogen). The SOC decomposition generally increases by a factor of two for every 10^{O}C increase in temperature (Q_{10} value). However, under substrate-limited conditions, the overall temperature response to SOC decomposition may differ from that predicted from Q_{10} function. As the substrate supply becomes limiting, the Q_{10} value of SOC decomposition increases. This occurs more frequently for the recalcitrant SOC pool than for the labile pool (Q_{10} labile pool, 2.1-2.3 versus Q_{10} recalcitrant pool, 3.3-3.8). Most GCM outputs predict an increase in precipitation in mid-latitudes and higher latitudes but reduced precipitation in the subtropics and tropics. Generally, precipitation appears to be more important than temperature in regulating soil and microbial respiration rates and biomass productivity, and hence C inputs or net SOC accumulation. Elevated CO_2 not only increases total C_3 plant biomass but also increases root:shoot ratio, primarily by increasing fine root production, especially under high N availability, and hence, increasing net SOC accumulation. Additional N supplied through atmospheric N deposition can stimulate plant growth, and thus, increase C inputs as well as soil N supply, which not only enhances the impact of elevated CO_2 concentration on SOC storage, but also slows organic matter decomposition by stabilising humus C in soil. Since SOC is critical to soil health and productivity, the increase in SOC storage will also contribute to reducing the threats to food security due to climate change, as well as providing environmental and ecosystem services to humanity.

Keywords: Soil carbon, temperature, precipitation, CO_2 fertilization, Atmospheric N deposition
Financial support: The University of Queensland

(6921 - 223) Soil contamination with heavy metals in China and implications for human health

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Rapid industrialization in the last three decades has caused widespread soil contamination in China. A recent nationwide survey showed that nearly one fifth of the soil samples from agricultural land in China were contaminated, mainly with heavy metals. Cadmium ranks the first, followed by nickel and arsenic. Although the levels of contamination in soil are mostly moderate, considerable proportions of crops, especially rice, produced in some areas of southern China exceed the food quality standards for heavy metals such as cadmium and arsenic. Soil acidification in agricultural land in some regions due to the long-term use of large amounts of nitrogen fertilizers has increased the bioavailability of cadmium in soil and elevated the transfer of cadmium to food crops. Flooding of paddy soil for growing rice results in the mobilization of arsenic in the anaerobic soil. Rice crop appears to be more efficient in taking up cadmium and arsenic than other cereal crops. Rice accounts for approximately 60% of the dietary Cd and As intakes for the general population in China. Dietary intake of Cd for the general population in China has doubled during the 25-year period from 1990 to 2015. The causes of heavy metal contamination and the strategies for reducing the transfer of these toxic elements to food crops will be discussed.

Keywords: heavy metals, cadmium, arsenic, rice, dietary intake
Financial support: National Natural Science Foundation of China

(1762 - 1502) Soil geochemistry, food systems and human health at a global and regional scales

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Human health is known to depend on nutrition, which in its turn is strongly connected with the quality and composition of agricultural products. It is a well-known fact that the lack of certain microelements in soil and water results in "hidden hunger" related diseases and excessive concentrations of some elements, either of natural or technogenic origin, may lead to intoxication of humans. Though endemic diseases related to geochemical anomalies are well described in literature, still there is no global inventory of soil geochemistry – human health relationship, and such inventories are also lacking for many regions of the world. Actually it is evident that for the regions with high proportion of urban population simple correspondence between soil composition and human health does not work, mainly because the inhabitants of metropolises hardly use local food as the main basis of their nutrition. The diet of an urbanite consists of the products collected from all over the world, and these products reflect geochemical characteristics of various remote soilscapes. The contribution of soil geochemistry of the source area depends on the products derived from each of these areas. Different plant species and even different varieties differ in their ability to accumulate microelements. Some food products such as milk have elevated concentrations of microelements due to their accumulation in trophic chains. All these details should be considered when calculating the balance of microelements in human nutrition. The analysis of relevant literature showed that the proportion of local food in the diet of a typical citizen depends on the location of the settlement (if it is situated in an agricultural area or not), its size, the level of development of the country and specific region, and on the cultural context. Bigger cities in more developed countries are more integrated in a global food system and thus their inhabitants do not depend on regional peculiarities of soil composition. Small settlements in less developed countries are almost entirely dependent on local food and thus are subjected to the negative effect of local geochemical anomalies. The same is true for the followers of a popular "100 Mile Diet". Further research is needed to understand the effect of soil conditions on food quality and human health. Food system structure should be taken into account to quantify the contribution of local and imported food in the micronutrient balance in human nutrition.

Keywords: food security; hidden hunger; geochemical anomalies; trophic chains
Financial support: subsidy of the Government of Russian Federation to the Eurasian Center for Food Security, resolutions No. 2226-r (08/12/2010) and 2448-r (18/11/2016)

(1181 - 2600) The Integral Soil Model to Address Local and Global Soil Health and Security

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The profound human-centric dominance in the Anthropocene has created changes in land use, biomes, climate, food networks, economies and social communities, which in turn have impacted global resources, such as food, energy, and water, as well as the soils that humanity and other terrestrial lifeforms depend on for survival. We posit that a new integrative science is needed to support global soil security and health that facilitates improved soil synthesis of data, knowledge, understanding, experiences, beliefs, values and actions related to soils considering multiple perspective-dimensions, such as soil-environment, soil-politics and soil-human. We formalized the Integral Soil Model that synthesizes these dimensions relevant in soil health and soil security. The integration process of the Integral Soil Model is grounded in Integral Theory and Integral Ecology and entails the following elements: (i) individual and collective human needs, uses, values, beliefs and perceptions of soils and nature coalesced with, (ii) quantitative knowledge of soils and nature derived through empirical observation and quantitative analysis, as well as (iii) systems in which soils are

embedded in (e.g., economic, political, social and legal systems). We present the Integral Soil Model that allows for a coherent and formalized framework to address questions and research in soil health, soil security, and food security not only from an objective perspective, but also from personal, cultural, and systemic perspectives.
Keywords: Soil security, soil health, food security, Integral Soil Model, Integral Theory, synthesis, integration
Financial support: University of Florida

(1983 - 825) Transmission of antibiotic resistance genes from agricultural soils to vegetables

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The emerging prevalence of antibiotic-resistance genes (ARGs) and their subsequent acquisition by clinically relevant microorganisms is a serious threat to public health. Land application of animal manure is a common agricultural practice potentially leading to dispersal and propagation of ARGs in environmental settings. However, the temporal pattern of ARGs in agro-ecosystems following application of animal manure has never been explored systematically. We constructed soil microcosm incubation to compare effects of poultry, cattle and swine manures on the temporal changes of soil ARGs, and a glasshouse study to explore the potential routes for transmission of ARGs from rhizosphere to vegetables (lettuce and cherry radish) grown in soils fertilized with poultry or cattle manure. The results showed that poultry and swine manures have stronger impacts on the diversity, abundance and lateral transfer potential of a wide spectrum of soil ARGs than cattle manure in soil microcosm experiments. Such effects of manure addition on soil resistome were enhanced by addition of the antibiotic tylosin, which selected for increased bacterial resistance to multiple categories of antibiotics and prolonged the persistence of ARGs during the soil microcosm incubation. The glasshouse experiment revealed that manure application significantly increased the number and absolute abundance of ARGs in the vegetable samples compared with those grown in the non-manured soil. Endophyte and phyllosphere samples shared a large number of ARGs with manure samples for both lettuce and cherry radish, which means that manure is an important source of ARGs found in vegetable samples. Our findings provide evidence that application of animal manures might enrich ARGs in soil and vegetables, which necessitates the appropriate treatment of animal manures prior to land application to minimise the transfer of ARGs from soil to the food chain.
Keywords: animal manure; tylosin; antibiotic resistance genes; mobile genetic elements; public health
Financial support: Australian Research Council (DP170103628, DE150100870).

(8299 - 2012) Soil biodiversity, Human health and Climate change: applying knowledge to address sustainability challenges

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The Global Soil Biodiversity Initiative (GSBI) as a scientific agenda was established in 2011 with the goal of advancing the knowledge of soil biodiversity science and implementing findings in management and policy decisions. Our dependence on soil organisms (microbes and animals) for sustaining human health and other ecosystem services is being recognized: For example, soil invertebrates enhance litter decomposition by an average of 25% globally. However, climate change can alter species and their mutiple compex interactions with effects on humans, soil pathogens, soil habitats and ecosystem processes such as soil respiration. To futher advance our understanding of changing ecosystems, we need to use all tools available to accurately identify and assess current levels of soil biodiversity, their global distribution and their known responses to climate change. Current research from regional and global assessments; soil and earth microbiomes; pathogens and parasites of plant, human and animals are contributing knowledge to existing databases of soil organisms. The GSBI members worldwide are actively assuring that soil biodiversity science is included in global policy agendas to address how biodiversity above and belowground responds to climate change and affects health of humans.
Keywords: Global Soil Biodiversity Initiative, pathogens, ecosytems
Financial support: only personal and institutional

C4.2.2 - Soil quality and food security in the tropics

(6522 - 1421) Biochemical characterization of selenium toxicity symptoms in cowpea plants

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Selenium (Se) is considered a beneficial element for plants; however, in high concentrations, it causes negative effects on plant physiology and development. This study reports the first physiological, nutritional, and ultrastructural description of Se toxicity in cowpea growing under field conditions. Selenium was supplied as a foliar application of sodium selenite at varying concentrations (0, 50, 100, 200, 400, 800, 1200, and 1600 g.ha^{-1}). An increased yield was observed with the application of 50 g.ha^{-1} Se. Application of concentrations higher than 50 g.ha^{-1} caused leaf toxicity. Increased lipid peroxidation and hydrogen peroxide concentration and reduced total sugars, sucrose, and carotenoid concentration were observed at highest doses tested (1200 and 1600 g.ha^{-1}). Applications of more than 50 g.ha^{-1} Se reduced the phloem diameter, caused chlorosis of the leaf blade with a coalescence of lesions, and caused pink salt deposits to appear. Lesions were observed mainly near the trichomes on the adaxial surface of the leaf blade. An analysis of the element distribution with microprobe X-ray fluorescence spectrometry (μ-XRF) revealed accumulation of Se, Ca, K, Cu, and Mn near the primary vein and in the necrotic brown areas of the leaf lesions. In contrast, Na was homogeneously distributed in the leaf tissue.
Keywords: selenium, Vigna unguiculata, phytotoxicity, food security
Financial support: FAPESP (Grant 2016/19773-8)

(1166 - 1337) Effect of different approaches of fertilizer recommendation on growth, yield and quality of soybean in a Vertisol.

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The field experiments were conducted on yield maximization in soybean through different fertilizer recommendation approaches at the Main Agricultural Research Station, Dharwad during kharif 2015 and 2016. The treatments consisted of different fertilizer recommendation approaches viz., site specific nutrient management (SSNM) and soil test crop response (STCR) yield targets at 20, 25. 30 and 35 q ha^{-1} and soil test laboratory (STL) approach and were compared with graded levels of fertilizer (125 and 150% of RDF NPK) and control (RDF). The experiments were laid out in randomized completely block design with twelve treatments replicated thrice. The yield attributes and yield of soybean was significantly influenced by different nutrient management practices in both seasons. Pooled data of two years indicated that the highest grain yield was recorded in the treatment SSNM yield targeted at 30 q ha^{-1} which was significantly superior over 125 and 150 per cent of RDF, STL approach, SSNM yield targeted at both 20 and 25 q ha^{-1} and STCR at all target levells and control but was on par with SSNM yield targeted at 35 q ha^{-1}and the magnitude of increase was 40.69 per cent over control, 35.04 and 32.04 per cent over 125 and 150 per cent of RDF, respectively, 33.35 per cent over STL method, 30.31 and 19.75per cent over SSNM

yield targeted at 20 and 25 q ha^{-1}, respectively, 37.87, 32.32, 30.59 and 18.88 per cent, over STCR yield targeted at 20, 25, 30 and 35 q ha^{-1}, respectively. The significant increase in seed yield was due to higher availability of nutrients and their uptake by the crop, improvement in growth and yield contributing characters like seed yield $plant^{-1}$, number of seeds and test weight. Significant improvement in protein (38.05 %) and oil (18.83 %) contents in seeds was also observed in SSNM yield target at 30 q ha^{-1} over control. Accordingly, benefit cost ratio was also higher in the treatment with SSNM yield targeted at 30 q ha^{-1} and lowest was recorded in 125 per cent of RDF and control. Therefore, fertilizer recommendation by SSNM yield targeting at 30 q ha^{-1} helps in getting higher yield with higher net returns over other approaches.

Keywords: SSNM,STL,soyabean,yield,quality.
Financial support:

(5187 - 834) Effect of methods of Zinc and Fe nutrition on yield and quality of chickpea genotypes

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Chickpea is the principal pulse crop in India with 8.25 mha area and 7.33 mt production and provides a major source of protein and vital mineral nutrients to the vegetarian population which is 65% of total population. In most of the soils Zinc and Iron deficiency is prevailing due to intensive cropping system and is mostly found in soils of neutral to alkaline pH. Zinc deficiency leads to loss of pollen function, impairment in fertilization and poor development of the seed which further contributes to a decrease in crop yield. Whereas Iron deficiency causes chlorosis in plant and contributes to yield reduction. Apart from this the deficiency in soil leads to lower content of these micronutrients in seeds and causes some health problems in human beings such as low fertility, poor immune system, depression, anaemia etc. Plant cultivars vary in their tolerance to soil with low plant available Zinc and Iron with respect to Zinc and Fe uptake and utilization. Hence the experiment was conducted at MARS, UAS, Dharwad during the *winter* season of 2015 and 2016 under rainfed condition to know the response of chickpea genotypes to method of application of Zn and Fe and their effect on yield and Zn and Fe content of seed. The soil of the experimental field was clay having fertility status of 234.3 kg nitrogen ha^{-1}, 31.2 kg phosphorus ha^{-1} and 298.9 kg potassium ha^{-1} and 0.5 mg/kg Zinc. The treatments comprised of two genotypes of chickpea (JG-11 and GBM-2) and six Zinc and Iron nutrition methods- T_1- No Zn and Fe (control),T2- 0.5% Zn foliar application, T_3- 0.05%Fe foliar application, T_4- 0.5% Zn and 0.05%Fe through foliar application T_5- seed treatment 2 g Zn and Fe/kg of seeds T_6- Soil application of ZnSO4 @ 25 kg/ha. Common dose of nitrogen and phosphorus (25 and 50 kg/ha) was applied to all the treatments at the time of sowing , which was done during second week of October in both the years. Potash was not applied as the soil was rich in that nutrient. Among the genotypes GBM-2 (2358 kg/ha) recorded significantly higher yield than JG-11 (1990kg/ha).Foliar application of 0.5% Zn + 0.05% Fe recorded significantly higher seed yield (2462 kg/ha), Zn content (42 mg/kg seed) and Fe content (30 mg/kg seed) in seed compared to control treatment (2008 kg/ha, 36 mg and 27 mg/kg seed, respectively) and it was on par with all other treatments except, seed treatment @ 2 g Zn and Fe/kg seeds.

Keywords: chickpea, yield, Zn, Fe
Financial support: AICRP on chickpea, ICAR, India

(6617 - 394) How can we mitigate impact of climatic variability on crop production in the semiarid tropics of Africa?

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In the semiarid tropics, where variable climatic conditions such as drought and flood are among the difficulties for smallholder farming, the mitigation of their impact on food security is of great significance. Our research objectives were to identify soil parameters controlling the crop production under variable rainfall conditions and to examine mitigation measures against impact of climatic variability on crop production. To achieve this, we conducted two field experiments in Eastern Province of Zambia and in north-central Namibia. Soils in Zambia and Namibia were classified as Plinthustalfs with 11% of clay and Quartzipsamments with 5% of clay, respectively. In both experiments, some parcels of fallow forest were cleared every year and continuously cultivated for 4 years with 3 replicates. Treatments also include fertilization in both and slash-and-burn practice in Zambia. Thus, we could distinguish the effects of climatic variability on crop production from those of cultivation periods and/or fertilization. In these experiments, we monitored soil parameters such as organic matter content and infiltration rate, crop yield and climatic variables. The rainfall in each cropping season in Zambia and Namibia ranged from 762 to 1022 mm, and from 77 to 235 mm, respectively. Major findings common in the two countries were 1) positive effect of fertilization was not consistent during the course of 4-year experiment, suggesting that fertilization will not mitigate climatic variations, and 2) soil physical properties such as infiltration rate were crucial characteristics to mitigate climatic variations. Crop production in the 4 cropping seasons after land clearing did not change in Zambia while that declined so drastically in Namibia. This contrasting result could be partly explained by the difference in soil organic matter decomposition pattern that was in turn controlled by soil texture. In conclusion, for mitigation of impact of rainfall variability on crop production in semiarid tropics of Africa, maintenance or improvement of soil infiltration rate is more crucial than fertilization. Because the measures to improve such soil physical properties vary across the regions, our thorough understanding of soils is requested.

Keywords: Rainfall variability, inorganic fertilizer, southern Africa, maize, pearl millet
Financial support: This work was supported by JSPS KAKENHI Grant Numbers JP23310027, JP26304045 and the RIHN projects on Vulnerability and Resilience of Social–Ecological Systems, and Desertification and Livelihoods in Semi-Arid Afro-Eurasia.

(8715 - 1811) Impacts of Commercial Rhizobium Inoculants on Tropical Soybean (*Glycine max*) Varieties in the Guinea Savanna Agroecology of Northern Ghana

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Commercial inoculants for grain legumes provide the effective *Bradrhizobium* strains that can stimulate N fixation, growth, and yield of grain legumes such as soybean. In Ghana, a dearth of information exists on how commercial rhizobium inoculants affect the growth, nodulation, and yield of soybean. A field study (2-yr) was conducted at CSIR-Savanna Agricultural Research Institute's experimental field at Nyankpala, Ghana to assess how different commercial rhizobium inoculants affect the growth, nodulation and grain yield of promiscuous nodulating soybean varieties. The experiment was in a split-plot design with the main plot factor as tropical soybean varieties (tropical Glycine max crosses (TGX); Jeguma (TGX1448-2E), Afayak (TGX1834-5E), and Songda (TGX 1445-3E).

The subplot factor consisted of three commercial soybean rhizobium inoculants, namely Biofix (USDA strain 110; obtained from Kenya), Nodumax (USDA strain 110; obtained from Nigeria) and Legumefix (*Bradyrhizobium japonicum* strain 532c, obtained from UK) plus a un-inoculated control. Nodulation pattern and shoot biomass yield were assessed at vegetative (V8, 8-leaf stage), full bloom (R2), beginning pod (R3), full pod (R4) and full seed (R6) stages as well as plant height and grain yield at maturity. Biofix and Nodumax increased both the number and mass of nodules on the root crown, tap root and side root compared to the control. Jenguma and Afayak produced a greater number of the crown, tap root and side root nodules than Songda. Inoculation with Biofix and Nodumax induced greater nodule mass and nodule number on the upper 5 cm root segments than the control. Inoculation did not affect nodulation on lower 5 cm root segments. In 2016, shoot biomass was affected by an interaction of inoculant and soybean variety where Biofix and Nodumax had greater shoot biomass with Afayak, Jenguma, and Songda. In 2017, only the main effects were significant where inoculation with Biofix and Nodumax significantly increased shoot biomass. Afayak and Songda also produced greater shoot biomass than Jenguma. Biofix and Nodumax increased plant height compared to the other treatments in 2017. In both 2016 and 2017, enhanced grain yields of up to 30% were observed with inoculation with Biofix and Nodumax compared to the control. Conclusively, Biofix and Nodumax seem to be the most promising commercial inoculants to enhance nodulation, biomass production and grain yield in Ghana.

Keywords: Rhizobium Inoculants, Agroecology, Soybean, Ghana
Financial support: United States Agency for International Development as part of the Feed the Future initiative under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013. 2. S

(8557 - 412) Promoting the 4R among smallholder farmers in the tropics: Successes, challenges and lessons learned

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The application of the four rights (4R) of nutrient management are essential to improve soil fertility, productivity, fertilizer use efficiency and reduce contamination. Although the potential gains are high, the adoption of the 4R by smallholder farmers in the tropics has been a challenge due to economic and agroclimatic constraints. There is a need to adapt the 4R recommendations and extension methods to smallholder farmers' decision-making strategies in the face of their economic and climatic uncertainties. We established 120 on-farm trials with maize and bean smallholder farmers in the Dry Corridor of Guatemala to evaluate the application of 4R recommendations for source, dose, moment and method of application. Recommendations were based on soil fertility parameters, crop yields and considered socioeconomic constraints. The successes and challenges of 4R promotion among smallholders were evaluated according to (1) yields, income and production costs and, (2) farmers' perceptions of their climate vulnerability and decision making. Our work demonstrated that: (1) Varying perceptions of climatic vulnerability lead to different results in the implementation of the 4Rs. (2) The 4R were most effective when applied together, however, the initial application of a single R can have positive effect and facilitate the subsequent adoption of other Rs. (3) On-farm comparison plots were effective in generating evidence among farmers, but it was not necessary for all farmers to implement trials for adoption of the 4R to occur, (4) There is a need to improve access to different sources of fertilizers and enable smallholders to develop their own physical mixtures of fertilizers. Perceptions of climatic vulnerability should be considered in addition to economic constraints and agronomic results to develop strategies to effectively promote the adoption of the 4R by smallholder farmers.

Keywords: 4R, smallholders, tropical soils, climate vulnerability, climate change
Financial support: Howard G. Buffett Foundation

(1974 - 1678) Relationship between Cadmium levels in soil and beans in cacao production systems of the Colombian central Andean region

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In Colombia, cacao is a traditional crop and is also a strategic commodity due its potential to replace illicit crops. At present, there is a worldwide concern about food safety, mainly in regard to heavy metals. In some Latin American countries have been reported levels from 2.5 to 7.1 mg/kg in cocoa beans, which are above the maximum level of 0.6 mg/kg established by the European community for cocoa powder. The aim of this study was make a diagnosis of Cd concentration in soil and cocoa beans, in productive systems of two regions of the Colombian Andean zone; and evaluating if Cd contents in plants is of geogenic or anthropogenic origin. Ninety five farms were chosen for this study, and one cocoa tree with mature fruits was sampled in each farm for determination of Cd in beans. The pseudo-total Cd (dissolved with HNO_3+H_2O_2), available Cd (extracted with DTPA), pH, organic carbon, P, Fe, Mn, Zn and Cu in the soils around the tree were evaluated. Cd levels in fertilizers and amendments and in parent material of soils were also analyzed. The Pseudo-total Cd in soils varied from 0.17 to 7.40 and Available Cd from 0.02 to 2.89 mg/kg, showing a high correlation among both variables ($r=0.77$, $P<0.01$); the available fraction accounted for 1 to 70% of the total Cd. More than 90% of the bean samples exceeded the maximum level imposed by the European Union, with an average value of 4.42 mg/kg and 84% of variation. Cd in beans showed a better correlation with Available than Pseudo-total Cd ($r=0.78$ and 0.62 respectively, $P<0.01$), which could indicate that Cd-DTPA extraction is a useful index to predict the accumulation of Cd in beans under the characteristics of study area. A high spatial variability of Cd in the study area was found, which could not be related to any of soil variables measured. The abundance of Cd in soils seems to be associated with the sedimentary parent material, formed in the two regions by clastic rocks and in a lesser extension by calcareous rocks, which both showed Cd levels from 9.27 to 21.20 mg/kg in the northern region of this study, where the concentrations in cacao beans were higher. However, Cd levels in di-ammonium phosphate (14.22 mg/kg) and lime (9.21 mg/kg) indicate that there is some anthropogenic influence, mainly in the southern region, with generally lower levels of Cd in beans. Mitigation strategies should be implemented to reduce the Cd content in beans in crops with high levels, in order to not affect the farmers' income.

Keywords: *Theobroma cacao* L., available Cd, pseudo-total Cd, DTPA, heavy metal
Financial support: Subproject of the project

(7585 - 1582) Soil Health for Climate Change Resilience and Food Security in the Central American Dry Corridor

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Improving soil health is an effective approach to increase productivity and improve climate change resilience in the highly vulnerable Dry Corridor region where soil and water resource degradation exacerbates the impact of an increasingly extreme and variable climate and threatens the food security and livelihoods of millions of smallholder farmers. Although the potential gains from improving soil health are great, agricultural extension systems, public agencies, private sector services, and non-governmental projects rarely focus on this critical factor and adoption rates of key practices remain low. The Water-Smart Agriculture Program for Mesoamerica works with local organizations to promote and evaluate practices to improve soil health in a network of 3000 on-farm trials with smallholder coffee and basic grains farmers across Nicaragua, El Salvador, Honduras, Guatemala and Oaxaca, Mexico.

Based on agroclimatic conditions, cropping system and socioeconomic context, we implement soil health improving practices including 4R nutrient management, soil acidity management, conservation agriculture, cover cropping and agroforestry. Together with farmers and local organizations, we are evaluating the impact of these practices using a set of soil health, productivity and economic indicators to directly compare soil health innovations with conventional practices on every farm. Preliminary results demonstrate significant improvements in soil health that translate into increased productivity and economic benefits contributing to improved food security for smallholder farming families. The participation of farmers in the trials and associated farmer field schools has stimulated adoption and farmer-to-farmer dissemination. Farmer experimentation also builds capacity to continually evaluate and adapt their agricultural systems as the climate changes and new challenges arise. These on-farm results are extremely promising and serve as the foundation of our work to build broad-based tools and capacity to support and provide soil health services for more than 250,000 producers in the region.

Keywords: 4R; smallholder agriculture; conservation agriculture; soil health; tropical soils

Financial support: Howard G. Buffett Foundation

C4.2.3 - Soil quality to secure human and environmental health

(8914 - 1190) Changes in soil attributes promoted by wastewater reuse in a rural community in Brazil

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Inadequate sewage disposal can pose serious risks to the protection of public health. Several rural areas where individualized solutions are used to treat and dispose of domestic wastewaters may cause groundwater contamination due to sewage infiltration in the soil, causing frequent infections of the local population that consume water from shallow wells. There is no data that shows the reality of sanitation in the rural areas of the city of Campinas, SP, Brazil, nor is there any information about possible microbiological contaminations due to the application of wastewater to the soil. In this scenario, the work developed in the rural area of Pedra Branca, located in the city of Campinas, was used as a case study. Its main objective was to construct alternative sewage treatment systems and provide subsidies for the application of treated sanitary sewage in agriculture, thus saving water and fertilizers for the farmers. Soil samples were collected at 0-20 cm depth from October 2016 to November 2017 in the different systems installed: two to treat black waters (Watson Wick adaptation and Biodigester Septic Tank) and two for greywater (Bamboo swale and Banana mulch basin), having as reference the native forest and adjacent arable areas. The following parameters were studied: chemical determinations pH, H + Al, Ca^{2+}, Mg^{2+}, K, Na, P available, organic matter (OM), base sum (SB), cation exchange capacity (CEC), base saturation (V), electrical conductivity (EC) and exchangeable sodium percentage (ESP). EcoPlate microplates were used to determine the metabolic diversity of bacterial communities. As an indicator of soil microbiological contamination, the concentration of *Escherichia coli* in CFU per gram of dry soil was determined. The original chemical characteristics of the soil, considering the native forest as a reference, were altered according to the treatment system used, being the OM directly affected by the application of sanitary effluents. The changes observed in the microbiological attributes are related to the changes in the chemical attributes of the soil, due to the application of the effluents, mainly to the increase of the P, OM, and Na in the soil. Changes were observed in the population density *E. coli* by application of sanitary effluents; the greatest cell densities, up to 3×10^3 CFU g^{-1} soil, were found in the Biodigester Septic Tank, and the lowest numbers, equal or lower than 1.0 CFU g^{-1} soil, occurred in the others systems evaluated.

Keywords: Decentralized sanitation; irrigation; soil quality; environmental education; rural sanitation

Financial support: Pró-Reitoria de Extensão e Assuntos Comunitários - UNICAMP, Project FAPESP 2017/07490-4, CAPES (PNPD 20131777)

(7819 - 1986) Ecological assessment of petroleum contaminated soils (Sakhalin Island) using ecological functions

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The issues of the environmental sustainable management and protection have become highly important with the increase of human needs, that affected the ecosystems and led to their degradation. The threat of a global ecological crisis in ecosystems defines the necessity to work out the strategy of optimal relation between humanity and nature, determine the main vital functions of the soils, find the criteria to assess how well a soil performs its functions. Soil ecological functions are determined by the set of their properties and soil formation processes, therefore, the soil becomes the connecting unit between environment components. Soils play a critical key role in providing ecological services and contribute to all defined classes of ecosystem services, including provisioning, regulating, supporting services. The proposal of this study is to find total petroleum hydrocarbon (TPH) acceptable norms, allowing a soil system to perform its ecological functions, for soils of Sakhalin island, to analyze ecological functions and ecosystem services. The migration water indicator has been applied to find the permissible content of TPH in soils, in case of not exceeding which, sustainable functioning of soils is provided with preservation of the hydrosphere functions. Biocenotic indicators have been used to set the maximum permissible concentration of TPH, which can be left in soils, holding biocenotic ecological functions. We used a set of biological parameters (soil mesofauna survival rate, enzymatic activity, plant seeds germination and root length) to determine the ultimate capacity of the soil to tolerate TPH contamination. Mathematical models were used to interpret the analytical data. The ultimate norms of TPH, at which histosols, podzols, haplic cambisols, fluvisols were still able to perform their biocenotic functions according to the biological parameters studied are 60; 18; 25; 12 g TPH kg-1 of soil respectively. The permissible contents of oil products, in which histosols, podzols, haplic cambisols, fluvisols retain their stable functioning, in terms of performing hydrosphere functions, established according to the water migration index, are 40; 4; 8; 3-6 g/kg soil respectively. We discuss how studied ecological functions clearly translate into ecosystem services. The economic interpretation of the soil functions and ecosystem services was done, basing on the parameter assessment of the soil quality degradation and its recovery.

Keywords: soils, ecological functions, ecological services, oil, assessment, Sakhalin

Financial support:

(8297 - 469) Effect of biochar on Cd bioavailability in soil-rice systems and human health implication based on a meta-analysis

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Soil heavy metal contamination is a worldwide concern, which poses a threat to human health through food chain. Cadmium (Cd) is one of the most toxic heavy metals with relatively high bioavailability. As a main staple food crop, rice exhibits a strong ability to take up soil Cd, especially in contaminated soils. Biochar is becoming a popular multifunctional material in remediating heavy metal contaminated soils and improving food safety over the last decade. Biochar is effective to reduce Cd uptake by rice. However, there are different effect sizes among studies depending on different biochars and soil conditions. It is important to investigate the overall range of biochar's effect on soil Cd availability and rice uptake. It is also important to explore the key factors that influence biochar's efficacy in reducing Cd uptake by rice. Herein we conducted a meta-analysis to solve the above questions. Factors that may affect the effect sizes were considered including soil properties, biochar properties and application rate. Because Zn deficiency in rice may promote Cd absorption in organs and tissues, changes of Zn accumulation and Cd/Zn ratio in rice grains were also considered after biochar application. The result of meta-analysis shows that biochar can significantly reduce Cd concentration in rice by 39.7% on average, while there was no significant decrease for Zn. Cd concentrations in rice grain, shoot and root significantly decreased by an average of 41.6%, 37.4%, and 39.8%, respectively, while there were no significant changes of Zn concentrations in rice grain and shoot. Thus the Cd/Zn ratios in rice grain were decreased in biochar treatment, implying that the rice grain become much safer for consumption. The meta-analysis shows that the biochar's efficiency depends on its pyrolysis temperature, pH, inherent Cd content and application rate. Biochar with higher pH, lower Cd content, and moderate pyrolysis temperature (400-500 degrees Celsius) is more effective in reducing Cd accumulation in rice. Besides, soil properties such as pH, SOC and texture can also affect biochar's efficacy. Finally, the overall effects of biochar on soil Cd availability and soil properties were analyzed using meta-analysis. The results provide useful insights into which biochars are most effective, and the extent to which biochar can be used to reduce rice Cd uptake in different soils, which is helpful for soil quality improvement and human health enhancement.

Keywords: Biochar; heavy metal; meta-analysis; soil quality improvement; human health

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(1824 - 1590) Efficiency of biodegradable and pH-responsive polysuccinimide nanoparticles (PSI-NPs) as smart nano-delivery systems to enhance fertilizer/pesticide efficacy

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Special attention has been given on great potential of using polymeric nanocarriers to encapsulate pesticides/nutrients for controlled release and site-specific delivery in agriculture. In this work, biodegradable pH-responsive polysuccinimide nanoparticles (PSI-NPs) were synthesized to deliver molecules (e.g., drugs, nutrients, pesticides) to the phloem of plants, in order to improve the targetability and efficacy of effective components. Characterizing the delivery efficiency of these smart nano-delivery systems in plants is critical for their application to crop-specific problems. The PSI-NPs had an average size of 20.6 ± 0.6 nm with a negative charge on the surface (-24.7 mv). Coumarin 6 - loaded NPs show similar characteristics as the NPs formed in the absence of any probe molecules, which with a size of 21.3 ± 0.4 nm and a zeta potential of -28.5 mv. The PSI-NPs showed perfect responsiveness to changes in pH, as determined by fluorescence spectroscopy. The release efficiency of the model compound coumarin 6 increased with increasing pH, and reached 88% at pH ~ 8.3, while < 50% was released under acidic conditions (pH 5 ~ 6) over 24 hrs. The PSI-NPs were internalized into grapefruit cells within 30 mins, and the fluorescence of coumarin 6 was observed in the cell nucleus in 2 hrs after administration. The number of PSI-NPs internalized by plant cells significantly increased with time, from 19.1% at 10 min to 55.5% at 2 hrs ($P < 0.05$), as revealed by fluorescence measurements. The PSI-NPs did not show significant inhibitory effects on soil microbial growth or activity ($P > 0.05$). These results indicate that this smart nano-delivery system has the potential for enhancing use efficiency of pesticides and fertilizers by delivering effective components to targeted sites in plants.

Keywords: polymeric nanoparticles; release efficiency; cellular internalization; soil quality

Financial support: This study, was, in part, supported by a grant (Agreement #: 15-5300-171) from Citrus Research Board.

(7245 - 289) Long-term Effect of Different Fertilization and Cropping System on the Persistence of Antibiotic Resistance Genes in Soil Measured using Highly Parallel qPCR and sequencing

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The influence of manure application on fertilization is increasingly questioned due to the potential for selection of microbial populations harboring antimicrobial resistance. Different fertilization and cropping systems may influence short- and long-term residues of antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs) in soil. Soils from dryland (peanut) and rice paddy fields, which originated from the same non-agricultural land (forested) land, were amended with either chemical fertilizer, manure, or no fertilizer for 26 years before sampling. Samples were analyzed for antibiotics by LC-MS-MS and ARGs and MGEs using a qPCR array containing 384 primer sets. Amplicons obtained from 48 primer sets targeting selected ARGs and MGEs, and the 16S rRNA gene were also sequenced. Samples were collected from plots 12 months after annual fertilizer application to observe long-term effects. Six of the eleven measured antibiotics were detected in the manure applied dryland and paddy soils, but none were detected in the non-manured soil. Compared to the dryland soil, a higher abundance and diversity of ARGs was observed in the paddy soil corresponding to microbial population when no fertilizer was applied for 26 years. However, when chemical fertilizer was applied, a lower relative abundance and diversity of ARGs in the paddy soil was observed as compared to dryland soil. In general, compared to the unfertilized control, after 26 years of manure application (with unknown antibiotic content), there is not a major buildup of ARGs although relative abundance of certain ARGs were increased regardless of tillage style. Effect of long-term chemical fertilizer application on ARGs in soil are highly tillage depended. Compared to the dryland soil, paddy soil has a higher potential to accumulate ARG alleles regardless of application of manure. However, long term application of chemical fertilizer decreased the relative abundance of ARG alleles in the paddy soil. Long term application of manure increased not only the relative abundance but also the diversity of ARG alleles, especially under the anaerobic condition. These results illustrate the unintended consequence of fertilizer application and land tillage and demonstrate the need for empirical analysis of agricultural practices on the agroecosystem.

Keywords: antibiotic resistome, mobile genetic elements, dryland, paddy field, chemical fertilizer, manure

Financial support:

(3197 - 463) Managing Soil Health for Improving Human Health

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That the "health of soil, plant, animals, people and ecosystems is one and indivisible" has been recognized by ancient civilizations, but the concept is more relevant during the Anthropocene than ever before. The interaction between soil health and human health can be both positive and negative, just as anthropogenic activities can improve or degrade soil health and impact human health accordingly. Soil impacts human health directly as a source of essential nutrients and heavy metals in food, and indirectly as a source of antibiotics and pathogens from soil's microbial community. Availability of nutrients and toxic compounds, and of microbes for antibiotics and pathogens, also depend on land use and soil management. Therefore, the need to translate the scientific knowledge into action is both timely and urgent because of the: (i) increase in human population of 7.6 billion in 2018 to 9.8 billion by 2050, and 11.2 billion by 2100, (ii) decrease in soil resources allocated to agroecosystems (croplands and grazing lands) because of other competing uses, urban encroachment and degradation by natural and anthropogenic factors, (iii) growing preference in animal-based diet by population of emerging economies, (iv) increasing wastage of food throughout the supply chain from the farm and field to the dinner table, and (v) poor retention of the food because of the poor quality of water, air and the environment in developing countries. Thus, the link between human diet and soil health need to be thoroughly studied for diverse soils, ecoregions and farming systems, including for soils of urban ecosystems used for urban gardens and other social activities. In addition to the impact of the health of soils managed for agricultural production; health of other degraded, polluted and contaminated soils, can also impact human health and be studied. Examples of such polluted/contaminated soils include: industrial and urban solid waste landfills, mined soils, soils contaminated by nuclear waste and radioactive pollutants, and those polluted by other industrial wastes containing organic and inorganic contaminants. Therefore, there is a strong need to develop multi-disciplinary programs involving research, teaching and outreach initiatives pertaining to the ever-growing impacts of soil health on human wellbeing and the environment quality

Keywords: Anthropocene, Urban agriculture, Human nutrition, Toxicants, Soil contaminants, Antibiotics

Financial support:

(6332 - 958) Prioritizing Biophysical and Socioeconomic Factors for Enhancing Soil Fertility in Sub-Saharan Africa: Summit Results

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This companion paper reports on a soil fertility summit held as part of an effort by the KSU Feed the Future Sustainable Intensification Innovation Lab to lead an evidence-driven effort to identify soil fertility priorities in Sub-Saharan Africa (SSA). These efforts focused around key barriers and priorities to overcome such barriers. The focus regions were West Africa, East Africa, the Great Lakes region, and Ethiopia. A survey and summit were utilized with survey results reported in a companion paper at the WCSS (Stewart et al.) Facilitated discussion was used over a 2-day period in August 2017 in Dakar, Senegal and included ~30 invited participants who had responded to the survey. Common themes were identified across all regions: 1) Solutions, barriers, and strategies were interrelated and applicable among/between the limiting soil fertility characteristics (e.g., strategies to overcome N and P deficiency also applied to low SOC), 2) there is a need for expanded research leading to improved recommendations for site/region-specific conditions, 3) there is a need for education, communication, and training for farmers with a focus on peer-training and on-farm demonstrations, 4) there is a need build the capacity of extension service providers, 5) there is a need to strengthen knowledge transfer among/between researchers, extension service providers, and farmers, and 5) socioeconomic factors need to be explored and more social scientists need to be involved in developing solutions. The survey and summit results indicated that there are key biophysical and socioeconomic barriers and strategies that can either create an enabling environment or hinder progress towards improving soil fertility. Inorganic fertilizer access, use, and related implementation issues were prominent but other biophysical (e.g. increased access and use of quality organic materials) and socioeconomic barriers (e.g. access to financial resources, fertility recommendations, and extension support) were identified as equally important. The combined biophysical and socioeconomic results provide a clear picture of the interdisciplinary and interconnected nature of priorities to improve soil fertility. Plans for improving soil fertility across SSA must take an integrated approach, inclusive of the identified biophysical and socioeconomic factors. Action plans that only focus on a single factor, such as inorganic fertilizer availability or fertilizer recommendations, will likely fall short.

Keywords: Sub-Saharan Africa, Soil Fertility, Prioritization, Sustainable Intensification

Financial support: Program activities are funded by the United States Agency for International Development (USAID) under Cooperative Agreement No. AID-OAA-L-14-00006.

(7497 - 1081) Prioritizing Biophysical and Socioeconomic Factors for Enhancing Soil Fertility in Sub-Saharan Africa: Survey Results

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Soil health is the basis of the productivity of our farming systems, food and nutrition security, and the improvement of livelihoods and poverty alleviation in our world. Soils of sub-Saharan Africa (SSA) are largely unhealthy due to years of nutrient mining and limited organic or inorganic resupply. Crop yields have stagnated and high levels of food insecurity and poverty persist. Over 80 percent of Africa's agricultural lands are degraded, having either biophysical or chemical constraints that limit yields. The Feed the Future Sustainable Intensification Innovation Lab led a multifaceted effort to identify soil fertility priorities in SSA focused around key barriers and sustainable priorities to overcome such barriers. The focal regions were West Africa, East Africa, the Great Lakes region, and Ethiopia and a survey and summit were utilized. This paper presents survey results from 491 participants while a companion paper at the World Congress reports on the summit results (Pierzynski et al.). Most of the recommendations presented are known and are based on established strategies; however, the evidenced-based process for prioritizing these recommendations makes these reports useful for setting forth a prioritized action plan for future investments and strategies to improve soil fertility in SSA. The most frequent reported soil limitations across all four regions were N and P deficiency, acidity, and low soil organic C. For Ethiopia and the Great Lakes region, micronutrient deficiencies were also reported as part of the top five limiting factors, while low available soil water holding capacity was noted for West and East Africa. For biophysical limitations, all regions reported a need for access to quality soil testing and increased availability of inorganic fertilizers. Both Ethiopia and the Great Lakes region indicated that retention of crop residues on the soil was a barrier, while limited opportunities to maintain and build SOM were reported for West and East Africa. For socioeconomic limitations, all regions emphasized that access to financial resources was a barrier, particularly for smallholder farmers, as was the availability of public sector service providers to deliver appropriate nutrient management recommendations. The need for access to mechanization was reported for Ethiopia and West Africa, while barriers related to gender equity and the need to develop private sector resources were reported for the Great Lakes region and East Africa.

Keywords: Sub-Saharan Africa, Soil Fertility, Prioritization, Sustainable Intensification
Financial support: This study was made possible by the support of the American People through the United States Agency for International Development (USAID) under Cooperative Agreement No. AID-OAA-L-14-00006.

(2438 - 733) Soil demand for ensuring food security – a case study for Austria

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Aiming at a possible threshold for the quantity and quality of soil necessary for an import independent food supply of the Austrian population, the productivity potentials of Austrian agricultural soils with regard to the current and predicted food consumption and climatic situation have been evaluated. The identification of soils with high productivity potential was conducted using data of the agricultural soil map and the soil taxation survey. Based on these results, agricultural priority areas were suggested on a regional scale. Simultaneously, crop- and grassland yield potentials based on soil and climate data have been modelled for the future situation (period 2036 – 2065) using one SRES A1B climate scenario ("moderate") from ENSEMBLES (regional model "ALADIN") and a high emission RCP 8.5 scenario from CMIP5 ("extreme"). For arable land, substantial yield decreases are expected, whereas for grassland losses in the lowlands, but increases in the mountainous regions were stated. The soils of the priority areas proved to be more resilient than areas beyond. Thus the designation of important production areas seems to be of high interest with respect to the maintenance of agricultural production and food security. However, in case of extreme climate conditions in the period 2036-2065, results show that for the majority of crops a self-sufficient production to assure the Austrian food security seems to be endangered even if using the complete area. The situation is even more tenuous if solely the production within the agricultural priority areas is considered, although these areas account for about three quarters of the total agricultural production in Austria. Regarding grassland products, the balances are more even due to widespread use of land for meadows and pasture in the alpine regions, where sufficient forage can be produced for livestock breeding. The results of this project underpin the long lasting claim for a trend reversal concerning soil consumption with ascertained facts and figures. The evolved approach for the development of agricultural priority areas could become a useful instrument for land use planning to strengthen the importance of soil and food security.
Keywords: food security, soil demand, soil quality
Financial support: Ministry for Sustainability and Tourism

(8913 - 1952) Using Chrysanthemums as Profitable Phytoremediation of Heavy Metal Contaminated Soils: A case of five-year field experiments in Shanghai, Southeast China

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Phytoremediation, using plants to extract toxic metals from contaminated soils, has become cheap and environment-friendly methods for soil remediation. Chrysanthemum has a high capability of heavy metal accumulation, and thus is often chosen for phytoremediation. To study the ecological cleanup effects of phytoremediation, field experiments of planting chrysanthemum on a heavy metal contaminated field caused by application of urban creek sediments in the western suburb of Shanghai had been carried out for three consecutive years from 2013-2015. A variety of chrysanthemum called June White originally growing in Hunan Province of northern China was selected in this experiment. The concentrations of Cr, Co, Ni, Cu, As, Se, Pb, Zn, and Cd in the soil before the experiment was 170.81 mg kg^{-1}, 15.06 mg kg^{-1}, 53.11 mg kg^{-1}, 70.43 mg kg^{-1}, 2.30 mg kg^{-1}, 41.33 mg kg^{-1}, 589.56 mg kg^{-1} and 1.46 mg kg^{-1}, respectively. According to the National Standards for Soil Environment Quality (GB15618-2008), the soil was suffered from combined pollution of Zn and Cd , with safe thresholds in soils 150 mg kg^{-1} and 0.5 mg kg^{-1} respectively. The concentration of Zn in the roots, stems, leaves and flowers of the chrysanthemum was 360.08 mg kg^{-1}, 166.22 mg kg^{-1}, 498.18 mg kg^{-1} and 111.62 mg kg^{-1}, respectively; Cd was 0.78mg kg^{-1}, 0.65 mg kg^{-1}, 0.76 mg kg^{-1} and 0.42 mg kg^{-1}, respectively. After three consecutive years of phytoremediation, the contents of Zn and Cd in the soil were 421.89 mg kg^{-1} and 0.32mg kg^{-1} on average in 2016, reduced by 28.44% and 78.08% on average, respectively.Cd content in the soil has been decreased to safe value according to the national standards. The contents of Zn and Cd in the rice grain growing in the remediated field from 2016 to 2017 were 33.16 mg kg^{-1} and 0.05 mg kg^{-1} on average, respectively. This values meet the requirements for food safety (GB 2762-2012), suggesting that the remediated field can be returned for rice production. Moreover, planting chrysanthemum in the contaminated fields is also profitable, and the earning was expected to 8601.91 US dollars per each ha.
Keywords: Phytoremediation, Chrysanthemums, Soils, Heavy Metal
Financial support:

C4.3 - Soils and land use change

C4.3.1 - Ecological soil management systems and soil quality

(3627 - 2505) Changes in soil organic carbon stocks across the Forest-Agroforest-Agriculture/Pasture continuum in various agroecological regions

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Although several studies on carbon sequestration under agroforestry systems (AFS) are reported in the literature, they are highly variable in the study procedures as well as the nature of systems and locations. This makes it difficult to extrapolate the results to broader contexts of systems and locations outside the specific locations of the individual studies. The objective of this study was to undertake a statistically rigorous, quantitative assessment of the scattered results on soil organic carbon (SOC) stocks reported under various AFS, in comparison with those in agricultural, forestry, and pasture systems in different agroecological regions. Using mixed-effect models of meta-analysis, we synthesized data from 78 peer-reviewed studies that generated 858 data points on SOC stock under various AFS from 25 countries in Asia, Africa, Europe, North America and South America. The data points were used to assess the variations in SOC stocks under AFS of different age groups in comparison with other land-use systems (Agriculture, Forestry, Pasture or Uncultivated Land) in various soil-depth classes (0–20, 0–40, 0 –60, and 0–100 cm) in four major agroecological regions (arid and semiarid, ASA; lowland humid tropics, LHT; Mediterranean, MED; and temperate, TEM) around the world. Comparing AFS vs. Agriculture or AFS vs. Pasture, SOC stocks under AFS were higher by +27% in the ASA region, +26% in LHT, and +5.8% in TEM, but –5.3% in the TEM in the 0–100 cm soil depth. The AFS aged between 10–20 years had higher SOC

stock than newly established, as well as < 10-year-old systems across all soil-depth classes and agroecological regions. Improvement of SOC stocks under AFS varied across agroecological regions, the highest being under low humid tropics. Additionally, older agroforests contributed to higher SOC stocks than newly established systems. The results indicate that a general pattern of Forest – Agroforest – Agriculture – Pasture continuum can be expected in SOC stock decline during land-use changes in all ecological regions.

Keywords: Agroforestry, Climate-change mitigation, Land-use systems, Meta-analysis, Mixed-effects model.
Financial support: Self-supported

(1280 - 1007) Chemical and physical attributes for quality assessment of soils from forest areas altered by the use of pasture and agriculture in the northern Amazonia

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The agriculture practiced in the areas of the northern Amazonia still tries the slash and burn system, using the resulting ashes during the first year of cultivation, causing the loss of soil quality. Characterizing soils chemical and physical attributes and their response to forest / agriculture / pasture conversion will present some responses with choices of more sustainable land use systems that will keep the soil quality (SQ). The objective of this work was the characterization of the chemical and physical attributes of the soils of forest areas altered by pasture and agricultural use in the northern Amazonia. Soil samples were collected in two pasture areas (PGD and PGC) two agricultural areas (MA and MAX), one newly burned area (QM) and one indigenous forest area (FLOR) with control function. Samples were taken at three different depths (0-5, 5-15 and 15-30 cm). Acidity present at the areas (PGD, PGC, MA, QM and FLOR) reflected the advanced degree of soil weathering, as well as soil depletion caused by inadequate management. The use of fire for the management of the QM area helps to raise the pH only in the first 5 centimeters of the soil. The highest levels of exchangeable cations (Ca2 +, Mg2 + and K +) and available P, found in the analyzed surface areas, especially in the QM area, show the contribution of ashes to increase the amount of nutrients and make them available. The SOC levels found in the analyzed areas show that the conversion of forest areas to pasture and agricultural areas didn´t change as time passed by. The highest soil densities were found in the soils of PGD and PGC areas, associated to the management applied to these areas, but they are still off the critical limit for the development of the plants radicular systems. The abandonment of pastures with resurgence of spontaneous plants established conditions for the reestablishment of natural conditions similar to the indigenous forest area. The areas of agricultural use, due to slash and burn system, soil tillage with breaking of aggregates and pulverization of the soil particles altered the indigenous forest area characteristics.

Keywords: Keywords: deforestation-burning, physical quality, chemical quality.
Financial support: CAPES and FAPEAM

(3072 - 2594) Establishment of a Silvopastoral System with selection of native forest species, consortiated with Brachiaria (Brachiaria brizantha) cv. Marandú and Mucuna negra (Mucuna pruriens), in the Chiquitano Dry Forest Biome, Chiquitania Region of Bolivia.

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The need to use self-sustaining technologies that generate less environmental impact in the establishment of pasture areas for cattle production that takes place in the Chiquitano Dry Forest Biome (eastern Bolivia), creates great challenges for producers for the inclusion of ecological management systems of our soils, mostly of medium to low fertility. This project started in september of two thousand and seventeen, at the Hacienda Ganadera Bonanza, municipality of Concepción Bolivia, develops the insertion of a silvopastoral system making selection of native forest species at the time of partial deforestation of the forest, establishing integrated systems that generate positive impacts on forage production and conservation of our water, ecological and soil resources. Forest species such as morado (Machaerium scleroxylon), momóqui (Caesalpinia pluviosa), tajibo rosado (Tabebuia impetiginosa), and tipa (Tipuana tipu), originating from this subcaduciform biome, trees of forest importance whose larger diameters at one hundred and twenty centimeters of base, they were left standing when these areas were cleared, and then they were established in a silvopastoral system of pastures with Brachiaria *(Brachiaria brizantha)* cv. Marandú as the main forage, consortiated with a legume Mucuna negra (Mucuna pruriens), which was planted in the places of accumulation of deforested plant material, distributed in protein banks for the cattle. The establishment of this system allows the shading the thirthy percent of the area, in a biome with seasons of the year are marked by rainy summers and especially season of drought in winter, in which, the shade generated from these trees provides greater moisture conservation in the established microclimate and soil, important factors for the absorption of nutrients in the plants and production of forage, in this critical stage of the year. This diversification with different forest and forage species within the same area, properly managed, provide large amounts of biomass and plant material in coverage, generating high microbiological activity and in turn obtaining available fertility with the constant cycling of nutrients from of decomposing biomass. The execution of this work in process, tries to show that through the innovation of new efficient systems and of lower environmental impact we can generate alternatives to conventional systems that have already proved unsustainable and degrading of our natural resources.

Keywords: Silvopastoral, diversification, forage, biomass.
Financial support: Universidad Autónoma Gabriel René Moreno and Fapemig

(1267 - 2060) Microbial activity and physicochemical traits of floodplain soils affected by tailings deposition from the Fundão dam breach, Minas Gerais, Brazil

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On November 5, 2015, the Fundão tailings dam (Samarco's Germano Industrial Unit, Mariana, MG, Brazil) failed, releasing c.a. 43.7 million cubic meters of iron mine tailings and water into the into the upper Doce river system. Along the flow path between the breach site and the Candonga reservoir, ca. 100 km downstream, soils were scoured and vegetation removed, resulting in extensive deposition of a mix of tailings, soils, and debris on river flood plains. Rehabilitation efforts have been conducted in the affected areas by the NGO Fundação Renova, including the seeding of forbs and grasses. The aim of this study was to evaluate the evolution of the microbial activity on tailings deposited in these areas, as a subsidy to the rehabilitation efforts. Sampling of these substrates (0-20 cm depth) took place 16 and 22 months after the event (rainy and dry seasons, respectively). In each season, 87 composite samples (i.e., three subsamples) were taken along eight affected flood plain sites (AFS; 81 samples), as well as at two reference sites: one affected flood plain left to recover naturally (no seeding) (RFS; 3 samples) and at an unaffected secondary growth natural forest site (NFS; 3 samples). We evaluated physicochemical and microbiological traits of the substrates, including their metabolic quotient (qCO_2 = microbial

respiration / microbial biomass) using multivariate analysis (PCA, PCoA) and artificial neural networks. In the wet season, total nitrogen, qCO_2 and Mg were determinant in distinguishing AFS from RFS and NFS samples, whereas in the dry season Mg, H^+ and CTCt showed the most discrepant values among these areas. The data indicate that the rehabilitation actions used in AFS sites resulted in C inputs to the substrates, improving their chemical properties and promoting the reestablishment of microbial communities, ultimately leading to a decrease in qCO_2. Twenty-two months after the event, six out of the eight AFS sites showed increased similarity to NFS, while the two remnant AFS sites - which are nearest to the breach site - presented the most distinct chemical and microbiological values. The implemented rehabilitation actions have actively contributed to the reestablishment of the chemical and microbiological properties in the affected floodplains. The continuity of this monitoring will be instrumental in informing on the resilience and need of directing management actions towards the rehabilitation of these areas.

Keywords: mine tailings; soil microbiology; degraded area rehabilitation; Fundão dam breach
Financial support: CNPq, Capes, Fapemig

(1581 - 946) Optimization of landscape structure and land use by designed method combining GIS and artificial intelligence approaches

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The most serious degradation factor affecting soil quality in the Czech Republic is water erosion (as in other countries), which is a threat to more than 50% of agricultural land. One of the reasons for the accelerated water erosion in the Czech Republic is the structure of the agricultural land fund, where significant changes occurred in the post-war period, namely by land consolidation, which caused the disappearance of landscape elements, including greenery. Changes and increased intensity of agricultural land use are common, to varying degrees, in a number of countries . The result in the Czech Republic is the present fragmented landscape with an average land area of about 11 hectares. The once typical richness of landscape and biodiversity is now disappearing. In our contribution, we present a possible approach to soil protection and biodiversity enhancement in the landscape, using our method of designing changes to the structure of the agricultural landscape, which takes into account erosion threats along with the reduced biodiversity of the landscape. Based on raster modelling of erosion processes and connectivity in GIS, Artificial Intelligence and Statistics, this method suggests remedial measures that will lead to an overall reduction in the risk of erosion and other related degradation changes, while increasing the functional connectivity to the landscape, resulting in increased biodiversity in the area of interest. In the presentation, we demonstrate the approach on South Moravian sites, which, with their Chernozems, are among the most fertile areas in the Czech Republic , and are also among the locations most endangered by erosion and other degradational effects, where there has also been a significant decline in landscape features.

Keywords: water erosion, functional connectivity, GIS, optimization
Financial support: This research was supported by the Ministry of Agriculture of the Czech Republic (Project No. QJ1630422).

(5684 - 1449) Soil biotic contributions to nitrogen fertility in manure-amended agroecosystems: perspectives and practical implications for humid temperate regions

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Management of soil nitrogen (N) fertility remains a challenge for the 21st century due to inefficiencies in nutrient transfer within the soil-plant system and susceptibility of N loss from agroecosystems, particularly in humid temperate regions. While manure from plant and animal sources is a suitable, low-cost N fertilizer, the heterogeneous nature of these manures makes it challenging to predict how quickly and how much of the applied manure N is transformed into plant-available N during the growing season. This problem is exacerbated by the fact that the plant-available N concentration in manure-amended soils is generally evaluated in laboratory-based soil tests, which are inherently biased because they reflect manure reactions in a highly-controlled environment, without plants and soil fauna, and do not represent field conditions. The objective of this work is to (1) discuss the barriers to develop simple indicators of potentially mineralizable N in manure-amended soils, and (2) consider alternative methods to predict the plant-available N supply *in situ* in manure-amended soils. Our discussion focuses on the contribution of microorganisms and soil fauna, notably earthworms, to the dynamic soil N supply in humid temperate regions. We will explore concepts related to the assimilable energy value and priming effects of manure, as well as the stoichiometric homeostasis in nutrient ratios maintained by soil organisms, that appear to control N turnover in the soil foodweb. We conclude with practical recommendations that aim to conserve more N in the soil-plant system and minimize N losses from manure-amended soils in humid temperate climates, consistent with the principles of ecological soil management.

Keywords: soil nurient management, soil ecology, temperate agroecosystem, green manure, animal manure
Financial support: National Science and Engineering Research Council of Canada

(1840 - 810) Soil macrofauna as indicator to recover degraded pastures with cover crops and agroforestry systems

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The objective of this long term research is to recover degraded lands for sustainable agriculture that were affected by shifting agriculture and overgrazed pastures, through the use of soil biodiversity indicators. The recovering trials in 3 farms are fertilized cover crops with the legume *Centrosema macrocarpum* (centrosema) and the establishment of 3 prototype agroforestry systems (AF) based in a) woody trees with *Swietenia macrophylla*, *Guazuma crinita* (GC) , *Calycophylum spruceanum* (CS) and *Simarouba amara* (SA), b) woody-fruit trees with *Cedrelinga cateniformis*, GC, SA, *Inga edulis* and *Bactris gasipaes* and a c) silvopastoral system with centrosema and woody trees with GC, SA and CS. Initial degraded compacted soils were covered with degraded grass (*Brachiaria brizantha*) and weeds and the soil was very acid (80% of Al saturation) with 4 ppm of P, low soil organic matter ,cation exchange capacity and soil macrofauna. Soil was weeded and fertilized with rock phosphate (40 kg/ha) and then centrosema was planted followed by the plantation of trees with localized fertilization application. After one year of the establishment of the cover crops, the soil macrofauna was evaluated during summer season using a metal sampler with a volume of 25x25x10 cm. at two depths 0-10 and 10-20 cm. The AF system based in woody trees presented a total of 2240 individual /m^2 in 10 orders at 0-20 cm depth and the AF based in woody and fruit systems presented 1337 individual /m^2 in 9 orders and the lowest was for the silvopastoral systems with 733 individual /m^2 in 10 orders. From the 13 taxonomic orders found in all treatments,the predominance was for Hymenoptera(Family of Formicidae) with 70% in woody trees, 46.6%in the woody and fruit trees and only 23.8% for the silvopastoral system. The second most abundant was for order Haplotaxida (Lumbriculida) with 23.2 % in woody trees, 26.1% in woody and fruit trees and 55.6%in silvopastoral systems. In conclusion, soil macrofauna with the predominance of the orders of Hymenoptera and Haplotaxida increased with the different land recuperation agroforestry systems.

Keywords: Keywords: agroforestry systems; macrofauna ; Hymenopthera ; Haplotaxida,
Financial support: The authors are grateful to VLIR (Belgium Flemish Universities) for financial support from the Belgium Government, and the Soil Science Department, Faculty of Agronomy, UNALM for the technical and laboratory facilities.

(6620 - 1441) Soil organic matter properties and greenhouse gas emissions in tropical peatlands under land use change

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In the last decades, large areas of tropical peatland swamp forest have been transformed into productive lands in Southeast Asia. These land-use changes have a noteworthy influence on global GHG emissions. Following drainage and land-use change, the alteration of soil physical and chemical properties is important for peat decomposition rates. To characterise the soil alterations induced by drainage and land-use change, we studied peat from three land management conditions (intact peat swamp forest, drained and logged forest, and oil palm plantation). Specifically, heterotrophic and total soil respiration, litterfall, litter decomposition and peat physico-chemical properties were determined. Peat was sampled at different depths and then partitioned into fine peat, small logs, medium logs and big logs component. Subsequently the fine peat was fractionated into very light, light, medium weight and heavy fraction with density liquids. The density fractionated samples were analyzed with attenuated total reflectance Fourier Transform InfraRed and X-ray Absorption Near Edge Structure. Soil respiration was separated using the trenching method and GHG was assessed monthly with static dark chambers for two years. Litterfall and litter decompositions were determined with litter traps and mesh bags, respectively. Overall, the GHG fluxes results produced in this study point towards a negative carbon balance (i.e. net ecosystem loss of carbon) for the drained forest, a pronounced negative carbon balance for the oil palm plantation and a near neutral balance for the intact forest. The impacts of N fertilizer application in the oil palm plantation lasted only a few days and were unlikely to have significant consequences on the annual carbon budget. Diurnal efflux measurements showed that concerns over the day/night variability of carbon dioxide fluxes are not particularly pertinent in these tropical peatlands. The principal soil property affected by drainage and land-use change was the abundance of logs in the soil. The Fourier Transform InfraRed and X-ray Absorption Near Edge Structure showed that the peat from the oil palm sites lacked phenolic peak and the aromatic peaks was slightly smaller than in the primary and degraded forest. In summary, the results generated in this work represent noteworthy data about the carbon budget and GHG dynamics in tropical peatlands and will help decision making by policy makers and land managers for sustainable use of these ecosystems.

Keywords: X-ray absorption near edge structure, total reflectance Fourier transform infrared, N-induced respiration, heterotrophic soil respiration, litterfall, environnemental variables
Financial support: Australia (Grant Agreement # 46167) and the European Community's Seventh Framework Programme [FP7/2007–2013] (Grant Agreement # 226310)

(8325 - 960) Valuation of soil ecosystems services under different restoration models in a tropical hotspot

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Atlantic Forest biome has gone through a period of land use changes, due to deforestation for urbanization and agriculture. Recently, many national and international restoration initiatives have been promoted to recuperate Atlantic Forest ecosystem services. Deforested areas can be restored by active (planting) or passive (natural regeneration) models. The use of passive or active restoration has both ecological and economic implications (passive, in general, may be cheaper). Understanding the differences of the impacts of different restoration models on soil ecosystem services provides important scientific and practical lessons for increasing forest cover in the Atlantic Forest. Certain soil parameters are essential for successful restoration of degraded lands and it is fundamental to incorporate soil ecology into planning of restoration projects. Nevertheless, there is a limited information in literature, describing comprehensively the effect of active or passive restoration on soil ecosystem services. Here, we examine soil properties under different models of reforestation in tropical conditions. We compared impacts of three different active restoration models with natural regeneration, pastureland, and old-grown forest on lowland soils in Brazilian Atlantic Forest. We show that while some soil ecosystem services will change (such as the concentration of some nutrients) under different restoration models other, vast majority, are similar (such as carbon content or water storage). We then valuate relative monetary difference of ecosystem services provided by each restoration model. Our research contributes to closing knowledge gap that exists on understanding soil-restoration interactions and to successful large-scale restoration of Atlantic Forest.

Keywords: tropical soil; restoration; model; valuation of soil ecosystem services;
Financial support: International Climate Initiative (IKI), Project title: Unlocking economic opportunities to scale Forest Landscape Restoration in Brazil, Project Number 17_III_089

C4.3.2 - Assessment and inventory of land use change under the SDG´s perspective

(5743 - 218) Assessing impacts of rural livelihood transition on non-point source pollution under different scenarios at the scale of small catchment: a case study in the Dongting Lake region

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Rural livelihood transition has a great important influence on water pollution. This study introduces a coupled model as a method which combines multi-agent systems (MAS) and improved export coefficient modeling (IECM) in anticipating the impacts of rural livelihood transition on non-point source pollution, at a small catchment scale. The MAS was used to simulate the dynamic process of household livelihood transition, while the impacts on non-point source (NPS) pollution were estimated by IECM. We applied this integrated model to a small catchment in the Dongting Lake region of southern China under 3 alternative scenarios of agriculture income increase(A), non-agriculture income increase(N) and current trend(T). The results are as follows. Rural livelihood strategies were significantly influenced by the factors of market price, causing transformation in cropping system, land use intensity, resident population and number of pigs. A continued projected decline of nitrogen load was detected under both "N" and "T" scenarios, but little change under "A" scenario; which only decreased for a short time and then slowly increased to initial level. Although the nitrogen loads under "N" scenario descended more than "T" scenario, its total rice yield and

the number of pigs decreased more either. Thus the "T" scenario was considered as the best development scenario which can achieve both food security and environmental sustainability. This integrated model is helpful for identifying more effective strategies to reduce agricultural pollution in the future.

Keywords: Livelihood strategy; Land use intensity; Non-point source pollution; MAS; IECM;

Financial support: the National Nature Science Foundation of China(41130526)

(3750 - 591) Learning from past land use changes to achieve SDG 2 and SDG 12

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Understanding past and present land use change is essential to achieve the Sustainable Development Goals (SDGs). The focus of this talk will be on SDG 2 and 12, and on land use changes in Central Europe due to the development of agriculture and technology. Agriculture is a complex system, which consists of natural variables such as soil, climate, the water cycle and vegetation. Society influences these variables, for example through tillage, carbon emissions, eutrophication of water bodies through excessive fertilization, and selective breeding. This has an effect on the achievement of several SDGs, such as SDG 2. Because agriculture is a combination of the natural and the social system, it forms a complex social-ecological system (SES). This SES developed during the Neolithic transition and changed through time. Analyzing the development of the SES agriculture in Central Europe by using the adaptive cycle contributes to our understanding of the complexity of the SES. By combining study results of different disciplines such as soil science, botany and social sciences, and analyzing them using the adaptive cycle, it is shown, that the SES agriculture has been a resilient system for thousands of years, despite facing challenges such as soil erosion. Further, the introduction of new methods of soil cultivation, for example the introduction of the plow or the mechanization of agriculture, changed the management practices within the SES agriculture and had an influence on soil. Still, the SES agriculture in Europe was and is adaptive to change and resilient. By examining past agricultural developments in other regions of the World using the adaptive cycle, the development of agriculture could be thoroughly understood. This might lead to new approaches on how to achieve SDG 2 and SDG 12 on a global scale.

Keywords: agriculture, social-ecological systems, adaptive cycle

Financial support:

(6722 - 1185) Mainstreaming gender into adaptation and mitigation strategies to combat climate change and its impacts to achieve sustainable development goals (SDGS)

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Gender Mainstreaming implies assessing the implications for women and men of any planned action and ensuring that both women's and men's concerns and experiences are taken fully into account in the design, implementation, monitoring and evaluation of development activities. Sustainable Development Goals (SDGs) are set out goals (17) which countries are expected to meet their implementation as an essential part of the 2030 Agenda with targeted SDGs such as the need to combat climate change and its impacts SDG 13; end poverty SDG 1, end hunger SDG 2, reduce inequalities SDG 10 and gender equality-empower all women and girls SDG 5. Climate change and its impacts, such as drought, floods, extreme weather events, reduced food and water security, loss of agricultural lands, affect men and women differently with women being the most vulnerable group. Due to their dependence on natural resources and low access base to agricultural assets women are disproportionately affected by adverse weather condition occasioned by Climate Change. Women are responsible for household water supply and energy for heating, cooking and as climate change impacts increase, these tasks become more difficult for them with limited coping strategies. Despite their contributions to food security, women tend to be invincible actor in development as they are virtually absent at decision making processes. As a result of huge gender disparities and pervasive negative effect of climate change on soil and agricultural sector, small holder farmers who are predominantly women are more vulnerable to climate change and need mitigation and adaptation strategies to cope with its impacts by addressing their concerns in these areas- increase in position of authority (voice), enhanced access and control of agricultural assets, bridge gender gap , address malnutrition and reduce domestic and international migration through infrastructural development and good governance. This paper seeks to bring to the fore the vulnerability of women in agriculture and the need build their skills and competencies on adaptation and mitigation strategies to deal with climate change and enhance the achievement of food security ,Sustainable Development Goals (SDGs)No wonderthe late female environmentalist WangariMaathai,underscored the role of women in combating the impact of climate change,said "Women hold the key to Climate's Future".

Keywords: gender, Sustainable Development Goals (SDGs) and Climate change

Financial support: Federal Ministry of Agriculture and Rural Development, Nigeria

(9868 - 2845) SDG's as a guide for the development of relations between soil science &society

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The SDG's provide an excellent focal point for soil research in terms of societal impact because at least food security (SDG 2), water quality (SDG 6), climate mitigation (SDG 13) and biodiversity preservation (SDG 15) cannot be achieved without substantial input of soil expertise. The SDG's should ideally be considered jointly in a systems analysis. There is a risk, however, that widely accessible soil databases will be used by colleague scientists focusing on agronomy, hydrology, climatology and ecology, assuming that using pedotransferfunctions in their models, fed by such data, will satisfy the demand for soil expertise in interdisciplinary modeling. But to adequately characterize the dynamic behavior of soils in space and time, that has significantly affected societal developments in past and present, more is needed than a set of seperate soil characteristics. Classes in soil classification can act as class-pedotransferfunctions, describing characteristic soil dynamic behavior of a given soil , also as a function of various forms of human management. Empirical expertise can in this context add substantially to results of modern quantitative modeling procedures. Every soil has a particular and unique story to tell ! Demonstrating that soils are not only important for agricultural production but also contribute significantly to a range of other ecosystem services is important to illustrate that soils form the foundation of human existence. Of particular importance are governmental rules and regulations covering soils. As bureaucrats tend to be splitters rather than lumpers, topdown regulations tend to become overbearing and evermore unconvincing if they get more detailed. A bottom-up approach, defining location-specific key indicators for economic, social and environmental performance based on the SDG's, coupled with intensive interaction with stakeholders, need more emphasis in future. Modeling of the soil-water-plant-atmosphere system, applying validated models, can provide such key data.

Keywords: pedotransferfunctions, soil classification, environmental regulations.

Financial support:

C4.4 - Soil education and public awareness

C4.4.1 - Soil science education in the 21st century

(3085 - 1621) A digital soil mapping training course tailored for land use planners

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Digital Soil Mapping (DSM) has given a new direction to pedology. DSM methods are in constant progress, but their use outside of academia is still limited. The objective of this work is to present the structure and results of a five-day DSM training course offered to a group of undergraduate teachers, applied researchers, rural extensionists, land use planners, and policymakers. The course was divided into three modules: 1. (day 1) Soil survey and classification, (day 3) with description of field soil profiles and identification of soil-landscape relationships; 2. (day 2) Introduction to DSM, including geographic information systems (GIS); 3. (day 4) Applied DSM, spanning spatial sampling, statistical learners, (day 5) spatial prediction, and statistical validation. Participants were asked to deliver a digital soil map at a spatial resolution of 30 m (scale of 1:10,000) with its accompanying uncertainty measures till the end of the course. To that end, they were provided with free and open source software, an open covariate data. To train the statistical learners, participants used 803 field soil profiles plus observations created on the computer screen based on soil-landscape relationships. Various statistical learners were used and their results were finally compared based on map purity computed using cross-validation and an independent set of 64 field soil profiles. Participants that produced the maps with the highest purity (53-58%) commented on their DSM decisions. The other participants commented on the reasons why their maps had an inferior purity (42-50%). Most of them mentioned the spatial sample size and configuration, while a few mentioned lack of experience with GIS. The small differences in map purity suggest a limited influence of previous knowledge. Next, participants compared their maps based on their visual appearance and purity. They concluded that different statistical learners produce different maps and that their performance is influenced by the spatial sample size and configuration. Prediction uncertainty maps were considered very useful to direct further field sampling. Overall, the course was very well evaluated by the participants, who reported that practical classes were fundamental to approximate the content studied to their reality. Although some said to feel uncomfortable to apply the new knowledge, others with more experience have already offered a similar course to rural extensionists and land use planners.

Keywords: Education; soil survey; pedometrics; expert knowledge
Financial support: CNPq

(9347 - 1301) A global network for a virtual world soils exhibition: a new approach to education and advocacy on soils

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The best place to teach and study soils is the in a pit in the field where properties and diagnostic features may be observed under natural conditions. Yet, this is not always possible. Soil monoliths are the best alternative to the study of soils in the field. Monoliths are undisturbed vertical sections from a soil profile wall that have been treated with a transparent glue for stability so that they can be maintained over time. The natural appearance of the soil is preserved in this way, including genetic layers (horizons), colour, structure and other features such as stoniness and rooting. Soil monoliths are mounted for display and teaching purposes and, in combination with field description and chemical and physical data, they are a reference for science and education. Soil exhibitions allow people to view and study soil from different geographic locations together in one place. The impact of soil monolith collections can greatly be enhanced by provision of online access. After having made high resolution images of the collections, various pathways for access and exploration of monoliths (images, descriptive and laboratory data) may be realised. Collection search and display tools, developed by ISRIC, provide access (images and data) to soil monoliths (the total collection of the world soil museum is over 1000 soil monoliths). These tools allow search of soils from a specific country and/or by taxonomic soil type. Or, in a geographic explorer, by their location (x,y coordinates) on a world map or a high resolution satellite image of the earth surface. This makes it possible to view the monolith or soil profile (through pojection of the profile image on the location of sampling) in the context of the terrain, land cover and land use of the given location. In support of education and advocacy on soils, exchange of experience on methods and ways to disclose knowledge and collections is required. The existing and new tools to create online access to the public of soil collections and information may be shared between soil museums and educational centres. A global network of soil museums and educational centres is proposed that facilitates this exchange. Partners subscribe on a voluntary basis to the network. The joint presentations of soil collections will be an open resource, accessible through a website of the network, and it will create a new virtual platform for education and exchange on soils of the world and of specific regions.

Keywords: education, exhibition, monoliths, virtual, network
Financial support:

(2211 - 1976) An *app* for teaching soil taxonomy. A first experience with agronomy students

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Soil Taxonomy is complex and uses difficult terminology. Therefore it is understood and used by only a small amount of people. The complexity of soil terminology is probably the greatest impediment faced by educators when teaching Soil Taxonomy. The system can be simplified for introductory level classes focusing on the links between soil classification and the soil forming factors and it is recommended to use a glossary for all the terms not clearly explained in the keys. The subject 'Soil system' is the first approach to soil for agronomy students of the UNRC. According to two surveys conducted in 2012 and 2016 after the end of the course, taxonomy was one of the most interesting topic for the students but was also the most difficult to understand (48% of the students chose taxonomy as the most difficult topic) and only 23% of the students considered it as the best understood topic. In order to improve the understanding of soil taxonomy we decided to incorporate new educational tools like education through mobile devices (m-learning). M-learning has some advantages as: portability, ubiquity and immediacy among others. There are globally several successful experiences with m-learning because students have a positive perception of learning through mobile devices. We developed an application for Android devices to introduce the students to soil classification in a more friendly way. The main aim of the app is to help students to classify soils (Great group level) through simplified keys. In addition the app includes distribution maps of dominant soil orders, soil profiles pictures, simplified keys with links to a glossary of terms and a glossary with pictures. A survey conducted in 2017 to students who used the application to learn soil taxonomy showed that the percentage of students who think that taxonomy is the hardest topic decreased from 48% to 31% and it was chosen as the topic which was best understood (41% of the students against 23% in the previous surveys). In addition most of the students think that using the application made easier the understanding of soil taxonomy. Until now the application was used only in one course but it seems very promising according to our preliminary results. The availability within the app of distribution maps of dominant soil orders and pictures of soil profiles and diagnostic characteristics could also improve the integration between taxonomy and other topics

as genesis and morphology.
Keywords: Smartphone, m-learning, soil taxonomy
Financial support:

(9215 - 2836) Interdisciplinary and participatory methodologies for education in soil science

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The management and conservation of healthy soils in the tropics is complex, demanding knowledge from different fields and the involvement of multiple stakeholders. The complexities involve soil social and political contexts, local knowledge and participation, role of organisations and development of new technologies. To address these complexities, the lack of interdisciplinarity and disconnection between farming realities and scientific knowledge in soil science education at universities is often a problem. In order to overcome this gap, there is a need for strategies and methodological approaches that link science, farmers' practices and social movements, enabling the horizontal construction of knowledge that is useful and effective on the ground. The objective of this study is to provide new insights on how to engage scientists, bachelor, master and PhD students and their research with farmers and their reality. For this, we will use as an example the experience of the interdisciplinary research Program: FOREFRONT, during the years of 2016 and 2017, at Federal University of Viçosa, in Zona da Mata region, Brazil-MG. The experience is described through different methods used during Scientific Excursions organised within a regular soil science discipline offered by the university. During the excursions, students were able to perform semi-structured interviews, participatory soil quality assessments and transect walks. Besides, students constructed fuzzy cognitive maps with groups of farmers to assess their perceptions on nature's benefits. Social organisations were involved during the process of organising and executing the excursions, sharing their ideas and vision. The first research results came out in 2017, and were shared with groups of farmers and students. For returning the results, sceneries, called artistic pedagogical installations, were prepared using artistic, audio-visual and ludic elements where people could observe, interfere, reflect and discuss about nature's benefits. Farmers were encouraged to share their own thoughts about soils and link it with other components of nature. Interdisciplinary and participatory education methodologies as proposed here, foster collaborative research and learning, towards an agronomic education more integrative and connected to farmers practices, perceptions and realities. This is only possible through the development and maintenance of partnerships and mutual exchange among different stakeholders.
Keywords: scientific excursions, fuzzy cognitive maps, artistic pedagogical installations, social movements
Financial support: Interdisciplinary Research and Education Fund of Wageningen University (INREF),

(4929 - 2608) Serving Society Through Soil Science: A Case Study of the "What's In Your Soil?" Project in Chicago, IL, USA.

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Once the domain of traditional agronomy and soils departments at U.S. land grant institutions, soil science undergraduate degree programs and soil science course offerings have have creeped into other academic majors, including environmental science and natural resources. This is the case at DePaul University, a private Catholic university in Chicago, where I teach in the Department of Environmental Science and Studies. Each autumn quarter I teach a course for undergraduates called "Environmental Soil Science". Students in the class are majoring in environmental science, environmental studies, geography, anthropology, sociology, and even commerce. Since my department does not offer a complete soil science curriculum, I focus my lectures and the accompanying three-hour laboratory on teaching students the concepts underlying soil quality. Students participate in my "What's In Your Soil?" (WIYS) research project in the laboratory section. The goal of WIYS is to map spatial patterns of soil quality indicators (SQI) on soils collected from residential lawns and gardens in Chicago communities. Using the USDA-NRCS Soil Quality Test Kit as a guide, students measure indicators including pH, carbon, nutrients, microbial respiration, and Pb. To date students have mapped spatial patterns of SQIs in over 140 soil samples in eight of Chicago's 77 official communities. We recruit homeowners to WIYS with assistance from community organizations, having students place flyers in mailboxes, pubs and coffee shops, and via crowd sourcing. All homeowners who participate in WIYS get their soil tested at no cost. Students perform all the tests and then prepare and send the homeowner a comprehensive written report that educates them on soil quality concepts, describes the results of each SQI, and provides recommendations on how the homeowner can maintain and improve their soil quality. The growing popularity of urban and community gardening in Chicago has brought more people in contact with potentially contaminated soil, hence the need for projects like WIYS that are designed to serve society through soil science education. WIYS embodies DePaul's mission by offering free soil testing, by giving students the opportunity to engage with homeowners, hone their written and public communication skills, and to "wear the hat" of a soil consultant by training them to conduct field collection and laboratory analysis of urban soils.
Keywords: Soil quality, Lead (Pb), urban soils, soils and society
Financial support: College of Science and Health Faculty Summer Research Grant

(4128 - 2087) Teaching soil science to engineering undergraduate students: introducing flipped instruction alongside institutional-regulated traditional methods.

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Traditional teaching at universities has been almost unchanged (and unquestioned?) over the centuries. It focuses on listening to lectures (knowledge transmission) in class and students are given a passive role on teacher-centered pedagogy. On the other hand, Soil Science field and lab classes represent opportunities for students to practice active learning. In spite of that, student engagement varies between theoretical and practical classes, and improving student active participation has to be a professor's concern and duty while planning the course. Therefore, the objective of this study was to analyze the effectiveness of introducing flipped classroom strategies (case-based learning), in addition to traditional theoretical classes, to promote active learning. The first class takes place at the Computer lab, where students download geological and soil maps and survey data, made available by CPRM and EMBRAPA, of a given municipality chosen by each student to work on throughout the term. They are also given all classes notes. As lectures (on reverse order) are given, Civil and Environmental Engineering students are guided to propose a sustainable soil use, either for building foundation/construction material or environmental issues (e.g. soil residues disposal and remediation), through data interpretation and application to real scenarios. As a result, several questions emerge and students seek orientation, both online (Whastapp group) and at the office. Online collaborative learning becomes regular and both students and professor may answer questions, but professor approaches it in class if involving more complex contents. Asking questions is a great change in student attitude and represents the main goal to achieve active learning. Students, particularly to discuss soil profile data outliers that they come across, demand additional class-time for knowledge construction. Two difficulties are found: i) flipped teaching adaptation is

challenging as students become responsible for being active learners usually for the first time; ii) solely adoption of traditional teaching by many institutions makes the use of flipped instruction an additional work and leads to unaccounted hours for students and professor. One question remains for us to reflect on: how professionally insightful is traditional teaching for all soil data users, which we are demanded by society to educate in order to rescue us from permanently environmental-damaging our Planet?

Keywords: active learning, student engagement, theoretical content
Financial support:

(5132 - 2550) These are the soils of my country! An educational project based on the methodology network

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It has been demonstrated that the sustainable management of soils contributes to increase food production and its nutritional content, as well as to adapt to climate change and its mitigation. The Regional Consortiums for Agricultural Experimentation (CREA), started an educational project on soil science for secondary schools. CREA is a non-profit organization formed by more than 2,000 farmers, share experiences, generate knowledge and power ideas, to foster sustainable development of our companies and nation. Within this context, in 2017, CREA, through the Environment Area (R & D) and the Education Area (Integration to the Community), with the technical support of the Argentine Association of Soil Science (AACS), the National Institute of Agricultural Technology (INTA) and of the Global Soil Partnership of FAO, developed a project named "These are the soils of my country". The objective is to promote in the educational field, especially in new generations of students, the awareness of the natural resource in which is based the mail economic activity of Argentine. With this purpose, during the past year, schools from different regions of the country were invited to prepare research projects about soil resources. These projects were guided by CREA farmers, science and technical professionals from different institutions advisors. A total of 43 research papers were received from more than 800 students, coordinated by school authorities and teachers from different subjects and 60 professionals from public and private organizations were part of the pilot test. Four interschool meetings were held, and teams of students exposed the methodology used and the results obtained in their investigations. Then a "value committee", composed by experts in the subject, could consult the authors about the aspects they had in to account to elaborate their work. Once the presentations were finished, each team received a personalized feedback of their work and were invited to continue developing the research on the subject. The purpose was that the students would consider the importance of soil in the food production and the care of the environment. In addition to the educational experience, "These are the soils of my country" allowed to consolidate a multidisciplinary network of teachers, technicians, researchers, agricultural farmers and future professionals (students), in the different communities.

Keywords: education, soils, learning, methodology, research
Financial support: Area of Social Vinculation (Integration to Community) and Environment Area (Development & Research) CREA

(7390 - 1727) Virtual Reality at the Rio Grande do Sul Soil Museum

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The Rio Grande do Sul Soil Museum (RSSM) has features that promote an inspiring, fun and engaging learning experience. MSRS is the pioneer in Latin America and since its inauguration in 1973 serves as an important tool to support teaching, research and extension activities. In the collection are more than 90 monoliths from different classes of soils of the state of Rio Grande do Sul, as well as rocks, minerals, maps, pictures, books and other equipment used in pedology. Monoliths are identified with taxonomic classification, environment of occurrence, analytical and morphological data. All this information can be accessed via QR Code directly on the visitor's mobile device. Since 2016 the museum has invested in partnerships for the generation of digital technologies that contribute to the dissemination of information on soils, putting itself at the forefront of innovations in soil education. New low-cost technologies and innovative approaches can motivate students and enhance understanding skills through immersive experiences. The objective of this work is to share the experience in the application of affordable e and user friendly tools to promote a learning about soils and their distribution in the landscape (soil-landscape relation). In the year 2017 during the collection of new monoliths for RSSM, images were taken from the environment where the soil occurs, using a mobile ZenFone 3 Zoom, Asus, equipped with the Camera Cardboard application, by Google. It is important to emphasize that several other devices can be used in this step. The images were acquired using the 360° function of the device and are available at *www.facebook.com/departamentodesolosufsm*. This social network was chosen because it has a 360° image recognition feature, without the need for post processing by the user, which reduces the need for specialized software. This protocol allows a quick availability of the material, does not require the use of a paid hosting service and facilitates the sharing of the information. 360° images can be viewed on mobile devices as a panoramic image and through the Cardboard app and viewer, made available on visits to RSSM. The virtual tour with greater interactivity, the expansion of the collection and physical space are next novelties for the museum.

Keywords: Soil museum, virtual reality, soil-landscape relation, education
Financial support:

(1800 - 2511) What do the undergraduate degrees students earn to pursue careers in soil science say about the place of soil science in different countries?

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Soil science is an interdisciplinary field. This provides soil science with many strengths, however, it has also led to questions concerning where the discipline belongs within the academic community. The titles of the degrees received by students who are training to work as soil scientists can provide insight into academia's views regarding where soil science belongs. Therefore, this study evaluated the degrees received by students in Australia, Canada, the United Kingdom (UK), and the United States of America (USA). For Australia it is estimated that 30 to 40 graduates with sufficient relevant soil science knowledge are needed annually to meet demand, therefore knowing the changing degree recognition, with sufficient soil science training, needs to be understood. In the UK there are no BSc degrees solely titled "Soil Science". Soil science training is primarily offered within Agriculture, Plant Science, Environmental Science, and Geography programs. In Canada the most frequent degree programs that deliver soil science coursework are Geography (36% of soil science coursework), Environmental Science (30%), other (30%), Natural Resource Science (24%), Ecology (15%), and Soil Science (12%). Only three "BSc in Soil Science" degrees are offered in Canada. In the USA, 57 universities were found that offered a 4-year degree that prepared students to work as soil scientists. Like Canada, only three of the degrees were titled "BS in

Soil Science". In the USA there were another five degrees that had soil as the first word in their title: "Soil & Land Resources", "Soil and Hydrologic Sciences", "Soil and Water Sciences - Soil Science Specialization" "Soil and Waste Resources - Soil Science option", and "Soil, Environmental and Atmospheric Sciences - Soil Resource Management emphasis". Other BS degrees that prepared students for a career in soil science were in the areas of Agriculture and Agronomy (14), Environmental Science (14), Plant and Soil Sciences (10), and Crop and Soil Sciences (6). An initial evaluation shows cultural differences between countries, with Canada more focused on soils as a geography and natural science topic while there is a stronger agriculture theme in the UK and USA.

Keywords: soil science, education, interdisciplinary, student degrees
Financial support:

C4.4.2 - Soil education and public perception of soils

(2399 - 1033) Celebrating Soil: exploring soils and landscapes from the Antarctic to the Arctic

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Sharing knowledge of, and appreciation for, soil provides an opportunity for soil scientists to encourage others to gain an understanding of the importance, complexity, diversity, and beauty of our global soil resource. Awareness of the soil also adds another dimension to people's appreciation of the landscapes in which they live, work, and play. Many cultures traditionally have close ties to the soil, for instance many creation myths suggest humans were formed from clay or soil, and cultures as diverse as the ancient Greeks and New Zealand Maaori have creation myths that include an earth mother and sky father. However the links people share with the soil are becoming increasingly tenuous as people live in urban environments and no longer need to derive their daily bread directly from the earth. People will be more motivated to manage soils sustainably and protect productive capacity for the future if they have a positive appreciation of the importance and diversity of our soil resource. The recently published book, entitled "Celebrating Soil, discovering soils and landscapes" attempts to provide such insight into soils to the wider community. The book explores soils and landscapes around the planet. We journey from one of the most southerly soils on Earth, at about 3500 m in altitude on the margin of the Antarctic polar plateau, where the harsh, cold, dry, conditions limit life to a few microbes. Such soils are studied to provide insights into the possibilities for life on Mars. Across mid-latitude farmlands, through deserts, to tropical rainforests, soils vary as a result of differing environmental conditions, as well as the impacts of human activities on the environment. In high latitude forests podzolic soils form as a result of the conifer dominated vegetation providing acids that interact with soil minerals. Ultimately in the high arctic tundra, organic soils form over permafrost . We encourage you, as soil scientists, to share your knowledge and appreciation of soil with others. The best way to learn to appreciate the soil is to go beyond the pictures in a book, or lecture, and get close to the soil. Plant a garden, make a clay sculpture, or take a walk through a forest or wetland where you can examine the changing earth beneath your feet. Enjoy the sight, sound, touch, and smell of our diverse and beautiful soils in their endless dance with water and life.

Keywords: appreciation, diversity, beauty, education, resiliance
Financial support:

(5484 - 3198) Collaboration between International Union of Soil Sciences and national societies in promoting soil education and public awareness as a pillar of International Decade of Soils (IDS): A good practice of "Shiny Soil Balls" in Japan

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The International Union of Soil Sciences (IUSS) started International Decade of Soils (IDS) Project in 2015 to advance scientific knowledge and technology, promote public awareness and enhance involvement in policy making about soils and soil sciences and one of the major topics during the decade is surely soil education. The volunteers in the Japanese Society of Soil Science and Plant Nutrition (JSSSPN) and the Japanese Society of Pedology (JSP) have been developed tools and materials and organized seminars and field schools for soil education in collaboration with the IUSS as well as NPOs, NGOs, etc., sometimes with private companies as a part of CSR activities. Based on the feedback from the above activities, we found that 1) small school children (hopefully with their parents) are one of the best targets, 2) workshop-type activities are efficient in giving satisfaction to with a sense of accomplishment and possibly withdraw further interest in soils from the participants. A workshop of "Shiny Soil Balls" is one of those that meet the above criteria on which we could promote in soil education for the future. We prepared the special soil ball materials and showed them how to make "Shiny Soil Balls" by polishing with the bottom of a spoon in a workshop. In making "Shiny Soil Balls" within 5 to 30 min., most children, even their parents, got concentrated, enjoyed, and satisfied, when completing "Shiny Soil Balls". By preparing them, most children paid attention to the soil characteristics which affect the quality of "Shiny Soil Balls". We analyzed the questioners for children in different ages and confirmed that "Shiny Soil Balls" was mostly attractive for those > 4-years, and was rather more for older children, though it is still unclear whether such positive attitude does really lead to an "interest in Soil and Environment" or was just due to a fun. Questioners to the parents showed that many of them highly appreciate it that their children touched and played with soils since they hardly provide a chance for them to do so, particularly in urban areas, and are hoping them to be more concerned about the environment in the future. We concluded that the workshop for "Shiny Soil Balls" was proved successful and could be a promising tool for education, in an introductory step in particular, for school children and their parents and public awareness of soil and soil sciences.

Keywords: International Decade of Soils, good practice, shiny soil balls, school children
Financial support: Science Council of Japan, Japanese Society of Soil Science and Plant Nutrition and Japanese Society of Pedology

(7702 - 2514) Dig It! The Secrets of Soils: A Public, Educational Partnership

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In a world that depends on soil to sustain life, most humans know little about soil's role and why we need this precious resource. Building knowledge through public engagement is critical to the mission of informal science learning organizations such as museums and science centers. Museums consistently rank among the most trusted public institution by the public, and thus content and exhibitions developed by museums and science centers have unique opportunities to catalyze broader public discourse on and about the role of science and society. The *Dig It!* Exhibit was conceived and constructed through a partnership between The Smithsonian National Museum of Natural History and the Soil Science Society of America. The exhibit was 5,000 square feet, with areas devoted to life in soil, soil structure, soil and people, soils of the world and a collection of 50 soil monoliths representing all 50 U.S. States. *Dig It!* was held at the Smithsonian's National Museum of Natural History, Washington, D.C. from July 2008 to January 2010, with an estimated 2,000,000 visitors and 4.3 million hits on the website (www.forces.si.edu/soils). It then travelled to museums in Nebraska, Washington, Minnesota, California and North Carolina where it was viewed by >200,000 visitors over a period of 5 years. Most recently, it became part of the permanent *Grow* installation at the St. Louis Science

Center in 2017. Currently, SSSA and The Smithsonian are partnering to create a virtual *Dig It!* 2.0 as the traditional museum exhibition represents a barrier of its own: the cost to produce and/or host a large-scale exhibition is typically prohibitive and the return on investment can be limited based on other resource or logistical implications. To overcome these challenges, we have created a highly accessible and flexible platform for broad dissemination of engaging science content: a digitally distributed print-on-demand exhibition that can be produced at low costs and customized to fit the priorities and needs of the hosting organization. Focusing on the science of soils and its critical roles in agriculture, food supply chain, urban environments and beyond, *Dig It!* targets libraries, community centers, botanical gardens, schools and other audience spaces. In this session, we present a novel model for engagement designed for the global community and also examine the precedences for this educational tool.

Keywords: soils education, public engagement, exhibition
Financial support: Agronomic Science Foundation, Soil Science Society of America, Smithsonian Institution

(1911 - 1363) Environmental education with soil emphasis in public schools: from speech to practice

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With the purpose of transforming scientific knowledge into a language more accessible to the population through innovators that stimulate curiosity, the Soil in School Program was created in the Department of Soils and Rural Engineering of the Center of Agricultural Sciences of the UFPB, with the purpose of carrying out activities practices to teach environmental education, with emphasis on Soil Science. The project was carried out at the Municipal School of Elementary Education, located in the city of Areia, Paraíba, Brazil, targeting primary school students. Practices were carried out addressing soil formation processes and factors; infiltration rates in soils of different textures; water erosion and its control in soils with different vegetation cover; composition of the soil and its functions for the maintenance of water sources; the soil as a habitat for the organisms, with presentation of the wormhole, anthill, cupistiro among other organisms that live in the soil; and in order to demonstrate the importance of soil for food production was also presented a terrarium. For a broader scope on environmental education, the concepts of garbage recycling were also worked out, where it was explained by the monitors that all the preparation of the practical demonstration instruments were with PET bottles, plastic pots and recycled glasses. During the activities the students were encouraged to participate in the workshops through manual and visual contacts. The evaluation of the knowledge was made through oral questions pre-elaborated by the executing team and by spontaneous questions of the students themselves formulated during the accomplishment of the demonstrative activities. The importance of the practical demonstration in the students' understanding of the subject Soil and environmental education was verified when it was realized that the students presented a broad knowledge about the topics addressed, being able to correlate the learning with their daily life. Through this methodology, in addition to accompanying the project workshops, the students are given the mission of sharing with the family and the community the knowledge acquired. Thus, it is hoped that the activities of the Solo Program in the School will be another tool to aid the popularization of the Solos theme among students and society.

Keywords: Keywords: environment; soil science; Solo in School Program
Financial support:

(5391 - 1267) Facilitating cooperation for soil awareness in Austria

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Due to the legal situation in Austria the competence for soil protection is fragmented between the national and regional administrations. Thus, information transfer and coordinated actions with regard to soil protection and soil awareness have been scarce. In order to improve cooperation, the Austrian Soil Forum as an informal conference format for discussion, information and communication has been established in 2002. It is organized by the Austrian Soil Science Society and the Environment Agency Austria and supported by the Federal Provinces and the Federal Ministry for Sustainability and Tourism. Twice a year soil experts and people interested in soil come together to exchange experiences, knowledge, current soil related issues and projects. The Soil Forum – besides the Austrian Soil Science Society and b[5], a formal cooperation of Austrian institutions working in the field of soil science - also serves as a framework to create new ideas, e.g. for awareness raising, finding project partners or harmonizing common strategies to facilitate soil protection in Austria. The longtime cooperation has strengthened the Austrian soil community and has supported the implementation of a huge number of instruments pushing soil awareness and protection. Recent examples are: Development and continuous expansion of a school workshop series for children between ages nine and thirteen Introducing the concept of peer teaching to these workshops Modification of these workshops for new target groups (e.g. technical schools for agriculture and forestry, key person groups in environmental education and protection, allotment gardeners) Establishment of soil trails (e.g. Vienna Soil Trail at the location called “Roter Berg”) Soil festivals, e.g. at the premises of the Federal Research Centre for Forest and in the course of regional thematic activities Vienna soil film day on the Dec. 5th (World Soil Day) Participation in events and presentations at the Vienna Zoo Citizen Science Projects like TeaTime4Schools, where the soil biological activity is monitored based on the decomposition of the bags All activities are reported in the Soil Awareness Guide, a tool at the Austrian Soil Platform(www.bodeninfo.net)

Keywords: awareness raising, peer teaching, soil trail, soil film, citizen science
Financial support: Federal Ministry for Sustainability and Tourism

(2917 - 1125) Institutional and cultural constraints in promoting soil science: a perspective from Eurasia

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Agricultural development with associated technology transfer is dependent on how effectively the knowledge gained from research is conveyed to the farmer--the ultimate end-user. The process is fundamental if growers are to improve farm outputs, incomes, and livelihoods with impacts on rural communities. Applied research in soil fertility, fertilizer use, and soil management is vital to making small holdings economically viable. Despite the wealth of soil research information, including validated in-country research, it remains in the "potential" domain for many farmers in developing countries. Much of the published research in soil science, as in other areas of agriculture, unfortunately remains "on the shelf", only notching up another publication for the researcher. Notwithstanding climatic constraints, obstacles to applying research-generated soil information at farmers' level are many, ranging from institutional, financial, societal, cultural and civil conflict. This is particularly true in the broad Eurasia belt that encompasses North Africa, West and Central Asia, and the Sub-

continent, a region of the world where the authors have spent most of their professional lives dealing with applied soils research with the goal of enhancing farmers' income and wellbeing in a sustainable manner. The challenges for agriculture, and for society as a whole in the region, are immense. Thus, an understanding of various constraints to technology transfer is fundamental to ensuring any degree of success in applying soil research for benefit of the farmer, the rural community, and the national economies.

Keywords: Promoting soil science, constraints, Eurasia
Financial support:

(9477 - 2873) Mainstreaming soil management competencies in Central American smallholder agriculture

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At-scale adoption of sustainable soil and water management practices in smallholder agriculture has the potential to significantly boost productivity, resilience and regional food security in Central America. Yet, after decades of agricultural development interventions, critical competencies for soil and water management remain a limiting factor. We propose that for soil and water management practices to reach scale, capacity building must occur at multiple levels from farmer field schools to universities. The Water-Smart Agriculture Program for Mesoamerica (ASA for its acronym in Spanish), implemented by Catholic Relief Services and partners in Central America and Mexico, puts capacity building in soil management at the center of a strategy to reach 250,000 Central American smallholder farmers with critical soil and water management competencies within 6 years. The ASA program is evaluating the effectiveness of multi-level soil management capacity building initiatives including: 1) Producer training through Farm Field Schools facilitated by extensionists and farmer promotors to create a culture of soil-focused experimentation, data analysis and learning among producers; 2) Extension system strengthening through training of soil management trainers with replication through a cascade from trainer to extensionist to farmer; 3) Reform of agricultural school, diploma program, undergraduate program and professional certification curriculums to include critical soil and water management skills; and 4) A regional master's degree program on soil and water management in tropical agriculture. The success of the above initiatives is being evaluated using the Water-Smart Agriculture competency framework that focuses on the abilities, knowledge, attitudes and behaviors required for the effective implementation of Water-Smart agriculture in the field. The competency model includes 7 macro competencies: 1) Conservation Agriculture; 2) Integrated Soil Fertility Management; 3) Green manures and cover crops; 4) Managing soil to manage water; 5) Agroforestry; 6) Sustainable pasture management; and 7) Collaborative learning. The program is working with the Central America and Caribbean regional network of Professional Training Institutes for adoption of the WSA competency framework as a standard for the region. We will present the Water-Smart Agriculture competency framework and the preliminary results and stakeholder perceptions of the iniciatives in Central America to date.

Keywords: Formal/non-formal soil education; scale; capacity building; Farm Field Schools; Central America
Financial support: Howard G. Buffett Foundation

C4.5 - History, philosophy, and sociology of soil science

C4.5.1 - Integration of historical, philosophical and sociological worldviews to secure and sustain soils in the future

(7688 - 401) Is there evidence for the validity of the doctrine to abandon synthetic fertilizers in organic agriculture?

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Organic farming is attributed with many connotations such as 'natural', 'superior', 'environmentally friendly' and 'sustainable'. The founders of organic agriculture disliked technological know-know to be introduced into agriculture and claimed that high food quality can only be achieved through natural means and methods. They shared the view that nature is the master with natural ecosystems serving as a model. Ideas from nature philosophies such as anthroposophy, nature romanticism and eco-philosophy were sources of inspiration for organic principles. Central historic statements of the founders motivating the exclusion of mineral fertilizers were as follows: Steiner (biodynamic agriculture, 1924) stated that life is affected by 'cosmic and terrestrial forces' and using synthetic chemicals in crop production prohibits the flow of 'forces' and make food worthless for humans. Balfour (Soil association, 1943) wrote that 'soil fertility depends on humus'. 'Artificial fertilizers speed up the rate at which humus is exhausted'. Rusch (biologic-organic agriculture, 1968) stressed that 'artificial fertilization is not a normal, physiological, and natural form of plant nutrition'. Today, advances in agricultural science allow us to partly verify the founders' statements. Steiner did not refer to known food quality variables such as protein, mineral or vitamin content, but to 'forces' affecting crop attributes needed for spiritual development of mankind. As the 'forces', he refers to, are unknown to science, validation of his theory has not been possible. Furthermore, his idea about spiritual development cannot substantiated as natural science does not address spiritual matters. Concerning Balfour's hypothesis that mineral fertilizers speed up decomposition of soil organic matter, results from many long-term field experiments have clearly shown that her statement is not valid. Decomposition of soil organic matter is not negatively affected by mineral fertilizers, formation of soil organic matter is enhanced and mineral fertilizers result in high crop yields followed by production of more residues leading to soil organic matter formation. Finally, Rusch's idea that natural release of nutrients from soils to crops is superior over controlled application, has been proven to be invalid. Lack of knowledge about synthetic fertilizer at that time explains the shortcoming of their reasoning. In the presentation, original ideas are outlined and validated through results.

Keywords: Organic farming, founders, food quality, nature philosophies
Financial support:

(9526 - 1306) Perception, beliefs and values of soil, its health and degradation along an urban – rural gradient.

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Soil degradation, like many of society's 'wicked' problems, share similar characteristics; they are global, complex, difficult to resolve and interconnected across environmental, social, cultural and political spheres, and present a risk to society. Adding to the 'wickedness' of soil degradation is the rapid urbanization that has and continues to occur. Compounding the problem of urbanization is the fact that individuals residing within urban areas may be less likely to recognize the importance of soil or its degradation. These individuals generally have less interaction with soil than those residing in rural areas, yet their survival also depends upon the ecosystem services that soil provides. This observation necessitates a paradigm shift in communication strategies to allow for the education of individuals, beyond those involved in agriculture, as to soil ecosystem services and soil health and security. The inclusion of urban and suburban dwellers, non-governmental organizations and decision/policy-makers with differing priorities and interests is imperative to securing soil. Therefore, it is necessary that scientists, educators and activists understand the factors that drive and shape these individuals' perceptions of soil, soil health and soil security to assist in the creation of education materials, shape marketing and media priorities, and bring forward priorities for the

legislative agendas of regulatory bodies and elected officials. While perception has been widely studied in relation to climate change, few studies exist in relation to soil and soil degradation. This study investigated the social-psychological perception, beliefs and values of individuals to soil and its degradation. A stratified survey of individuals residing throughout the urban–rural gradient of greater Miami, Florida, USA, was conducted to assess the knowledge of the causes, impacts and responses to soil degradation as well as individuals' knowledge, cognition, connection, relationship and experiences with soil. Findings suggest that soil valuations and beliefs differ along the urban –rural gradient with a variety of influencing factors, such as connectivity to nature, social normative factors, economic status, gender, cultural beliefs, political alignment, and others. In conclusion, the closer physically, emotionally, socially and culturally the connectivity and interaction between individuals and soils are, the more they are motivated to protect soils from degradation

Keywords: Soil security, soil health, soil valuation, beliefs, perceptions, culture

Financial support: University of Florida, Soil and Water Sciences Department

(8038 - 546) Stripping science off soil: soil conservation in the post-truth era

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Preserving soils for future generations is a noble task fighting an uphill battle against wide-spread abuse of soil resources, land degradation and desertification. Soil science along with other environmental sciences informs land users and decision makers of the need for soil conservation and explains the processes of land degradation and recovery. It contributes to development of soil conservation and amelioration methods and technologies. The main role of science is explanatory. It serves as a knowledge base that helps an individual to formulate own Weltanschauung (worldview) - the core of cognitive philosophy. It is an instrument of representation of the world around us and our place within it. As such it is in conflict with alternative worldviews based on other beliefs. Since the start of the enlightenment period, science slowly but surely started claiming from religion the space of philosophical guide to political establishment. Science and technology became the decision support system for interaction of the political elite with nature. Religion still remains in many parts of the world an important instrument (along with humanities, economics and law) for the rich and powerful to manipulate both individuals and large groups of people. In the latter interaction the laws of nature (apart from ballistics and electrodynamics) offer limited tools. Soil science as a science discipline offers explanation of processes occurring in soils and provides insights into life below the ground surface. The main method of scientific enquiry into soil in the XX century treated soil as a form of organized matter that changes in time both in its composition and structural organization. Some new trends in environmental philosophy are influencing the way we think about and study soil today. Inductive reasoning through statistical analysis of evidence has taken priority over deduction. The demand for transdisciplinary approach in study of such complex systems as agriculture by incorporating a study of human belief systems tries to change the worldview of soil science. Achieving soil conservation goals may be easier by exploiting religious and other popular beliefs, rather than educating the population and explaining the science behind the need to preserve soil. The ruling elites also have at their disposal such means as forced deportations and fencing off large swaths of vulnerable land. The moral value of the above approaches apart from science education is doubtful, though.

Keywords: Epistemology; oubscurantism; knowledge systems

Financial support: private

(2863 - 2202) The first German Handbook of Soil Science and its Editor Edwin Blanck

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Edwin Blanck had important influence on soil science in Germany and at the University of Göttingen. He was active for more than 30 years that means from the end of World War I until the Federal Republic of Germany in the early 1950s. But his important impact was the "Handbuch der Bodenlehre", the first German Handbook of Soil Science. This handbook is initiated short after the foundation of our international society in 1924 and was printed in nine issues and 4800 pages during three years1929 to 1931. A tenth issue followed in 1939 with new knowledge, mainly applied soil science, and 600 pages. All books were printed by Springer Company. Edwin Blanck followed mainly two aims. At first, he was afraid that soil science may break in different sub disciplines. Therefore he liked to combine soil science in one single system. Second, he had the idea to offer worldwide knowledge on soil. His hope was in this time, that a German book may influence soil science internationally. His own possibility to summarise the knowledge was excellent. His strong editorial power and his excellent pupils made a Springer book in few years possible. The presentation must also cover the influence of the Hitler regime on soil science in that period.

Keywords: Handbook of Soil Science, Germany, Blanck, 1929

Financial support: German Research Foundation?

C4.5.2 - Foreseeable breakthroughs in soil science

(9673 - 549) The cavalry charge: attractive plants and army ants in an organic farming experiment

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We registered the activity of ground dwelling arthropods in an Abruptic Acrisol (Dystric) for six months, from June to December of 2017 in an experiment involving attractive plants, at EMBRAPA-CNPAB experimental field at Seropédica city, Rio de Janeiro, Brazil. The attractive plants included *Crotalaria spectabilis* Röth., *Canavalia ensiformis* (L.) DC., *Cosmos sulphureus* Cav., *Foeniculum vulgare* Mill. and spontaneous vegetation. These plants can provide food resources and refuge to natural enemies and are used in a context of conservative biological control. The capture of ants was performed with pitfall traps with a diameter of 10 cm containing a 1% formol solution was left in the field for seven days. Several groups of arthropods were collected among them the most abundant are ants from the following genera in order from most to less abundant: *Labidus*, *Atta*, *Solenopsis*, *Wasmannia*, *Odontomachus*, *Ectatomma* and *Carebara*. Ants are commonly neglected as natural enemies of agricultural pests. Here we pinpoint ants as an important agent in the control of the soil food web. Amongst the collected ants *Labidus praedator* (Smith, 1858) are of special interest due to the army ant syndrome and the large number of individuals that can surpass 500 in a single pitfall trap. They conduct swarm raids to search for preys that results in a large retrieve of food items especially arthropods. Army ants are commonly associated with forest environments, but as this study shows they can have impact in agricultural fields. Among their prey are some common potential agricultural pests: the leaf cutter ants from the genera *Atta*, wireworms and soil termites, the first are common in the study area. These results are preliminary, and experiment will be repeated in a neighbor area to clarify the effect of the attractive plants in a different condition of rainfall and daylength that have influence some plant traits and can influence the dynamic of natural enemies and their prey. We argue that the use of attractive plants and the conservation of hedgerows, and even small patches of low diversity forest can maintain this ecosystem service that involves the regulation of the soil food web and thus have impacts in soil nutrient dynamics. The capacity to attract natural enemies are dependent on the existence of a source of those enemies within the

effective radius of action of the attractive plants, in this manner, the surrounding soils and their associated vegetation can be that source.
Keywords: crop protection, macrofauna, landscape, ecosystem services
Financial support: EMBRAPA, CAPES, CNPq

(8510 - 1255) The Cooperative Research Centre for High Performance Soils – An innovative approach to soil research in Australia.

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Australia has a long and proud history of innovative and collaborative research to advance our understanding of soil science and soil management. This is partly because Australia is characterized by many soils that are inherently fragile, infertile and susceptible to various forms of degradation, and hence, are limiting to agriculture production in many ways. However, soil research is sometimes not closely connected to or informed by the end-users who are expected to implement the outcomes of the research. Through the Australian Government's Cooperative Research Centre (CRC) Program, substantial funding has been allocated to a new research collaboration that brings together researchers and industry end-users to undertake research to address soil-based constraints to agricultural production and performance. Commencing in 2017 with A$60 million funding over 10 years, plus access to significant in-kind resources and additional funding sources, the CRC for High Performance Soils (Soil CRC) brings together 39 partners, including 8 universities, 3 state agencies, 24 farmer and catchment groups and a range of other industry partners to form the biggest collaborative soil research effort in Australia's history. A key feature of the Soil CRC is the involvement of farmer groups in setting the research priorities, collaborating in the research activities and being involved in the dissemination and application of the resulting new knowledge and techniques. Research will be multi-disciplinary bringing soil scientists together with emerging expertise in nanotechnology, data analytics and sensor technology as well as sociology, economics and the biophysical sciences. Through the Soil CRC, opportunities exist to enhance international collaboration as well. Program areas include soil performance metrics, new products to enhance soil function and fertility, precision practices and integrated soil management, and market-based incentives for investment in soil management. With long-term secure funding, the Soil CRC provides Australia's soil science community with the opportunity to undertake extended, innovative research, with the potential to make transformational improvements to how farmers manage their agricultural soils for higher performance and productivity. Further information can be found at www.soilcrc.com.au.
Keywords: research, innovation, collaboration
Financial support: Australian Government's Cooperative Research Centre Program

(6940 - 418) Three critical failures of soil science and opportunities to overcome them: spatial inference, uncertainty, economics

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Soil science has largely failed to meet user needs due to three critical failures. First, geographical areas for which recommendations are to be made are rarely adequately sampled using statistical sampling schemes, preventing valid inference of results for the region of interest. Second, uncertainty is largely ignored in presenting recommendations, and they are rarely validated, which passes the risk on to the user and impedes learning on how to improve recommendations. Third, the type and form of soils information required for economic decision making is rarely provided. Solutions are provided for all three failures. 1. Use of population-based sampling approaches in soil survey and crop agronomy to make valid inference and recommendations for a region of interest, exemplified with use of soil-plant dry spectroscopy at local to continental scales in Africa. 2. A Bayesian approach to making soils-based recommendations, which explicitly represents uncertainty, exemplified for fertilizer recommendations in Africa. 3. A decision analysis framework for identifying and analysing the uncertainty in stakeholder decisions to identify high-value soils information, exemplified for a land restoration planning decision.
Keywords: Sampling, Inference, Uncertainty, Decision analysis, Information-value
Financial support: Bill and Melinda Gates Foundation. CGIAR Program on Water, Land & Ecosystems.

C4.5.3 - Field to Palette: A Nexus Approach to Soil and Art

(1969 - 2916) Soil Functions as Boundary Objects for Sci-Art Dialogue

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This presentation examines soil functions as boundary objects for interdisciplinary dialogue between scientists and artists. Boundary objects, according to sociologists Susan Star and James Griesemer (1989) are conceptual entities that bridge different understandings of information by different user groups. Boundary objects are interpreted differently depending on the group, but contain enough content to allow members of different disciplines and social groups to talk and work together, making them an important tool in transdisciplinary stake-holder processes. We present the publication project, "Field to Palette – Dialogues on Soil and Art in the Anthropocene" as a case study of cross-cultural, interdisciplinary dialogue which relies on different interpretations of soil functions as a way of focusing knowledge sharing. The result of the four-year project is a rich volume of authentic exchanges about the material properties, cultural histories, environmental functions, and existential threats of the soil in a range of different practices, places and cultural traditions. It is a collection of conversations in different formats and time frames which fluctuate from solemn to humorous, fictional to factual, and objective to deeply personal. We present the dialogic mechanisms of the production of this book as an iterative process of bringing two very different disciplines together to share perspectives on human-soil relationships and their importance for the existence of life on the planet. Finally, we argue that dialogue is a fundamental process of social change and a tool often overlooked in soil protection contexts that value data over discourse and policy statements over people.
Keywords: Soil, Art, Anthropocene
Financial support: IUSS and WCSS (?)

(3736 - 802) The Science and Art of Soils Transforming the Earth

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This presentation will consider the transformative function of soil and the complimentary contributions of soil scientists and artists in understanding and activating ecosystem restoration. Examples from several chapters of the new book, *Field to Palette – The Soil Art Dialogues (Toland et al. 2018)*, will be used to illustrate these relationships, including "Rocks, Radishes, and Restoration: on the Relationships between Clean Water and Healthy Soil" (Rahmani and Weil). The interactions that produced these chapters teach us how scientists can communicate with artists – and in the process how to better communicate with the public and enlist their support for science and restoration activity.
Keywords: Transformation Environment Soil Scientist Artist Communication
Financial support:

PLENARY SESSIONS

Working Groups

WG01 Cryosols: Progress in understanding the dynamic soils of colder regions

(5088 - 507) Emission of Greenhouse Gases from Natural and Human-Affected Cold Soils of Eurasia: controls of spatial variability

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Nevertheless the annual rate of increase of Greenhouse Gases (GG, primarily carbon dioxide) amount in the atmosphere is well known, it still remains unclear the relative input of their specific terrestrial natural and anthropogenic sources and sinks. Amongst those, the importance of different types of land use is especially poorly studied. To do this, one way is to evaluate the most easy determined decomposition component of C-balance, i.e. soil emission, since it comprises in terrestrial ecosystems 60-99% of Gross Respiration. Permafrost-affected soils occupying 15% of land surface (mostly in Eurasia and North America), contribute about 25% of total terrestrial carbon in frozen state. Nevertheless the biogenic GG soil emissions from permafrost is only 5% of the global, this makes those soils of high importance in the warming world. Field measurements of CO_2, methane and nitrous oxide were conducted in Aug-Sept 2014-2017 in natural and human-affected (HA) biotopes in 37 tundra, steppe and forest permafrost sites of Russia and Svalbard. It is shown that depending on nature and duration of anthropogenic influence (AI), or the types of ecosystems, it is observed either increase or decrease in soil emission of biogenic GG compared to natural rates. Nevertheless, acting together land use factors provide an additional net source of CO_2 to the atmosphere with high probability. This is due to the imminent elimination of Primary Production and the delayed CO_2 emission from soils resulted from heterotrophs respiration. HA methane sources depending on the type of AI could show positive (emission increase) or negative (emission reduction) effect on radiation forcing of the atmosphere, whereas anthropogenic sources of N_2O have only positive effect. Despite weather changes, HA sites in all years of observations show consistently greater rates of CO_2 emissions compared to the natural analogues. Calculations show that local anthropogenic soil GG emissions are comparable with the impact of Climate Change over the same period. Ultra-continental cryogenic soils (UCC) of Siberia demonstrate greater emission rates of CO_2 than either natural or AI soils in the Arctic, with higher rates in forest stands as compared to steppe biotopes. The Birch effect is less expressed in UCC than in European soils. We hypothesize that first is mostly due to more expressed cryogenic microcracks, whereas the second is resulted from adaptation of UCC soil biota to extreme dryness and freezing.

Keywords: Permafrost-affected soils; Greenhouse gases emission; Natural and Human affected ecosystems; Birch effect.
Financial support: Research Grants ## 17-05-41157 RGO_a, 16-04-01580a of Russian Foundation of Basic Research

(4912 - 431) Sulfur and phosphorus speciation in soils on James Ross Island, Antarctic Peninsula, as assessed by XANES spectroscopy

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Soils in the Antarctic Peninsula region are subject to a peculiar cold and arid climate with strong seasonality which strongly retards (bio)chemical mineral weathering and pedogenesis and almost completely prevents the establishment of vascular plants. Using synchrotron-based X-ray absorption near-edge spectroscopy (XANES), we studied the speciation of sulfur (S) and phosphorus (P) in five Cryosol profiles at an initial stage of pedogenesis along a transect from coastal to interior sites on James Ross Island. The soils differed in site elevation, climate, aspect, parent material composition, and degree of seawater influence. The S and P speciation of the soils generally reflected the initial stage of pedogenesis (dominance of apatite P in all soils; no or little topsoil enrichment in organic S and P forms). However, the different soils showed specific S and P content levels as well as speciation patterns, which were related to profile-specific site conditions and/or soil properties (e.g. content of organic C and N, pedogenic Fe and Al minerals, easily soluble minerals). In detail, for two P- and S-rich coastal soils with different seawater influence (soil with tidal vs. infrequent flooding), the former showed larger contributions of K,Na phosphates and $CaSO_4$. Two mid-altitude soils with identical parent material and elevation, but different aspect and micro-climate (E-exposed profile: very cold and arid climate; W-exposed profile: moister climate, more sea-spray), the latter soil showed more advanced weathering of subsoil pyrite to sulfate, accumulation of alkali phosphates, and topsoil enrichment of $CaSO_4$. In contrast to all other soils, a high-elevation volcanogenic soil characterized by particularly large contents of P as well as of pedogenic Fe and Al minerals showed a dominance of Al- and Fe-bound P over apatite-P in the entire profile. Finally, topsoil P at small patches with initial establishment of mosses was characterized by a decreased contribution of apatite and increased contributions of Al,Fe-bound P and organic P compared to the soils without moss cover. Our study for the first time presents information on S and P speciation for Antarctic soils. Moreover, it highlights and explains the peculiar S and P speciation patterns of these soils and thus contributes to our understanding of pedogenesis as well as nutrient availability and turnover in these ecosystems.

Keywords: S speciation, P speciation, Antarctica, Protic Cryosols, catena
Financial support: German Research Foundation

WG02 Digital soil mapping: Progress in digital soil mapping

(1831 - 316) Assessment of digital soil class mapping at high resolution in mountainous areas

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Soil class mapping is an important tool for knowledge about environment. Despite its importance, the methods used to produce these maps can differ between conventional and digital ones. Digital soil mapping (DSM) has become popular for producing maps of soil classes and properties from spatially explicit soil inventories and from auxiliary landscape data (McBratney et al. 2003), bridging gaps between discrete soil maps and the continuous nature of soil cover (Burrough et al. 1997). The DSM techniques can represent a formalized alternative to the conventional soil mapping, where both the soil classification and mapping are handled numerically. The purpose of this study was evaluated the digital soil mapping to produce a finer resolution soil class map, in a mountainous area in Rio de Janeiro State (Brazil). The Bonfim watershed was located in Petropolis municipality and cover almost 3000

hectares. Eighty-three ground control points was achieved in fields trips and from them, 1844 pixels were sampled to use in the digital models. This dataset was random sampled into training (1476) and validation (368) samples. The Random Forest (RF) and Multinomial Linear Regression (MLR) were used. The auxiliary dataset were achieved from terrain attributes (31) and remote sensing of gamaspectrometry (14), totalizing 45 covariates with 10meters of resolution. The models were tested to the complete dataset and the terrain attributes alone. The values of global accuracy and kappa index were used to evaluate the models. The results shows to MLR with complete dataset a global accuracy of 91% and Kappa index of 0.89, while considering the MLR with the terrain dataset alone the values of 73% and 0.66, respectively. The RF model with the terrain dataset show 97.5% of global accuracy and 0.99 of kappa index. The maps produced by the models were very different and the RF map was the best fitted one, considering the statistics results and the expert observation in fields trips. It is possible to conclude that the use of DSM techniques provide a logical model of the soil distribution in the area and the terrain attributes were the most important covariates, closed to the geomorphological conditions that control the soil distribution. The DSM techniques were usefull to map soil classes in higher resolution and can help to provide more detailed soil information.

Keywords: Random Forest, Multinomial linear regression, Petropolis, Rio de Janeiro

Financial support: FINEP

(6155 - 1818) Consistency of soil legacy data from different sources in regional and national scale

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There is a number of legacy datasets collected by various institutions for different purposes in different times. These legacy data are a valuable source of data for spatial prediction and digital soil mapping including GlobalSoilMap project. They differ in their coverage, distribution, methodology, types of data measured etc. This study was motivated by two research questions: (i) Is it possible to combine the data from different sources to one harmonized database? (ii) Can data from one legacy dataset be used as an independent dataset for validation or evaluation of prediction provided by models using data from other legacy datasets? Topsoil organic carbon content was chosen for the comparison. Several legacy databases were included resulting from both national (Systematic Soil Survey of agricultural land from 1960s, forest soil surveys, agricultural soil monitoring) and international surveys (Biosoil, LUCAS, INTERREG). The datasets were compared based not only on basic statistical parameters (mean, variance), but also on the parameters of spatial distribution (variograms) and on spatial distribution patterns. It was done in a regional scale in selected pilot districts and on the whole country level. The datasets on forest soils and agricultural land were compared separately. Bigger relative differences were found mostly in the regional scale which is caused usually by a smaller number of data for the region than for the whole country and consequently a bigger effect of sampling sites localization. The effect of data age, as well of the stand conditions (altitude, topography, land use, local geology etc.), sampling design, sampling depth, analytical methodology and other possible factors on the differences between different datasets was assessed.

Keywords: legacy soil data; soil survey; database; soil organic carbon; digital soil mapping

Financial support: Czech Science Foundation, project No. 17-27726S on "Spatial prediction of soil properties and classes based on the position in landscape and on other environmental covariates"

(5790 - 1762) Exploring co-spatial patterns between soil biodiversity and pedodiversity across New South Wales

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The University of Sydney[1]

The co-spatial association between soil microbial diversity and pedodiversity has not been explored at global scales. Hence, we aim to verify this relationship by mapping soil microbial alpha and beta diversity using a pedometric approach. We used high-throughput sequencing of 16S and ITS marker genes to analyse soil microbial diversity at different agroecological zones and land uses using two orthogonal transects across the state of New South Wales (Australia). We found that microbial communities are geographically structured by soil type and vegetation. The extent of such a relationship varied upon the environmental conditions as well as the microbial diversity component analysed (e.g. diversity, abundance, dominance, rarity, etc.). A co-spatial association was evidently based on soil heterogeneity even beyond the environmental gradient and the land uses evaluated.

Keywords: Digital mapping of soil biodiversity; Soil biogeography; Soil biodiversity

Financial support: The University of Sydney

(2091 - 2083) High Resolution Digital Soil Mapping on a Complex Landscape in the Sandspruit catchment, Western Cape, South Africa

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This research serves as a preliminary study to map the whole Sandspruit catchment in the Western Cape, South Africa for hydrological modelling and agricultural management. This study represents the first study in South Africa evaluating feature selection techniques combined with supervised machine learning to map soil spatial variability. The objectives of this study were i) to evaluate feature selection techniques to objectively choose environmental covariates, ii) to evaluate multiple supervised predictive models to determine soil spatial variability, iii) and to determine which regions require a higher soil density for further research. Eighty-four environmental covariates, four feature selection techniques, ten regression models, and nine classification models were used to determine the soil special variability of gravel, sand, silt, clay, soil organic matter, soil associations, great groups, presents of a bleached A horizon, depth class, and USDA textural class. The top performing regression models were then subjected to regression kriging (RK). For regression models, satisfactory results were achieved for gravel (RMSE = 8.9 and *R2* = 0.77) and sand (RMSE = 4.8 and *R2* = 0.66) content with RK and support vector machines, respectively. Silt (RMSE = 4.3 *R2* = 0.48), clay (RMSE = 2.5 *R2* = 0.43), and SOC (RMSE = 0.32 *R2* = 0.44) achieved moderate results with quantile regression, random forest, and cubist models, respectively. For classification, satisfactory results were achieved for soil associations (kappa = 0.64 accuracy =74%), presence of a bleached A horizon (kappa = 0.7 accuracy = 88%), and soil depth (kappa = 0.48 accuracy = 74%) using stochastic gradient boosting (SGB), linear discriminatory analysis, and SGB, respectively. Soil texture showed moderate results (kappa = 0.43 accuracy = 66%) with multinomial ridge regression. Finally, uncertainty maps show the highest uncertainty on slope positions. In conclusion, this study shows the importance of feature selection and predictive model combinations when determining soil spatial variability of each soil attribute. Finally, this study produced DSM at a resolution that can be used for environmental models as well as small scale farming.

Keywords: Digital soil mapping, soil spatial variability, feature selection, predictive models

Financial support: The African Science Service Centres for Climate Change and Adaptive Land Management (SASSCAL) , Nation Research Foundation of South Africa

(2716 - 529) Identifying the spatial drivers and scale-specific variations of soil carbon in a montane natural forest ecosystem in Sri Lanka

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National Institute of Fundamental Studies, Sri Lanka[1]; Smart Agriculture - Australia[2]; School of Environment Sciences, University of Guelph, Canada[3]

Soil organic carbon (SOC) is a key driver of ecosystem functioning, more importantly in the areas with very little stocks. The SOC socks were mapped in this study using spatial linear mixed models over the Knuckles forest reserve in Sri Lanka using a variety of environmental covariates. The study area consisted of diverse ecosystems ranging from Montane to submontane to grasslands and characterised by rigid terrain. Results of the spatial modelling revealed that for 0-15 cm depth interval SOC stocks were mainly driven by vegetation type and elevation while for 15-30 cm depth interval SOC stocks were driven mainly by the forest type, elevation, slope, and wetness index. Furthermore, the model quality assessment proved that fitted spatial models were acceptable and reported RMSE values of 6.93 C t/ha, 7.93 C /ha and Lin's concordance value of 0.60 and 0.56 for upper and lower depth intervals respectively. Further several (4) spatial transects of 100-m interval were extracted from the digital maps representing the study area and noise-assisted ensemble empirical mode decomposition analysis was carried out to examine the scale-specific variability of SOC stocks. Spectral analysis was performed to identify the exact scales and the correlation analysis was performed with different environmental covariates to identify the dominant controlling factors at different depths. Majority of the large-scale variations were attributed to the elevation and climatic factors, while small-scale variations were attributed to the land management (e.g. forest type, vegetation index). The scale-specific controlling factors at different locations and their relative controlling factors may help to select environmental factors in digital soil mapping at different scales for improving mapping accuracy.

Keywords: Forest soils, spatial modelling, Digital soil mapping, wavelets analysis

Financial support:

(1472 - 2415) Mapping highly organic soils in Scotland using remote sensing

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The James Hutton Institute[1]

Organic soils are an important sink and a potential source of carbon. Remote sensing data can be instrumental in mapping and modelling of presence of highly organic soils and its variability. The aims of this study were to assess Copernicus Sentinel sensors (Sentinel-1 and Sentinel-2) to map the presence of highly organic soils in Scotland, and to evaluate the potential benefits of using exclusively a radar sensor for this when working in regions with a high cloud cover. Different approaches were tested: non-linear regression kriging, machine learning and deep learning. The preliminary results show that Copernicus Sentinels 1 and 2 have great potential to detect highly organic soils. The radar sensor of Sentinel 1, coupled with morphological features derived from a digital elevation model, provides a very good modelling choice. The use of radar sensor has important implications for mapping soil in regions with high cloud cover.

Keywords: remote sensing, sentinel1, peat

Financial support:

(8443 - 2121) Mapping soil bulk density in Brazil by machine learning

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UFV[1]

The bulk density is a key soil property that allows understanding soil quality and process, hence using more precise map of bulk density can lead to more effective soil monitoring. To achieve the best performance on bulk density mapping, in this study, we used techniques for selecting powerful variables and robust predictive model to estimate soil bulk density in Brazil territory at five depths (0-5, 5-15, 15-30, 30-60, 60-100 cm). The soil dataset accounted for 37,000 soil samples from 8,227 sites distributed across Brazil. A total of 62 spatial dense maps of environmental variables used as predictors variables, with 1 km resolution, included map of soils, vegetation, lithology, terrain attributes and bioclimatic variables (temperature and rainfall). For each soil depth the most important variables were selected by applying the Recursive Feature Elimination algorithm, implemented in R software and the bulk density estimated using the Random Forest algorithm. The most important variables were soil class map, Gross primary production vegetation index, slope height, latitude, topographic wetness index and NDVI index. Model assessment with external validation showed R^2 range from 0.36 to 0.40, related to the depth 60-100 and 15-30 cm, respectively. The average value of bulk density was 1.30 kg / dm^3. Overall, bulk density in depth, showed lower variation with no evident abrupt changes in the soil texture, in soil types where this change usually happens. The highest values of bulk density occurs in the North of Minas Gerais State, Northeast and the Midwest of Brazil, with values around 1.35 kg / dm^3. The lowest values are in the southern Brazil. The variables selection proceed allowed to reduce the number of predictor with good performance of Random Forest on mapping bulk density at all depth

Keywords: pedotransfer functions, digital soil mapping, random forest, feature selection

Financial support: UFV

(2112 - 1623) Mapping soil organic carbon stocks at a field-scale by using 3D regression-kriging

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Soil organic carbon (SOC) plays a key role in the carbon cycling of terrestrial ecosystems and climate change through greenhouse gas emission, especially from organic soils. Thus, quantification of SOC stock is important but faces a series of challenges. For example, most current studies are based on either, one-dimensional profile depth function, or a two-dimensional horizontal interpolation technique, which does not allow true 3D visualization of spatial soil heterogeneity. In addition, limited research, which developed 3D variograms for mapping, only used environmental covariates at the land surface and these were copied to multiple depths, which cannot be considered as complete 3D. At the same time, soil profile data obtained using emerging proximal soil sensing platforms can rapidly obtain soil data at multiple depths and, therefore, be used to predict many soil properties and considered as 3D covariates. The objective of this study was to map SOC stock using 3D digital soil mapping (DSM). In this study, 32 soil cores (1-m maximum depth) were collected and fragmented at 10-cm depth intervals from Field26 (11 ha field) of Macdonald Farm, McGill University. A total of 251 samples were analyzed for bulk density (BD) and soil organic matter (SOM) (later converted to SOC) in the lab. On-the-go proximal sensors (DUALEM, Gamma, RTK GPS) were used to map the apparent electrical conductivity, gamma radiometric and field elevation. Furthermore, vis-

NIR spectra data were collected to about 1-m depth *in-situ* at 148 sites (including these 32 cores) using the Veris® P4000 soil profiler. A Cubist model was developed to calibrate vis-NIR spectra against BD and SOC measurements at 32 sites. This model was then used to predict SOC and BD at the remaining 116 sites. The spatial relationship of these properties and environmental covariates (including soil profiling data, field topography, gamma-ray radiation, and apparent soil electrical conductivity) was used to estimate 3D variograms and pursue regression kriging. 3D variability of BD and SOC then combined to calculate the depth-wise C stock at the field scale. The combination of proximal soil sensors and 3D regression kriging based DSM showed promise in mapping SOC stocks.

Keywords: carbon stock, 3D digital soil mapping, regression kriging, vis-NIR spectra, proximal soil sensors
Financial support: Natural Sciences and Engineering Research Council of Canada (RGPIN-2014-04100)

(1481 - 2666) The modifiable areal unit benefit – choosing the optimum analysis scale for digital soil mapping

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A key concept in spatial analysis is the modifiable areal unit problem (MAUP), which includes both the zone effect and the scale effect. The scale effect exhibits different results when the same analysis is applied to the same data, but the size of the aggregation units is changed. For digital soil mapping (DSM), the scale effect of MAUP could be a useful tool if properly understood and leveraged. This presentation explores why changes in analysis scale affect DSM by adopting the framework from geography of separating cartographic scale, phenomenon scale, and analysis scale. While cartographic scale has less bearing in a geographic information system, analysis scale is still very applicable in terms of grid resolution (cell size) and neighborhood (window) size in raster analysis. Analysis scale is a measurement that can be adjusted and used to detect phenomenon scale. For example, the calculation of slope gradient on a digital elevation model requires a neighborhood that consists of cells surrounding the cell being calculated. The analysis scale is dependent upon both the grid resolution and the number of cells used to define the neighborhood size. Our hypothesis is that the correlation of covariates with soil properties are maximized when the respective covariates' analysis scale matches the structure of soil spatial variation as captured with a given spatial sample. Identifying the analysis scale at which different covariates are best correlated with soil properties reflects the classic geographic strategy of using map generalization (relative size of map delineations) to identify the scale at which phenomena occur. The reason for changes in correlation with different analysis scales could be that data (dis)aggregation causes the covariance between variables to change. Questions remain about the susceptibility of these patterns to differences between landscapes and sampling design. The scale effect of MAUP is most problematic for DSM when it obscures correlation between variables. Conversely, this concept becomes a benefit to DSM if used to find the optimal analysis scale. Indeed, the identification of multiple peaks of correlation across analysis scales could indicate multiple processes, operating at different phenomenon scales, affecting the distribution of a soil property. Utilizing these concepts will improve digital soil maps and possibly provide some evidence about the geographic nature of soil forming processes.

Keywords: scale, multi-scale, MAUP, covariates, analysis scale
Financial support: Agriculture and Food Research Initiative Hatch project No. 1004346

(8736 - 1628) The Water-Smart Agriculture Project in Central America – A multi facet Digital Soil Mapping Platform for building soil information capacity and rescuing soil data

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Countries in the Central American region are among the most vulnerable to climatic variations and natural disasters. Land management issues such as unbalanced fertilizer use, unsuitable crops and crop rotations, inefficient water management, and a lack of public infrastructure, are exacerbated by the effects of climate change. Extreme drought and intense unpredictable rain make it difficult to maintain a healthy crop and a stable soil. The current state of soil data limits its use in decision-making for people relying on subsistence farming under these rain fed conditions. The Water-Smart Agriculture project, aims to improve soil and water conservation management by providing useful soil information to decision-makers from field to national scales. Digital Mapping of Functional Soil Parameters is being used as a platform to develop high resolution soil property maps, build soil survey capacity and rescue soil data and information. The approach combines existing data (general soil maps, geological surveys, geomorphological maps, aerial imagery, climate maps), tacit/expert knowledge and remotely sensed data (digital elevation models - DEM and/or vegetation) to generate high resolution soil property maps capable of supporting several management interpretations. A series of workshops and field trips conducted in Mexico, Guatemala, Honduras, El Salvador, and Nicaragua have brought together local scientists, farmers and experts to build in-country capacities for carrying future soil surveys. A versioning concept of soil maps is being implemented allowing for continuous improvements and updates as more soil information and data becomes available. This approach aims at reducing the overall cost and instilling a sense of ownership in the collaborators to assure continued efforts beyond the life of the project. We present some of the achievements, lessons learned and future challenges.

Keywords: Digital Soil Mapping, Soil Data Rescue, Water Smart Agriculture, Central America, expert knowledge
Financial support: Howard G. Buffett Foundation

WG03 Digital Soil Morphometrics: Soil imaging and image analysis at multiple scales

(6529 - 2959) An in-situ soil methodology for characterizing soil porosity changes through the vegetation period.

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The agricultural cultivation has several direct and indirect effects on the soil properties, among which the soil structure degradation is the best known and most detectable one. Soil structure degradation leads to several water and nutrient management problems, which reduce the efficiency of agricultural production. There are several innovative technological approaches aiming to reduce these negative impacts on the soil structure. The tests, validation and optimization of these methods require an adequate technology to measure the impacts on the complex soil system. This study aims to develop an in-situ soil structure and root development testing methodology, which can be used in field experiments and which allows one to follow the real time changes in the soil structure - evolution / degradation and its quantitative characterization. The method is adapted from remote sensing image processing technology. A specifically transformed A/4 size scanner is placed into the soil into a safe depth that cannot be reached by the agrotechnical treatments. Only the scanner USB cable comes to the surface to allow the image acquisition without any soil disturbance. Several images from the same place can be taken throughout the vegetation season to follow the soil consolidation and structure development after the last tillage treatment for the seedbed preparation. The scanned image of the soil profile is classified using supervised image classification, namely the maximum likelihood classification algorithm. The resulting image has two principal classes,

soil matrix and pore space and other complementary classes to cover the occurring thematic classes, like roots, stones. The calculated data is calibrated with filed sampled porosity data. As the scanner is buried under the soil with no changes in light conditions, the image processing can be automated for better temporal comparison. Besides the total porosity each pore size fractions and their distributions can be calculated for every soil profile. The main advantage of this method is the ability to follow the temporal development, as the scanner is buried in the soil at the beginning of the measurement series and stays undisturbed for the entire period. The procedure was successfully applied in both arable-and horticultural crops.

Keywords: Soil scanning, porosity, image processing, soil morphometry, soil imaging
Financial support:

(5492 - 526) Digital managing and processing of soil and forest habitat data on a country scale

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Bureau for Forest Management and Geodesy is an institution that develops soil and habitat operations for the State Forests Administration of Poland, i.e. for ca. 30% of the country area. All new cartography works are carried in a digital mode; therefore, a technology has been developed for collecting the forest soil and habitat data and for their processes in accordance with the obligatory instructions and practical needs. The Support System for Habitat Works (SWPS) is an universal database used to create both the digital maps and text/data reports. Soil and forest habitat maps are created at various scales in accordance with the instructions. SWPS is a program that allows recording the results of field investigation (including all relevant environmental conditions) and laboratory tests. Also, SWPS supports the cooperation with the laboratory performing all kinds of soil analyzes. SWPS has a simple and clear interface that allows data managing and processing in a fast and error-free way (automated control options). Flexibility of the software allows adaptation to any soil classification, including the international WRB system. The particular modules supports the project manager in literature managing, keeping deadlines etc., and allows to keep records in accordance with the standard EN ISO 9001: 2015. SWPS technology is a key step toward the full digital mapping of soils and forest habitats in Poland, and digital support of national soil-related programms, including the carbon sequestration politics and organic matter inventory.

Keywords: *soil carthography, soil database, digital cartography, soil profile*
Financial support: The project was financed from own resources.

(9361 - 2171) InfoSoilsBr: The Brazilian Soil Profiles Framework

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Providing accurate and updated information on the soil profiles of Brazil is an enormous task and continuous challenge that requires an interdisciplinary approach. InfoSoilsBr is a novel framework that aid researchers to collect, store, compute, harmonize and publish Brazilian soils profiles data and geographic information. The InfoSoilsBr aims to serve high quality-assessed, georeferenced soils profiles database to the Brazilian and international communities upon their standardization and harmonization. The focus of this work has been on developing the computational framework and a distributed relational database schema that can store not only new soils profiles data (collected by mobile devices like cell phones and tablets during field works) but also to import/export legacy data from/to the other soil databases. The database was conceived to be fully compatible with ISRIC, SSURGO, BDSolos and FAO databases. The database was designed according to big data, data provenance, open data, data integration requirements, taking advantage of the latest information communication technologies (ICT). Each profile description recorded in the database has a set of key attributes (e.g., mineralogical, morphological, chemical, physical and environmental data). Furthermore, the database stores georeferenced data as text and images about each profile and analytical data from soil samples that were analyzed in wet laboratories. Differently, from previous works, our research incorporated the use of scientific workflow: knowledge and application workflows, which provide complementary perspectives about soils studies. This perspective postulates that soils data comprise a raw material that, when combined with metadata, provenance and high-quality data attributes can be linked to other information sources and placed in causal flows to produce knowledge that can be easily accessed by end-users through the mobile applications. The second perspective focuses on the application workflows whose tasks include, for instance, ingestion, extraction, transformation of data of one or multiple existing datasets. Besides, the workflows compute large amounts of data in high-performance computing environments, offering maps, analytics, and data visualizations. The current version of InfoSoilsBr framework and its database are available at labbd.ufrrj.br/infosoilsbr; the database is registered in INPI under number BR5120170013411.

Keywords: Soil Database, Soil Morphometry, Field work, Mobile Device
Financial support: UFRRJ; PET-MEC/FNDE, red CYTED-BigDSSAgro

(3011 - 1478) Measuring soil properties with your smartphone

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Many soil properties can be estimated by experienced soil scientists using the naked eye, based on colour, visual structure and visible features within the profile. In doing this, the observer often includes knowledge about the location of the site, which informs the assessment of which properties and characteristics are more likely. Smartphones contain the technology to capture imagery and provide location information, and so provide the potential for on-site soil characterisation to be automated. The extent to which this can be achieved depends on a number of factors, which can be summarised accordingly: (A) acquisition and preparation of spatial datasets allowing the site to be described in a way that informs the assessment; (B) availability of appropriate legacy information about site location, soil sample extraction, analysis and properties; (C) preparation, capture and preprocessing of digital imagery of the soil; (D) appropriate and accurate data mining approaches that can link the site, image and soil information together to allow estimation of properties at new locations; and (E) the ability to provide a simple but effective interface to communicate instructions and results to the user in the field. Here we discuss what is needed to satisfy all of these requirements, and give some examples of how the whole process has been carried out in practice. We identify common challenges and how to tackle them, and also discuss necessary steps for future development. Finally, a demonstration is given of the current system under development for estimating a number of soil properties using in the UK.

Keywords: Smartphone; image analysis; field observations; digital soil mapping; proximal sensing
Financial support: Scottish Government and RCUK funding

(1516 - 1300) Viewing soils

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Here we summarise how the soil profile is viewed and studied. An

overview is presented of the measurement of soil properties and morphometric characteristics, soil depth functions, and soil profile imaging and mapping. The overall purpose is enhanced understanding including more objective ways of identifying and delineating soil horizons and treating the soil as a continuum with depth. There has been considerable progress in the in-situ measurement of soil properties and soil functions linking a range of instruments with soil inference systems. Some progress has been made in the mapping of the soil profile that includes raster sampling of a soil profile wall, digital image analysis of soil profiles, and monolith scanning. This has resulted in improved soil horizon delineation and assessment of soil horizon purity, and the realization that there may be a recurrent pattern in soil features at different levels that can be studied using similar pedometric approaches.
Keywords: digital soil morphometrics, soil profile, raster sampling, soil image, horizons
Financial support: UW Madison

WG05 Proximal soil sensing (PSS)

Applications of electromagnetic induction techniques in soil studies across different spatial and temporal scales

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Electromagnetic induction (EMI) techniques have been widely used in soil studies. Because of the noninvasive nature, they provide rapid measurements of the soil apparent electrical conductivity, which can be directly and indirectly correlated to a number of soil properties (e.g. salinity, moisture, and texture). Over the past 40 years, EMI surveys have been carried out at different spatial and temporal scales to improve the understanding of soil physical properties and processes, and how they interact with other environmental factors across various spatial and temporal scales. At the plot scale, EMI techniques have been successfully used to map the spatial and temporal variation in soil water content and understand the crop water use efficiency. At the field scale, the EMI technique has been applied to map the spatial variation in soil salinity, and monitor the soil water dynamics for irrigation management. At the catchment scale, EMI measurements can value-add to the legacy soil data and provide insights on soil management and land conservation. However, the limitations of the EMI techniques also need to be taken into account, including requirements of site-specific calibration models, and the susceptibility to environmental noises. With the advent of the Internet of Things, EMI instruments have the potential to be integrated with other sensor platforms and provide real-time and fine-resolution information on the variations of soil properties within root-zone and vadose zone for soil and environmental scientists, agronomists, hydrologists, ecologists, and policymakers.
Keywords: physical properties; physical processes; non-invasive; sensors;
Financial Support: Department of Soil Science, University of Wisconsin-Madison flexible funds

Machine Learning and Computer Vision applications in Proximal Soil Sensing

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Characterization and quantification of soil properties are important for the optimum use and management of our soil. Traditional methods for estimating soil properties are time consuming and laborious. In contrast, recent technological developments around proximal soil sensing has been showing great promise to meet the high-resolution spatial and temporal data demand for modern-day precision agriculture. More recently, with the advancements and developments in imaging techniques and computational powers of modern computer and handheld devices to process high-resolution images have been gathering interest to characterize soil properties. Often the color and the surface textural characteristics of an image and image pixels is nothing but the presentation of the characteristics of that soil. Developing a relationship between the colors and the image surface textural properties as derived from an image with laboratory-measured soil properties show strong promise of image-based soil characterization. Image processing and various machine learning and computer vision algorithms provide the basis for developing these relationships. This paper brings together some examples from current studies on imaging soil in laboratory and in field conditions using various devices including handheld microscope, cell phone camera and digital camera and various image processing techniques including geostatistical, artificial neural network, support vector machine, wavelet transform to characterize soil texture and organic matter. Design and development of image acquisition systems, collection of soil images, processing and extraction of image parameters and development of models will provide information on the use of machine learning and computer vision applications to develop new proximal soil sensors.
Keywords: Soil imaging, computer vision, soil carbon.

D4
Soils Contribution to Ecosystem Services Provision: Using Land Information for Farm Planning and Design Within Boundaries

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In the last 20 years, there has been some remarkable progress in recognizing the value of soils beyond their agronomic value towards characterizing the role of soils in sustaining healthy environment and thereby economies and societies. With the emergence of the ecosystems approach to resource management and the recognition of soils central role in sustaining the provision of the whole range of ecosystem services, many disciplines are reinventing themselves in order to enable the quantification and valuation of all benefits obtained from farm landscapes. Here we explore how several disciplines such as land evaluation, ecological theory and farm planning can be brought together to advance farm planning and design which are not only sustainable and operate within environmental boundaries but also are performant as businesses and provide social and cultural benefits to the wider society. Land evaluation has a long history of describing and quantifying the productive capacity of land, but there is a global recognition of the need for this discipline to evolve and recognize other services provided by landscapes, beyond food production, as well impacts on receiving environments. The land evaluation process is embedded in geology, geomorphology and soil science, which in actual practice puts heavy emphasis on an agro-technical analysis. Therefore, it is still relevant and needs to be at the heart of farm system design. Ecological theory provides the relationship between stocks and processes and supports the premise that the manipulation of key stock attributes changes ecosystem function and service provision. Finally, farm planning which has more of a focus on socio-economic constraints to the production system, is the tool with which strategic planning at the farm scale can happen. The combination of three disciplines enables more of the interactions between natural capital, which includes in addition to soils, vegetation and waterways, and built capital stocks and the intensity of a use and practices as they influence the provision of all services and impacts on receiving environments. This approach allows the analysis to be extended beyond productive performance and the associated financial analysis of the farm business, to an integrated analysis of all services. Building this into farm system analysis will require the development of new analytical capabilities.

Keywords: Natural capital; multi-functional land evaluation; ecosystem services; farm planning; farm system design; optimisation.

(1373 - 1690) Development of a low cost MIR spectrometer for proximal soil sensing: progress and challenges

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Numerous spectroscopic modalities have been explored for proximal soil sensing (PSS). The capabilities of techniques like near infrared (NIR) and mid infrared (MIR) reflectance spectroscopy have been well documented in the literature. Although MIR typically provides better performance over a broader range of soil characteristics than NIR, the use of MIR in the field has been limited by the instruments' lack of portability. In the context of aiding smallholder farmers in the developing world, both techniques have historically been cost prohibitive as well. Recent developments have created the potential for portable, field-robust, and dramatically lower priced MIR systems based on components like linear variable filters, pyroelectric array detectors, and tuneable Fabry-Perot detectors. With the lower costs come inherent trade-offs in performance relative to typical Fourier transform MIR systems – e.g. reduced spectral range and resolution and lower sensitivity. To assess the feasibility of using these components for PSS, we first examined a soil spectral database with over 1000 samples and corresponding reference data from the African Soil Information Service. The spectra were altered in software to match the range and resolution of the lower cost components. The primary ranges considered were 2.5 – 5.0 um (4000 to 2000 cm^{-1}) with a 50 cm^{-1} resolution and 5.5 – 11 um (approximately 900 to 1800 cm^{-1}) with a 30 cm^{-1} resolution. Using both partial least squares and a neural network approach, the soil property predictions were only marginally worse (about 10%) for the reduced spectral ranges compared with the full range, high resolution data. We then constructed a proof of concept MIR reflectance prototype in the 5.5 – 11 um range and tested it on a set of 100 diverse soils from the collection at the International Soil Reference and Information Centre (ISRIC). Although some features of the prototype spectra showed a good correspondence to the manipulated spectral library data, other spectral regions appeared to suffer from limited sensitivity and/or further degraded resolution. As such, the prototype spectra were able to predict some soil properties reasonably well (R^2 for sand = 0.69), but others rather poorly (R^2 for soil organic carbon = 0.45). Future work will examine the causes for the worse-than-expected performance of the MIR prototype, and compare performance with other novel, low cost NIR sensors.

Keywords: mid infrared spectroscopy; MIR near infrared spectroscopy; NIR low cost developing world
Financial support: Global Good Fund

(4857 - 2678) Estimating soil organic carbon with soil Vis-NIR spectroscopy: a comparison of different algorithms in two forest areas.

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Sustainable forest land management requires the development of rapid, accurate, and cost effective methods to determine forest soil organic carbon (SOC). Reflectance spectroscopy in the visible, near infrared (Vis-NIR) region could be an alternative to standard laboratory methods. The work was aimed to evaluate the performance of different multivariate calibrations techniques analysing soil reflectance spectra to estimate soil organic carbon (SOC). The study was developed within two study areas located in southern Italy: (1) the Bonis catchment (139 ha), mainly covered by Calabrian pine, and (2) the "Marchesale" Biogenetic Nature Reserve (33.2 ha) covered by forest beech. The two study area show relatively homogeneous features in terms of parent material and soil type, whereas they differ in soil sampling density: 135 samples collected in the Bonis catchment and 231 in the "Marchesale" Biogenetic Nature Reserve. In both areas, soil samples were collected up to a depth of 0.20 m, oven dried at 40° and sieved at 2 mm, and then used for spectroscopic measurements and analyses of SOC content. SOC content was determined using a TOC-analyzer (Shimadzu Corporation, Kyoto, Japan), whereas Vis-NIR reflectance was measured in laboratory, under artificial light, using an ASD FieldSpec IV 350-2500 nm spectroradiometer (Analytical Spectral Devices Inc., Boulder, Colorado, USA).To reduce the amount of data and computation time, the spectra were averaged every 10 nm. Spectral reflectance (R) was transformed to apparent absorbance (A) by A = Log (1/R). Each data set was randomly split into a calibration and a validation set (70% and 30%, respectively). Three techniques including principal components regression (PCR), partial least squares regression (PLSR) and support vector machine regression (SVMR) were used to estimate the calibration models, which were validated through the independent datasets. The models were compared through the coefficient of determination (R^2), root mean square error of prediction (RMSEP) and interquartile distance (RPIQ). For both study areas, the results showed that PLSR outperformed with higher R^2 and RPIQ values and lower RMSEP. PCR showed similar results than PLSR but with lower R^2 and RPIQ values and higher RMSEP, whereas the worst results were obtained for SWMR. These preliminary results bring out the need to analyse the effects of different factors (soil type, sample size, etc.) on the relative performance of the prediction techniques.

Keywords: Soil carbon, Soil spectroscopy, Principal component regression, Partial least square regression, Support vector machine regression
Financial support: (1) 'ALForLab' PON03PE_00024_1 co-funded by the National Operational Programme for Research and Competitiveness (PON R&C) 2007–2013; (2) LIFE09 ENV/IT/078 Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing

(1582 - 300) Monitoring soil moisture dynamics at the plot scale using repeated electromagnetic induction surveys

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Soil water dynamics are important parameters to monitor in any field-based drought research. Although inversion of apparent electrical conductivity (EC_a) measured by electromagnetic (EM) induction to calculate depth-specific electrical conductivity has been used to determine soil water dynamics, little research has shown its successful applications in heavy clay soils or plot-scale comparisons of crop water use. An EM38 conductivity meter was used to collect time-lapse ECa data across a Vertosol field cropped with 36 different chickpea genotypes. An empirical multiple linear regression model was established to predict water content measured by neutron probes and electrical conductivity generated by a 1-D EM inversion algorithm. Soil water dynamics and movement were successfully mapped with a coefficient of determination (R^2) of 0.87 and root-mean-square-error of 0.037 m^3 m^{-3}. The rate of soil drying varied with depth and was influenced by chickpea growth stages and genotypes. The results were also used to evaluate the differences in soil water use and rooting depths within- and across- plant species and during the growth stages. Coupled with physiology measurements, the approach can also be used to identify mechanisms of drought tolerance in the field and screening for effective water use in crop breeding programs.

Keywords: EM38; EM inversion; genotypes; drought-tolerance; water use;

Financial support: Australian Research Council (ARC), ITRH—Legumes for Sustainable Agriculture (IH140100013) (program 1b) and the Grains Research and Development Corporation

(3986 - 2667) Prediction of total silicon concentrations in French soils using pedotransfer functions from mid-infrared spectrum or pedological characteristics

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Silicon (Si) is the second most abundant element of the Earth's crust, after oxygen. The terrestrial Si cycle notably depends on the type of vegetation and is suggested to be perturbed by human activities. However, the spatial extent of the perturbation is still poorly documented since soil Si maps are rare to our knowledge and Si is rarely measured in non-paddy soil databases. In this study, we propose pedotransfer functions to determine total topsoil Si concentrations based on either pedological data (particle size fraction, pH, organic carbon, cation exchange capacity, calcium carbonate and parent material), total element concentrations or mid infrared spectra (MIRS) data. These data are all available within the French monitoring network of soil quality, RMQS (Réseau de Mesures de la Qualité des Sols). Pedotransfer functions were first built on a RMQS subset on which total Si concentrations were measured using a regression tree Cubist approach and a repeated cross-validation approach combined to a bootstrap procedure. In order to compare the relative performance of the models obtained for the three different PTFs, common performance indicators were calculated. Both the MIRS- and the pedological-PTFs provide reasonable to accurate estimations of the Si concentrations for French soils. The PTF based on MIRS data produces highly accurate and precise Si estimates. The pedological PTF is less accurate, but nevertheless provides a reasonable estimation of the Si concentration for French soils. Thus, it serves as an alternative method when only basic pedological data are available and an approximate estimation of Si concentrations is sufficient. These PTFs can be readily applied at the European scale with the possible exclusion of a few soil groups not represented in France.

Keywords: Silicon, silica, pedotransfer function, mid-infrared spectra (MIRS), RMQS, regression tree
Financial support: ANR BioSiSol project ANR-14-CE01-0002

(8981 - 2434) Seeing is believing: managing soil variability, improving crop yield and minimising off-site impacts in sugarcane using proximal soil sensing and digital soil mapping

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Over 70 % of sugarcane industry operates next to the Great Barrier Reef. Sugarcane farmers are therefore under pressure to improve practices to minimise off-farm pollution. They also need to improve fertiliser (e.g. lime) and amelioration (e.g. gypsum) efficiency to minimise yearly in-field yield variation. Farmers therefore need to know soil variation to apply fertilisers and ameliorates efficiently, to improve soil condition, maintain productivity and reduce runoff. In this presentation we provide demonstrated case studies which show how proximal soil sensors are being used to develop digital soil maps (DSM). In the field, we showcase how a gamma-ray spectrometer (RS-700) and an electromagnetic induction instrument (DUALM-421) can be used with mathematical models to map individual soil physical (e.g. clay) and chemical (e.g. CEC) properties using additive log-ratio transformation and Bayesian statistics, respectively. We also show how these two proximal soil sensors can be used jointly to identify management zones using clustering (k-means). In the laboratory, we describe the application of Cubist modelling with soil spectra from a portable visible near-infrared spectroradiometer (ASD FieldSpec4) to develop a spectral library to predict various soil physical and chemical properties. The results are leading to a DSM framework to provide farmers with proximal soil sensing tools based on science to better map, manage and monitor soil variability, improving yield and reducing off-site impacts.

Keywords: DUALEM-21, CEC, clay, proximal soil sensing; digital soil mapping, electromagnetic induction, gamma-ray spectrometry
Financial support: Australian Federal Government, Sugar Research Australia, Project Number SRA JT002

(9099 - 789) Soil spectra fusion based on Outer Product Analysis (OPA): a strategy for modeling soil properties

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The energy reflected from soils is affected by their mineral and organic compounds, and their water content besides. Therefore, by reflectance spectroscopy is possible to quantify soil physical and chemical properties when it is associated to multiple regression models. In fact, the modeling of some soil properties useful as quality indicators, such as, sand, clay, organic carbon (OC), pH, cation exchange capacity, etc., has achieved satisfactory results by using vis–NIR (350-2500 nm) and mid-IR (4000-400cm^{-1}) spectra. However, these quantifications can be improved if both spectral ranges are used together. So, we evaluated the predictions of clay, OC, and pH modeled with spectra fused by OPA and compared them to the individual ranges. We used 1259 soil samples from central region of Brazil. Contents of clay and OC were determined by densimeter and modified Walkley-Black methods, respectively, and pH was determined in water. Vis–NIR and mid-IR reflectance spectra were respectively obtained by FieldSpec Pro and Nicolet 6700 FTIR, and they were log-transformed into absorbance values. For spectral fusion, OPA algorithm was applied where all aborbances of vis–NIR were multiplied by all of mid-IR producing a matrix with all possible products between ranges. Soil properties were modeled by Support Vector Machine with linear kernel function, and modeling performance was assessed by R^2 and RMSE. Predictions were performed five times for each property, and Tukey's test was used to evaluate the significance of differences among performance indices from individual and fused spectra. The modeled properties showed the following mean values for clay: 444.40 g kg^{-1} (± 250.40 g kg^{-1}), OC: 8.80 g kg^{-1} (± 5.60 g kg^{-1}), and pH: 5.7 (± 0.7). For clay, the models showed the following mean results: $R^2_{vis–NIR}$: 0.86c and $RMSE_{vis–NIR}$: 92.34a g kg^{-1}; R^2_{mid-IR}: 0.89b and $RMSE_{mid-IR}$: 84.59b g kg^{-1}; R^2_{OPA}: 0.91a and $RMSE_{OPA}$: 74.61c g kg^{-1}. For OC, the mean results were: $R^2_{vis–NIR}$: 0.69c and $RMSE_{vis–NIR}$: 3.38a g kg^{-1}; R^2_{mid-IR}: 0.77b and $RMSE_{mid-IR}$: 2.90b g kg^{-1}; R^2_{OPA}: 0.81a and $RMSE_{OPA}$: 2.42c g kg^{-1}. For pH, the mean results were: $R^2_{vis–NIR}$: 0.36c and $RMSE_{vis–NIR}$: 0.54a; R^2_{mid-IR}: 0.64b and $RMSE_{mid-IR}$: 0.40b; R^2_{OPA}: 0.75a and $RMSE_{OPA}$: 0.34c. Indeed, the OPA fusion significantly improved the predictions where all R^2 values were increased and their associated errors were reduced. The spectral fusion by OPA algorithm is an efficient strategy to improve the soil property modeling.

Keywords: proximal soil sensing; vis–NIR; mid-IR; reflectance spectroscopy; support vector machine
Financial support: São Paulo Research Foundation - FAPESP (multi-user process 2009/54144-8).

(8080 - 968) Soil survery for agricultural land physical quality grade assessment using in-situ vis-NIR spectroscopy in Jiangxi Provicne, China

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Assessment of physical quality grade of cultivated land on provincial scale is a routine job of the Department of Land and Resources of local provincial government in China. Conventional soil survey involves intensive soil sampling and laboratory analysis, which are time consuming and expensive. Visible and near infrared (vis-NIR) spectroscopy, especially in-situ spectroscopy, of soil has proved to be accurate, cheap and robust for survey of soil quality. To test its potential, 294 sites were selected from land consolidation and exploitation projects of cultivated land in Jiangxi province in south of China. Fresh soil cubes of topsoil were scanned by an ASD vis−NIR spectrometer with wavelength range from 350 to 2500 nm. Then, Soil samples were air-dried, ground and passed through a 2 mm sieve. Soil organic matter (OM), pH, total nitrogen (TN), available nitrogen (AN), clay, silt, sand, and CEC were also measured on soil samples to build calibration models and also to validate the models' accuracy. For eliminating the influence of soil water contents, the Least Squares Support Vector Machines (LS-SVM) with a direct standardization algorithm were used to build the prediction model for the soil indices. On the basis of the ratio of prediction deviation (RPD), which is standard deviation of prediction divided by the root mean square error of prediction, and R^2. The accuracy of leave-one-out cross-validation of soil OM, clay, silt, and sand model was classified very good (RPD=2.06, RPD=2.25, RPD=2.14, and RPD=2.00, respectively. R^2=0.77, R^2=0.81, R^2=0.79 and R^2=0.79, respectively) and soil TN, AN, CEC was good (RPD=1.96, RPD=1.91 and RPD=1.77, respectively. R^2=0.74, R^2=0.72 and R^2=0.75, respectively). However, the model accuracy of pH was poor due to non-direct soil spectral response for soil pH in vis−NIR spectroscopy. According the 'Regulation for gradation on agriculture land quality' of China, the mean value of the soil index, e.g. SOM, is selected as the value of each assessment unit based on at least 75 samples per hectare. Then the SOM should be reclassified into five ranks, which larger than 30 g/kg, 30-20g/kg, 20-10k/kg, and less than 6g/kg. The measured and predicted mean value of SOM of the 98 validation samples in this study were 19.66 g/kg and 19.90 g/kg, respectively. The methodology of the agricultural land physical quality grade assessment makes the application of in-situ vis−NIR surveys of soil indices at regional or national scales more feasible.

Keywords: Soil survey, agricultural land physical quality grade, vis−NIR, LS-SVM, China
Financial support: This work was supported by the National Science Foundation of China (No. 41561049), the Natural Science Fund for Distinguished Young Scholar of Jiangxi Province (No 20171BCB23049), and the Science and Technology Project of Jiangxi Provincial Education Dep

WG06 Soil Monitoring: Soil monitoring evolving tools and challenges

(6689 - 2710) Agriculture's role as a terrestrial carbon sink: Getting back what was lost

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As a scientist and farmer–one with money in the game– I have seen the changes in US agriculture first-hand. With the 1985 Farm Bill and its conservation compliance mandate, US agriculture leaped forward in ways that reduced erosion and improved soil structure...for at least a few years. Alas, recent trends in the past few decades have seen a tillage relapse/rebirth and with it the loss of the recently sequestered C acquired through conservation compliance's minimal tillage practices. While there are many arguments for why more tillage is being used today, one important factor is that rainfall patterns have changed necessitating the perceived need for tillage to dry the soil for planting. Using 120 years of local rainfall data we will show how the farmer's climate has changed, how the farmer has reacted to these changes, and why it is imperative that soil management be addressed and included in policy in climate change mitigation. Micrometeorology/eddy covariance data from Tennessee, Ohio, as well as southern Africa (Lesotho and Zimbabwe) Africa, will provide evidence that soil can be an important sink for carbon dioxide. Soil can play a very important and passive role in climate change mitigation if policies help provide action. Making minor changes to our production systems can change soils' role from a contributor to "global warming" to a mitigator.

Keywords: mitigation, soil carbon, tillage, no-till, carbon sequestration
Financial support:

(5467 - 947) Sampling methods for topsoil monitoring – A Comparison of spade and gouge-auger sampling for topsoil monitoring at continental scale

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The election of the sampling method is a key aspect when designing a soil monitoring network with the purpose of detecting temporal and spatial changes on soil conditions. The early detection of such changes is a primary objective for scientific and policy organizations, because it enables to design and implement policy measures to facilitate a sustainable soil use and management so that soils continue delivering ecosystem services while preventing degradation. The use of standardized and reliable sampling methods is essential to detect changes on soil variables. At European scale, the Topsoil Survey of LUCAS (Land Use and Cover Area Frame Survey) is a good example of a harmonized soil monitoring network with circa 27,000 point locations throughout Europe in 2015. The aim of this study was to assess the accuracy of two sampling methods for topsoil characterization at regional and continental scale. We compared the LUCAS sampling with spade, and a sampling with gouge auger, often used in soil monitoring as for example in the Swiss Soil Monitoring Network (NABO) at 160 sites under various land cover (LC) classes in Switzerland within the LUCAS 2015 Survey. The sampling methods differ on the accuracy of the litter removal and the control of the sampling depth, which were more rigorous in the gouge auger than in the spade method. The adjusted R^2 between the two sampling methods was ≥ 0.80 for all soil parameters regardless of LC. Considering LC, the adjusted R^2 of linear regressions between the sampling methods was lower in woodland and grassland classes than in arable land for organic carbon (OC), nitrogen (N), phosphorus, and potassium due to variations in sampling depth with the spade. The adjusted R^2 of linear regressions for OC and N contents were lower in coniferous forest (0.87 and 0.89, respectively) than in deciduous and mixed forest (≥ 0.92 and ≥ 0.94, respectively) due to the difficulty of litter removal in coniferous forest. Furthermore, the adjusted R^2 for OC and N contents were lower in pasture (0.86 and 0.79, respectively) than in meadow (0.95 and 0.91, respectively) because of the spatial heterogeneity of livestock excreta in soil surface that interfered with the sampling schema. We concluded that the LUCAS spade method is an accurate method for topsoil sampling at continental scale, although some improvements on the control of sampling depth and the accuracy of litter removal are needed especially when monitoring forest soils.

Keywords: topsoil monitoring, sampling methods, spade, gouge auger, organic carbon

Financial support: Federal Office for the Environment FOEN, Project Number A2111.0240 environmental observation

WG07 Universal Soil Classification: Progress for the development of a Universal Soil Classification System

(8042 - 1063) An international system of soil horizon nomenclature

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We have entered an age of instant communication, global agriculture, and international environmental problems. Consequently, there is a need for better communication, including better international communication about the nature and properties of soils. At the 2010 World Congress of Soil Science in Brisbane, Australia a working group on the Universal Soil Classification System was established. Within that working group, several task groups were formed, including this one whose objective is to compare and blend existing nomenclature systems and make a recommendation for an international standard. Much commonality exists among different national systems. For example, nomenclature for eluvial, illuvial and organic horizons is ubiquitous. Pedogenic carbonates, gypsum, silica, soluble salts, slickensides, concretions, buried genetic horizons, gleying, strong cementation, ploughing, and weak development are also widely recognized, although symbols for these properties often differ. Other properties are more diversely recognized, such as phosphorus accumulation, sulfides, unweathered material, low bulk density, lamellic features, and dry permafrost. We will present a recommendation developed from this compilation and blending of existing systems with the expectation that the standards will not only enhance international communication, but will also provide a greater understanding of global soils.

Keywords: Soil horizon designations; pedogenesis; classification; soil survey standards

Financial support:

(5453 - 2661) Evaluation and correlation studies of centroid units from Brazilian Soil Classification System

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The development of soil classification systems originated with local and regional efforts of scientists to group individual soils by their attributes and associated environments. Currently the World Reference Base (WRB) and the Soil Taxonomy (ST) are two systems of soil classification which are accepted as international. However, these systems were not developed from a data base including many tropical soils, especially the ones rich in Fe and Al. In this study, a large soil data base (SISolos - Information System of Brazilian Soils) from the Brazilian Agricultural Research Corporation - Embrapa was used to evaluate the attributes of tropical soils. Brazilian data was accessed through the Embrapa open access portal (https://www.sisolos.cnptia.embrapa.br/) and the profiles are classified in the Brazilian Soil Classification System (SiBCS). Soil properties and profile descriptions were obtained in the SISolos data base, and the central properties defined by the Universal Soil Classification System (USCS) were extracted by using R software. In order to investigate the taxonomic distance, centroids were calculated based on 22 major properties for 18 agreed intervals. Spline functions were applied to get the interpolated standardized depth intervals. The SiBCS centroids were generated from the data acquired from SISolos. The WRB centroids were derived from the ISRIC-WISE v3.1 data base, from the 1200 validated profiles that were classified according to the WRB. Taxonomic relationships were defined by calculating the Euclidian distances between the centroids of the great groups of the SiBCS and centroids of the WRB reference soil groups. The taxonomic relationships present the possibility to contribute to the development of USCS by the definition of a new entities, to better express the tropical soils in the system. The adoption of the US can promote a common “soil language” among the soil science community, and also to make improvement in soil science, and correlated areas, due to the further harmonized data.

Keywords: Global soil classification; Soil units; Diagnostic properties

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WG08 WRB: Soil Classification for understanding soil genesis, map legends and soil functions. Experiences with WRB and other systems

(1906 - 1153) Ability of WRB system to classify the soils with clay illuviation under various (pedo)environmental conditions

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A majority of the soils in Central Europe was formed under humid climate conditions and percolating water regime that affects an intense leaching. As a result, clay illuviation is one of the most widespread soil-forming processes in this region. Large heterogeneity of pedons with argic horizon emphasizes diversity of pedoenvironmental conditions under which the process has developed. International soil classification is expected to reflect this diversity in soil unit names. The aim of this study is to evaluate ability of WRB classification to reflect the impacts of diverse environmental conditions on the development of clay illuviation. The studies were conducted in 8 European countries (Estonia, Latvia, Lithuania, Poland, Czechia, Slovakia, Hungary, and Slovenia). Detailed description of 97 soil profiles and surroundings was made. Soils were classified according to WRB (2015) based on their morphological features and the results of analysis of soil samples collected. More than 30% of soils had an argic Bt horizon. In the other 70% of pedons, the factors limiting clay illuviation were: sandy texture, shallow ground water and/or OC accumulation, erosional truncation, fauna activity and humus accumulation in the material rich in carbonates, specific parent material, and high anthropic pressure. The clay-illuvial soils were mainly developed in silty or loamy materials. The vast majority of pedons with Bt horizon was classified as Luvisols or Retisols (80%). Vertical texture differentiation in many of these soils resulted from overlapping of the clay translocation and the primary lithological heterogeneity of parent materials. Moreover, an abrupt textural difference and the stagnic properties allowed to classify the soils as Planosols. Only ca. 10% of clay illuvial soils had well-developed albic material. The shallowing of pedons by erosion is the main factor leading to disappearance of albic horizons. An absence of eluvial horizon is also typical for soils with accumulation of humified organic matter as dominant soil-forming process (Luvic Chernozems, Phaeozems and Umbrisols). Also, a parallel clay illuviation and podzolization was confirmed in the mountain soils (Skeletic Alic Podzol). Wide spectrum of RSGs and qualifiers in the WRB enables precise reflection of soil variability in relation to the present or past environmental conditions. Obtained results specify the current knowledge and are valuable for the soil science education.

Keywords: WRB, clay illuviation, argic horizon, Central Europe,

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(1049 - 640) Collisions of the „genetic" and „quantitative" approaches in an international soil classification WRB 2015

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Although the WRB system has adopted apparently quantitative approach to soil classification, manifested in the diagnostic horizons, properties and materials, the "genetic" approach is still visible in traditional soil names, often referring to the fundamental concept of soil zonality, also related to global zonality of climate and vegetation. Thus, many reference soil groups (RSG) of WRB are considered zonal soil or are defined in a clear relation to specific soil-forming process, and are unexpected to occur under climate and ecological conditions unfavourable for soil-forming processes responsible for development of these soils. However, the combination of local factors may generate such a soil transformation, that soil profile under classification meets the criteria of RSG unexpected in this climate zone. Final analysis of more than 100 soil profiles discussed within the project FACES (Freely Accessible Central European Soil, Erasmus+) has indicated at least three collisions of the "genetic" and "quantitative" approaches in WRB 2015 when applied in Central Europe. Kastanozems have to be recognised in profiles of arable or colluvial Chernozems under humid temperate climate, probably due to restrictive criteria for chernic horizon or insufficient criteria for RSG Kastanozems; Calcisols have to be recognised under humid climate of North Poland and Baltic Countries due to erosional exhumation of carbonate-enriched subsoil, young age of carbonate-rich glacial materials, or unclear criteria for distinguishing the finely dispersed secondary carbonates; Phaeozems have to be recognised in intensively managed arable soils of various origin. Human impact (deep ploughing and intense mineral and/or organic fertilization) rather than zonally differentiated natural conditions and respective soil-forming processes. If the current concept of WRB system is to be maintained (relatively large number of narrow RSGs, clearly related to soil-forming processes or conditions), the diagnostic criteria for some RSGs have to be corrected (supplemented) to avoid incidental classification of soils.
Keywords: diagnostic criteria; classification systems; soil zonality; WRB
Financial support: Project FACES (Freely Accessible Central European Soil) is co-funded by Erasmus+ Programme of the European Union

(4156 - 1386) Evaluation of the world reference base (wrb, 2015) as a strategy to reduce the propagation of uncertainties in the national soil cartography in Mexico.

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Soil information in Mexico consists of 64,800 soil profiles and 3 series of taxonomic maps of national coverage, produced by the National Institute of Statistics and Geography (INEGI) through global protocols such as FAO Legend (1968-1983), FAO-UNESCO-ISRIC (1984-1995) and the World Reference Base (1996-2018). The dataset represented in the national cartography aims to implement measures to solve problems related to food security, conservation of biodiversity and socio-ecological adaptation to climate change, continuously aligning with the new scientific, technological and political context worldwide. To meet this objective, INEGI performs the estimation of the uncertainty associated with the soil data based on the evaluation of completeness, comparability, precision and accuracy in all field and laboratory protocols and the processes related to the transfer of information, in order to transit from an error approach to an information uncertainty approach. It has been quantified that the national set of data has decreased its level of total uncertainty (Ui) from 67.2% to 59.8% in the last ten years of production. Most of this reduction is mainly due to three fundamental processes: the geo-statistical analysis of the data (2.4%), the analysis of soil factors and processes in field (3.3%) and the harmonization of processes about analytical tests of the participating laboratories (0.7%). All the evaluated processes are interdisciplinary concatenated and any increase in the error of one process corresponds to the increase of the error in all the others. The transition from a Soil Legend to a Taxonomic Reference Base has not only generated more detailed field classifications, but also improves sampling design and better understanding of soil factors and processes by specialists, which is reflected in a better segmentation of the soil polygons and a better interpretation of the taxonomic groups and inter-grades during the final cartographic representation. Of the total uncertainty that still remains in the information (Ui= 59.8%), it has been estimated that 24.2% comes from the natural complexity to separate the soils and 28.0% comes from imperfect criteria for selection and representativeness. In both cases, the development of better diagnostic criteria in the World Reference Base, and its better integration with other more detailed national levels, may be the key to diminishing the propagation of high uncertainty in the national cartography.
Keywords: WRB; UNCERTAINTIES; ACCURACY; CARTOGRAPHY; MEXICO
Financial support: Instituto Nacional de Estadística y Geografía (INEGI)

(7385 - 2761) Red soils of the tropics – challenges for soil classification

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A primary objective of soil classification is to aid the understanding of soil function and facilitate the efficient communication of important soil properties. However, the selection of particular diagnostic properties, and the adoption of arbitrary soil attribute thresholds sometimes results in a diversity of soils being included in one taxon and essentially similar soils being separated. This results in confusion when attempting to communicate important soil information and extrapolate the results of research activities, for example when deriving spatial entities to model crop production potential and develop soil suitability indices. This paper examines aspects of soil classification relating to the strongly weathered soils of the tropics, focussing on the implied soil forming processes (e.g. ferrallitization) and the diagnostics that have traditionally been used to assess the degree of weathering and hence generally rank the contrasting utilisation potentials of these soils. Reference Soil Groups of the World Reference Base (WRB) including Nitisols, Ferralsols, Lixisols and Acrisols are correlated with soil classes of various national systems including the Ferrosols, Kandosols and Kurosols of the Australian Soil Classification; the Kaolinitic soil classes of the Zimbabwe Soil Classification; the soils with red and yellow-brown subsoil horizons (South Africa) and the Nitissolos, Latossolos and Argissolos of Brazil; with further examples drawn from Kenya. This review briefly considers options for future work in the development of taxonomic relationships (quantitative models) that can more effectively capture and describe the functional diversity in the strongly weathered tropical soils.
Keywords: tropical soils, ferrallitization, Nitisols, Ferralsols, Latosols, Ferrosols, Australian soils, Zimbabwe soils
Financial support:

(4788 - 410) Suggestions for the 4th edition of the WRB

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The third edition, update 2015, is the currently valid version of the

international soil classification system World Reference Base for Soil Resources (WRB). For 2022, the 4th edition is planned. This presentation will give a summary of the major suggestions that came in up till now without anticipating any decision to be taken later by the WRB Working Group. 1. General: Replace all distinctions by base saturation by distinctions by pH (water). 2. Key: 2.1. Position all hydromorphous soils together between Solonchaks and Andosols in the sequence Plinthosols - Gleysols - Planosols - Stagnosols. (During some excursions through Brazil, it was suggested to have Planosols and Stagnosols before Nitisols and Ferralsols.) 2.2. Exclude from Gypsisols and Calcisols soils with an argic horizon not permeated with secondary carbonates or secondary gypsum. (currently not excluded if with a petrogypsic or petrocalcic horizon) 3. Diagnostics: 3.1. New diagnostic horizon for (lateral) accumulation of Fe oxides. 3.2. New diagnostic horizon for hardsetting mineral soil surfaces. 3.3. New diagnostic horizon for buried A horizons. 3.4. Revise the sombric horizon to clearly separate it from buried A horizons. 3.5. Revise the diagnostic horizons for the Anthrosols and bring them into a hierarchical order to avoid that a horizon fulfils the criteria of two or more of them. Harmonize the methods for P concentrations. 3.6. Introduce an additional criterion for the cambic horizon, not related to overlying or underlying layers (which is only possible if there is no lithic discontinuity), e.g. a certain soil aggregate structure. 3.7. Chernic horizon: Weaken the structure and colour criteria for ploughed horizons. Require the high base saturation throughout (in order to make Chernic Umbrisols unlikely). 3.8. Abrupt textural difference: Enhance the minimum clay content for the underlying layer. 3.9. Lithic discontinuity: Additional criteria. 4. Qualifiers: 4.1. Chromic and Rhodic: require soil formation as in a cambic horizon to avoid that colourful parent materials are Chromic or Rhodic. 4.2. (Sub)qualifier for drained histic horizons, which fell < 20% soil organic carbon in the upper part and still have ≥ 20 % in the lower part. 4.3. New qualifier Insectic to cover soils reworked by termites and ants. 4.4. New qualifiers for soil degradation 4.5. Split the Technic qualifier: one for artefacts with a weighted average ≥ 10 % from 0 to 100 cm, one for a thinner layer with many artefacts.

Keywords: WRB, edition 2022, diagnostics, qualifiers
Financial support: none

(4472 - 2874) The diagnostic continua of the soil of Europe to support the definition of soil function

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Diagnostic horizons, properties and materials are defined and commonly applied building units in national and international soil classification systems. The presence, depth or exclusion of the diagnostic information supports the process of objective soil classification. In the World Reference Base (WRB) the qualifiers are also defined elements, supplementing the highest taxonomic level -the Reference Soil Group (RSG) - with additional information. The diagnostic units and the qualifiers convey information by themselves, on important and often complex soil properties, that are related to soil functions. Soils may have properties that are characteristic for different soil types and the principles and priorities of the classification system (defined in the classification key) support the decision on the soil classes (RSGs in the WRB). The spatial extent or the continuum of the diagnostic units may be (and often is) different from the soil mapping units (mostly classification units) in general soil maps. This paper will present the spatial distribution of selected diagnostic units and qualifiers that can be attributed to the major soil functions in a continental scale for Europe. The data source for deriving of the diagnostic continua was the 1:1 M Soil Geographical Database of Europe hosted by the European Soil Data Center (ESDAC). The database consists of Soil Typological Units (STU), defined by the WRB RSGs and one qualifier. As, the original geographical representation did not allow the delineation of STUs, they were grouped into Soil Mapping Units (SMU) to form soil associations. The percentage of the STUs within the SMUs are given without spatial definition. The visualized maps generally present the polygons of the SMUs by representing the dominant STU. The digital database includes further analytical and environmental information for the semantic units. Each dominant STU is also supplemented with a representative soil profile with basic horizon data. An algorithm was developed to derive the selected diagnostic elements and qualifiers for each STU and their weighed % was calculated for the association in the SMU. The derived layers represent the continua of the properties “stored” in the definition of the diagnostic elements. The paper will demonstrate the value and applications of the derived products and will provide examples for the assessment of spatial definition of soil functional capacities based on the presence of the diagnostic elements.

Keywords: WRB, diagnostic units, qualifiers, spatial continuum, soil functions
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WG09 Soil Modeling: Challenges and perspectives in soil modelling

(3884 - 1834) A global assessment of future risks for below-ground biodiversity

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In terrestrial systems, soils comprise an inherently complex dynamic reservoir of biodiversity within which the interactions between microbes, animals, and plants provide many benefits for human well-being. Although many ecosystem services are related to soil biodiversity, soil biota and ecosystem processes are significantly understudied and under-represented in many biodiversity databases, modeling frameworks, and synthesis analyses. Nevertheless, land use, management, and climate change are reported as the key determinants of biodiversity distribution and dynamics. Likewise, soil ecosystem function is similarly affected by these drivers as fluctuations in precipitation, temperature, or land use may have significant implications water infiltration, decomposition, soil protection, among others. Given the significance of these global drivers to shape soil biodiversity and ecosystem functions, the question arises if and to what extent global soil biodiversity and ecosystem functions are vulnerable to future changes in these drivers. Using global spatially explicit datasets on future predictions of drivers like climate (e.g., precipitation, temperature), land use (e.g., crop type), and aboveground ecosystem functions (e.g., evapotranspiration), together with datasets on current distribution soil biodiversity (e.g., soil functional diversity) we aim to identify the vulnerability of soil biodiversity and ecosystem functions to future dynamics of global change drivers. Our results show that, although 56% of earth presents high soil functional diversity, most of it is affected by changes in precipitation and in land use, with extensive areas of South America, Asia and Africa being affected by both.

Keywords: Biodiversiy, climate, land use, projections, function
Financial support: European Union's Horizon 2020 research and innovation programme under grant agreement No 641762-ECOPOTENTIAL project ("Improving future ecosystem benefits through earth observations")

(6389 - 480) An improvement of the hydraulic-energy indices for physical soil structure evaluation

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Soil physical quality (SPQ) is related to soil health and in many studies indices, which manifest soil structural behavior, are applied. A widely used hydraulic function is the soil water retention curve (SWRC) and its integration holds quite important information, which manifests SPQ changes. SWRC is usually mathematically described relating volumetric soil water content (θ) and soil water tension (h) in both θ(h) and h(θ) functions. Since 1978, many works have presented the concept of the integral ∫θ(h)dh (or ∫h(θ)dθ) (Mualem, 1978; Minasny and McBratney, 2003; Shi *et al.*, 2011; Asgarzadeh et *al.*, 2011; Armindo, 2013; Deepagoda *et al.,* 2013; Armindo and Wendroth, 2016). Unfortunately, the domain of the integral ∫$\log_{10}h$(θ)dθ is defined only for h³1, since the logarithm of real numbers > 0 and < l generates negative values. Also, because fitting the parameters of the Van Genuchten (1980) -Mualem (VGM) equation to θ($\log_{10}h$) and θ(h) functions generate different results of field capacity (θ_{fc}) (by dynamic method), saturation (θ_s), and permanent wilting point (θ_{pwp}), the integral ∫$\log_{10}h$(θ)dθ is not applicable. Thus, five hydraulic energy indices and two cumulative energy functions based on defined numeric integration ∫h(θ)dθ of the VGM equation in available water (AW, AW= θ_{fc}-θ_{pwp}) and drainable porosity (DP, DP= θ_s-θ_{fc}) ranges were examined by Armindo and Wendroth (2016). These indices are: absolute aeration energy (A_a, A_a=∫h(θ)dθ defined in DP range), absolute water retention energy (WR_a, WR_a=∫h(θ)dθ defined in AW range), relative aeration energy [A_r, A_r=100·A_a/(A_a+WR_a)], relative water retention energy [WR_r=100·WR_a/(A_a+WR_a)], and relative air-water energy (AW_r, AW_r=100·A_a/WR_a). Because the h(θ) function is non-linear, with h ranging from 0 to 15,000 hPa and 0<θ£1, WR_a became much larger than A_a (WR_a>>A_a) causing the relative indices A_r and AW_r to become usually close to 0 and WR_r close to 100 % (see Table 5 in Armindo and Wendroth, 2016). This work presents a new approach to calculate the energy indices to improve their performance by manifesting SPQ changes using h values in log scale. The analysis was performed for a database of SWRCs in h(θ) against $\log_{10}h$(θ) basis and was programmed in R. Results showed that the new approach is better applicable to calculate the work-energy indices, which were more sensitive to exhibit SPQ changes, keeping the same integration limits of θ_{pwp}, θ_{fc}, and θ_s as well as AW and DP ranges.

Keywords: soil water retention integration; integral energy; SPQ indices.
Financial support:

(9959 - 2009) Goals and activities of the ISMC soil development and intercomparison panel (Soil-MIP)

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The soil model development and intercomparison panel (Soil-MIP) is a science panel of the International Soil Modeling Consortium (ISMC) with the mission to foster the further development of soil models that can predict soil functions and their changes due to soil use and land management, as well as climate change and pollution. As a first step, a model collection that displays different models and their characteristics, features, properties was setup. This step forms the basis for model comparisons, in particular on how different processes are represented by different models, how parameters are derived from other available soil information, and how these differences lead to different predictions. Such model intercomparison studies are important to assess uncertainties of model predictions and how they depend on uncertainties in the models themselves, model inputs, and model parameters. In crop modelling, climate modelling, and weather forecasting, such model intercomparison studies have been shown to reduce the prediction uncertainty when predictions by different models (i.e., model ensemble predictions) are combined. Recently, a number of model intercomparison studies have been initiated or are being planned, focusing on specific processes like root growth and root water uptake, soil evaporation, soil freezing, soil heat fluxes, infiltration and runoff processes, and coupling between preferential flow in soils and groundwater. From these comparisons, lessons can be learned about how process controls at small scales propagate to larger scales and how

this leads to effective process representations at larger scales. In addition to comparing models, model integration activities also have been started. These integration activities are important to describe feedbacks that exist between different processes. An example of such an integration that is currently being investigated is the coupling between soil biota models and soil physical models. Further information can be found at https://soil-modeling.org/.
Keywords: Models, Soils, Intercomparison
Financial support: Forschungszentrum Jülich GmbH

(1120 - 2014) Modelling below-ground fungal communities: a mechanistic and trait-based approach

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Soil structure provides a home to large numbers of microorganisms offering them a food base, support, access to water, air and nutrients and protection from predators. To be able to function, soils need to deliver these essential requirements for life, at micro-habitat scales. Soil structure is the soil characteristic that makes this possible. Therefore soil structure holds the key to life in soil, regulates many ecosystem services and ultimately underpins sustainable life on Earth. Despite this, the exact way in which soil structure exerts its control is not fully understood and considered to be too complex to be explicitly included in modelling of key processes such as C dynamics. Neither does currently a framework exist that links microbial dynamics in soil with ecosystem functioning. The lack of such a theoretical framework hampers our understanding how soils respond to perturbations. In this presentation we address this gap in our understanding. Recent advances in soil characterisation and mathematical modelling now make it possible to advance our understanding of soil microbial ecology through modelling. Exemplified for fungi, we present a mechanistic model for the effect of diversity on C dynamics, and identify environmental factors and fungal traits that affect stability in functioning. Uniquely we consider fungal interactions at scales directly relevant to the organisms (micro-meters) in order to predict ecosystem services, such as the evolution of CO_2, as an emergent property of these interactions. We present the first theoretical framework for below-ground fungal ecology that links physico-chemical heterogeneity and fungal traits to identify key traits and environmental drivers that shape fungal communities and affect the evolution of CO_2 from fungal activity. We used X-ray CT to obtain detailed information about the pore network and applied lattice Boltzmann modelling to create connected water and air pore volumes through which fungi spread. We show how the evolution of CO2 emerges from interactions between biological traits and micro-scale heterogeneity.
Keywords: fungal traits; Xray CT; Lattice-Boltzmann; pore network
Financial support:

(8163 - 1426) Retrieving systemic information for modeling soil processes interactions: the BonaRes knowledge portal

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Our goal is to develop systemic model tools to predict the impact of soil management and climate on soil functions based on a mechanistic understanding of soil processes. The proposed modeling approach is based on defining relevant soil components, i.e. soil matrix, macropores, organisms, roots and organic matter. They interact and form the soil's macroscopic properties and functions including water and gas dynamics, and biochemical cycles. The challenge is to formulate the interactions between the various components based on our current understanding of soil processes. This will form a complex network of process interactions, which is in the position to represent the dynamics of soil properties and functions in response to external forcing. In order to collect the required information and to facilitate the retrieval process based on published knowledge we have chosen an open, community based approach. A web interface gives the opportunity to enter information on soil related articles, and to collect the results on processes and interactions that are reported therein together with the important meta information on the specific site conditions. Visual and text-based retrieval tools enable the fast identification of the related literature, and the major findings. It is as such comparable to google scholar, but more powerful to structure the huge amount of information with respect to different soils and site properties. The portal is implemented and currently tested by a limited group of soil scientists. It will be opened for the entire community to hopefully fuel our understanding and modeling of soils as complex systems.
Keywords: systemic soil modeling, literature retrieval, process understanding
Financial support:

(6857 - 2863) Soil as a self-organized system: theoretical and practical considerations

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Although earth's soils are limited in area (and resilience), increasing pressure is leading to significant and ongoing degradation. Nevertheless, the growing demand for their ecosystem services is leading towards even more intensive and multifunctional usages. We propose a conceptual model based on the theory of self-organization to guide an understanding of soil functioning, to help research in addressing its complexity and to ensure efficient and sustainable management systems. Self-organization is the only current theory that incorporates the complexity of the soil system. This model integrates the effects of soil organisms of all sizes, the structures they create through their activities and those created by physical or chemical processes, together with their interactions and feedbacks. It also incorporates the broad temporal and spatial scales at which soil processes operate and includes the successional processes that occur in the functional units comprising the system. We present a general soil model based on this theory, together with supporting data on its physical and biological organization. Finally, we consider the utility of this representation for soil management and communication with the non-scientific public.
Keywords: Self-organization, aggregate and pore size distribution, soil habitats, microbial and faunal communities
Financial support: Institut de Recherche pour le Développement, IRD

(1210 - 1014) The Agricultural Ecosystems Services (AgES) watershed model is used to estimate the spatial complexity of soil hydraulic properties in a field-scale agricultural watershed, Colorado, USA

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Soil hydraulic properties that control water storage flow rates can vary

markedly in space, and surface layers may vary temporally due to management events, reconsolidation and biological activity. Field measurements are expensive to collect and generally reveal complex variability that is difficult to fully characterize. Yet, these soil properties are represented using model parameters that may strongly affect simulated flows and the distribution of soil water in space and time. Thus model calibration using available measurements of soil moisture and surface runoff is essential. Here, we address the level of calibration detail needed to estimate available data by using five levels of spatial complexity in the calibrated soil parameters. Results are also explored to address issues of spatial scaling. Furthermore, a new model component of temporal changes in soil porosity and saturated hydraulic conductivity is tested to simulate effects of tillage and soil consolidation related to rainfall. Interactions between spatial and temporal parameters and processes will be discussed in terms of their influences on simulated soil moisture patterns and surface runoff. Non-uniqueness of the estimated parameter sets is recognized, but further work is needed to better quantify the information content of data needed to infer unique space-time patterns of the estimated soil hydraulic properties.

Keywords: Soil hydraulic properties, spatial variability, agricultural watershed, temporal dynamics
Financial support: USDA-ARS

(3957 - 2859) The International Soil Modeling Consortium: status and perspectives

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The International Soil Modeling Consortium (ISMC) was established in 2016 with the aim to integrate and advance soil systems modeling, data collection, and observational capabilities. The underlying principles and scientific basis were outlined in a recent white paper on "Modeling soil processes: review, challenges and new perspectives" published in Vadose Zone Journal in 2016. Its activities are organized in three science panels: data and observation model linking, soil modeling development and intercomparison and cross cutting activities. ISMC has an executive board and a scientific advisory that guides ISMC in pursuing its objectives. ISMC is a community effort based on voluntary contributions and people can sign up freely (https://soil-modeling.org/). In this presentation, we will highlight the most recent developments and activities that are currently ongoing as well as future projects that are under preparation.

Keywords: soil processes soil systems modeling data-model linking
Financial support:

WG10 Hydropedology: Hydropedology and critical zone science: toward systems soil Science

(1865 - 1251) A systemic approach to model soil functions

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Soil functions, like acting as a buffer for water and nutrient, as a reactor for matter turnover and as habitat for organisms and, last but not least, as basis for plant growth, are considered to be integral properties emerging from the complex interactions between physical, chemical and biological processes. It is well known that soil water plays a crucial role for almost all soil processes as has been stressed in the field of hydropedology. Yet, to understand how soils behave in response to external forcing that is brought about by changes in land use and climate, the perspective needs to be widened towards a systems approach. Such an approach needs to analyze the complex interactions between various processes and properties. We suggest a systemic modeling concept based on a well-defined network of such interactions. It is intended to serve as a model tool to predict the impact of land use and climate on soil functions but besides this, it is also a valuable "toy model" to analyze the effect of model assumptions on the system's behavior. We present examples for soil structure and carbon dynamics in arable fields. The hydraulic properties are also treated as an emerging property of the soil and its structural dynamic, in order to study the interplay between soil water dynamics and structural changes.

Keywords: soil functions soil ecosystem services soil structure complex systems
Financial support:

(4613 - 2764) Spatial and temporal variations of SWC and its response to intensive human managements in the critical zone of the Loess Plateau, China

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The Earth's Critical Zone (CZ) is a new comprehensive discipline by using a unified framework to understand terrestrial ecosystems. The Chinese Loess Plateau (CLP) is an unique critical zone, which is characterized by fragile ecosystem with deep loess thickness on the vertical direction, geomorphic diversity on the horizontal direction, serious soil erosion, and high intensity of human management. Soil water content (SWC) is highly variable and plays a key role for sustainable development of ecosystems in the CLP-CZ. To investigate the spatial and temporal variations of SWC and evaluate its response to intensive human managements such as the Grain-for-Green project (GFGP) and the Gully Land Consolidation project (GLCP), we used "3 M" methods and monitored the dynamics of SWC from the surface down to 5 meters or deeper by utilizing the neutron-probe and electrical resistivity tomography at the Gutun watershed, which is a typical CLP-CZO and located at the middle part of the CLP. We then developed the distribution maps of SWC at different soil layers and different monitoring occasions from 2015 to 2017. Combined with the collected data of land use/land cover patterns (determined by the GFGP), micro-topography changes (determined by the GLCP), soil physical and chemical properties distributions, and meteorological forcings traits in the watershed, we found that soil water changed significantly both in water quantity and spatial pattern—SWC in slopes decreased gradually and usually caused the occurrence of a dried soil layer in the profile; while SWC in gullies increased dramatically and was benefit to farming after a proper management of water drainage. Our results provide a guideline for the sustainable management of watershed water processes in the CLP-CZ, which is increasing needed by local policy makers and is also helpful for understanding the influence mechanisms of applying the GFGP and the GLCP on the structures, functions, and services of the CLP-CZ.

Keywords: Critical Zone; Deep soil; Electrical resistivity tomography; Soil water management; Spatial heterogeneity
Financial support: This study has been supported by the National Natural Science Foundation of China (Nos. 41571130083, 41530854, and 41471189), and the Youth Innovation Promotion Association CAS.

(5134 - 2547) The contribution of hydropedological assessments to the availability and sustainable management of water, for all (SDG#6)

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The UN Sustainable Development Goal number 6 (SDG#6) strives to "*Ensure availability and sustainable management of water and sanitation for all*" by 2030. SDG#6 is accompanied by specific targets which include; improving water quality through reducing pollution and treating polluted water, increasing water use efficiency of all sectors, protecting and restoring water-linked ecosystems and implementing Integrated Water Resource Management (IWRM) at all levels. The ecosystem services provided by soils through their functions can contribute to realizing these targets. In this paper we maintain that hydrology/soil physics and pedology cannot by themselves solve land use issues related to water management at landscape scale. The synergistic integration between these disciplines, i.e. hydropedology, can however contribute considerably to realising targets associated with SDG#6. We will discuss several cases to illustrate how hydropedological information and assessments can be used in pollution management, protection and rehabilitation of wetlands, contribute to water use efficiency and IWRM. In many of these cases, satisfactory answers could be provided using a combination of existing knowledge of- and expertise in various disciplines. This highlights the importance of multidisciplinary and transdisciplinary approaches to address the targets of the SDGs. The case studies also showed that hydropedological inputs are applicable at various different scales (from pore geometry of horizons to regional soil distribution patterns of large watersheds). The level of hydropedological information required is determined by a specific problem; for example, the identification of pollution plumes require detailed transect surveys combined with soil physical and hydrometric measurements, whereas the modelling of 5th order catchment (> 8 000 km^2) only necessitate hydropedological interpretation of regional soil information. By increasing the detail of hydropedological information (with increased costs), more accurate simulation results are obtained. Lastly, the importance of understanding the hydrological system is emphasized through each of the case studies. The improved understanding of the hydrology of landscapes should be the driving force behind mapping and characterisation of soils in order to find similarities and common hydrological behaviour. This will facilitate IWRM, especially in ungauged basins, and contribute towards realisation of SDG#6.

Keywords: Pedology, soil physics, hydrology
Financial support:

(5733 - 969) Towards 3D-modelling of critical zone evolution: achievements and challenges

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Modelling the evolution of the critical zone in its landscape context is a long-term target. It requires the understanding of processes in the critical zone and the ability to select the most important ones as model components in a well-described geo-environmental setting. Currently, large efforts are done on sampling and process identification and on modelling. Here, we focus on achievements and challenges related to modelling. A recent survey has shown that 1D-models for processes in the critical zone have the highest process coverage, and are because of the incorporation of hydrological modules and linkage to climate models the most "Global Change ready" (GC-ready). We show this by an example study on paleosoil development in the Chinese loess belt where the effect of the climate signal on soil development was not understood by using a conventional Earth System Model. Incorporation of organic carbon dynamics and weathering in a high process-coverage model opens pathways to evaluate possible feedbacks between geochemical (weathering) status and organic matter turnover rates. We will show results from a chronosequence study to illustrate this possibility. The same survey showed that 2D- and 3D-models are less advanced in terms of process coverage, and need better hydrological modules to become GC-ready. Nevertheless, progress has been substantial as will be shown with example studies on modelled redistribution of a radionuclide and organic carbon in Catena's and landscapes. The strength of 2D/3D-models is that they allow investigating possible landscape-scale feedbacks, e.g. between erosion, sedimentation and C-sequestration. Challenges for all critical zone models that consider water flow are related to their process coverage (e.g. volume strain in managed topsoils and in the weathering zone), their modularity and accessibility to the modellers' communities, and availability of data for model parametrization and testing. These challenges suggest that linkages between groups focusing on data collection and on modelling need to be strengthened to arrive at GC-ready models of the critical zone in a landscape context.

Keywords: Critical Zone; Modelling; Hydrology;
Financial support: -

(4223 - 2768) Towards integrated modeling of soil systems

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Soil is one of the most critical life-supporting compartments of the Biosphere and its provides numerous ecosystems services such as a habitat for biodiversity, water and nutrients, as well as producing food, feed, fiber and energy. Soil models are key to quantify and predict soil processes and related ecosystem services. However, a new generation of soil models based on a soil systems' appraoch comprising all physical, mechanical, chemical and biological processes is now required to address critical knowledge gaps and thus contribute to the preservation of ecosystem services, improve our understanding of climate-change–feedback processes, bridge basic soil science research and management, and facilitate the communication between science and society. The International Soil Modeling Consortium (ISMC) was established in 2016 with the aim to address these challenges and to integrate and advance soil systems modeling, data collection, and observational capabilities. The underlying principles and scientific basis were outlined in a recent white paper on "Modeling soil processes: review, challenges and new perspectives" published in Vadose Zone Journal in 2016. Its activities are organized in three science panels: data and observation model linking, soil modeling development and intercomparison and cross cutting activities. ISMC has an executive board and a scientific advisory that guides ISMC in pursuing its objectives. It is a community effort based on voluntary contributions and people can sign up freely (https://soil-modeling.org/). In this presentation, we will highlight the most recent developments and activities that are currently ongoing as well as future projects that are under preparation.

Keywords: Soil systems, ISMC, data, observations, soil models
Financial support:

WG11 Land Degradation: Restoring degraded lands through soil carbon management

(3143 - 2702) Application of different organic amendments in restoration of contaminated soils of Kola Peninsula

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A heavy metal contamination – is a serious widespread ecology problem. Changes caused by anthropogenic activity affect all coenosis levels and lead to the worst consequences in industrial areas. By inhibition of plant and soil microorganisms' growth and activity processes heavy metals (HM) cause appearance of the barren areas – highly damaged eroded ecosystems required remediation. There are a lot of remediation ways, but an appropriate restoration method, which does not expensive, does not demand special technical support and corresponds to the natural conditions of soil development is still open to question. The objects of our investigations were soils of technogenic barrens near mining-and-metallurgical integrated works located in Kola Peninsula, Russia. Soils are represented by 1) Al-Fe-humus abrazen and 2) chemically contaminated ferric podzol. Soils are characterized by the absence of vegetation, low pH , low exchangeable acidity, depletion of organic mater as a result of the erosion processes. Nowadays organic amendments become more popular in remediation purposes, because they are environmental-friendly, cheap and may be easily applied in-situ. In our work we have applied organic amendments different by theirs properties and origin a) coal-humates and b) peat-humates inoculated by nitrogen fixers and mycorhizae-forming fungi; c) peat-gel inoculated by mycorhizae-forming fungi, d) biochar. We have evaluated their influence on contaminated soils and compared with influence of e) lime; f) NPK-ferilizer in short-term experiments (from 45 days to 3 months). The efficiency of the proposed method was estimated by the state of test-culture, native for the object in undisturbed conditions, and by the dynamics of the microbiological activity. As a result we concluded that amendments of different origin have unequal influence on soil properties and cause decreasing as well as increasing of HMs mobility in the conditions of short-term experiments, and also may have no effect. The collected data about changing of chemical, biological and physical properties and also about the character of HM accumulation in plants due to application of different amendments allow to predict ways of organic matter transformation, efficiency of chosen remediation technique, so make a prognosis about soil restoration.

Keywords: heavy metals, soil organic mater, exogenous organic matter, microbiological activity, humates, biochar, contaminated soil, industrial area

Financial support:

(9735 - 1584) Biochar stabilization in two Chilean soils of volcanic and non-volcanic origin

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Universidad de Concepción[1]

Restoration of degraded soils could be through the promotion of adequate use of the soil, for example increase of soil organic carbon. Sometimes application of non-stabilized products (manure) can be an important source of greenhouse gases. An alternative to improve the quality of the soil are the applications of biochar. However, their effect on greenhouse gas emission has not yet been elucidated, with contradictory results depending on the soil type and crop systems. In Chile, around 70% of agricultural activities are carried out on soils derived from granitic material and volcanic ashes. The aim of this study was to measure the evolution of carbon dioxide emissions in volcanic and non-volcanic soils amended with biochar. Two Chilean soils (Dystric Fluventic Xerochrepts (Inceptisol) derived from volcanic ashes and Ultic Palexeralfs (Alfisol) derived from granitic material) were incubated with three biochars produced from chicken, cow, and pig manures. Carbon dioxide emission was evaluated during 260 days. Carbon dioxide emissions in the soil derived from volcanic ash were greater than carbon dioxide emissions in the soil derived from granitic material, during the first 15 days of incubation. However, the emissions were greater the first 10 days in both soils, with other high values recorded between days 45 and 50, possibly associated with microbial soil successions. Carbon dioxide emissions were less than 0.5 mg CO_2 kg suelo^{-1} h^{-1} between days 90 and 260 in all treatments. The emissions of soil-biochar (pig and cow) treatments did not have significant differences with the control soil emissions. While soil- chicken biochar emissions were superior the first ten days in both soils. Volcanic and non-volcanic origin soil did not change its carbon dioxide emissions in the long term with the application of biochar from animal manure.

Keywords: Carbon dioxide emission; Climate change; carbon sequestration

Financial support: Fondecyt 1160795

(7096 - 3075) Chemical attributes of anthropic A horizon under different soil uses in southern Amazonas

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Conventional agriculture eventually uses agricultural practices that are incompatible with the fragilities of Brazilian biomes, especially in a fragile ecosystem such as the Amazon. In addition to the factors intrinsic to soil quality, cost of the land and extension of the biome facilitate a still common practice, where, after loss of soil quality, native forest areas are deforested, aiming to compensate for productivity losses, with areas even larger. In this environment, there are soil patches of anthropogenic origin called *Anthropogenic Dark Earths* (TPI), in which the increment of material from diverse origins formed over time a thick, normally fertile, dark A horizon with the presence of remains of fauna and flora, pyrogenic coal, ceramic fragments and lithic material. Its occurrence is described in restricted areas in the north of Brazil and neighboring countries of the Brazilian Amazon. Thus, this study aimed to verify the similarity of the attributes of the soil in TPI areas under different uses of palisade grass (*Urochloa brizantha*) e cocoa (*Theobroma cacao*). The study was carried out in areas with different soil uses and presence of A horizon. The sites of collection were in the municipalities of Apuí e Manicoré, both located at the south of Amazonas state. Two TPI areas were selected, where sample grids with dimensions of 80x56m for the Palisade grass area and dimensions of 88x42m for the cocoa area were made. The soils were sampled at the crossing points in the layers of 0-0.05m; 0.05-0.1m; and 0.1-0.2m, taking a total of 88 sampling points in each area. In the laboratory were determined: pH_{H2O}, Al^{3+}, H^+ Al, Ca, Mg, K, P, Organic Carbon (COT) and Carbon Stock (Est. C). The value for the sum of bases (SB); potencial CTC (T); bases saturation (V%) aluminum saturation (m%). The factorial analysis of the main components was carried out in order to find statistical significance of the sets of soil attributes that more discriminate the environments in relation to the land use, obtaining, in response to the land use, which environments suffer greater management influence. Analysis was observed for the three systems of land use, considering that the palisade grass area showed along the three evaluated layers a relation with attributes that indicate soil acidity (Al^{3+} e H + Al), whereas the cocoa area showed relation with attributes that indicate fertility (Ca, Mg, K, SB e V%).

Keywords: *Anthropogenic Dark Earths*, multivariate, soil management.

Financial support: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)

(2732 - 2397) Cropping systems to prevent water erosion in sloping

lands of Colombia under a changing climate

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Several studies confirm that rainfall amounts and intensities in the tropics are increasing; consequently, there is a significant potential for climate change to increase soil erosion rates leading to further impacts on agricultural production unless conservation measures are undertaken. Therefore, it is hypothesized that under changing climate with likely rainfall storms of higher amounts and intensities, avoidance of soil erosion mostly would depend on the ability of cropping systems to intercept rain drops and reduce the effects of rainfall erosivity and runoff. This article shows experimental data on effects of cropping systems to prevent soil losses in the high marginal coffee zone of the central Colombian Andes where emerging risks of soil erosion are particularly serious due to soil mismanagement including slash and burn, intensive tillage, use of herbicides and overgrazing. Residue-based zero tillage, integrated weed management and contour alley cropping systems of Andean raspberry crop (*Rubus glaucus*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), and pumpkin (*Cucurbita maxima*) were evaluated on volcanic ash soils with slopes ranging between 35 and 67%. Results showed a significant reduction ($P < 0.05$) on soil losses in cropping systems with permanent cover of crop residues and integrated weed management (0.576 $Mg.ha^{-1}.y^{-1}$) in comparison with the control bare soil treatment (144.561 $Mg.ha^{-1}.y^{-1}$). Also, there was a significant reduction ($P < 0.05$) on soil losses in contour farming mono-cropping system (16.054 $Mg.ha^{-1}.y^{-1}$) in contrast with the bare soil control trial. It is concluded that integrated weed management, residue-based zero tillage, contour farming and inter-planting crops are promising cropping systems to implement climate smart sustainable productive landscapes on steeplands in Colombia as well as in other parts of the tropics.

Keywords: Key words: conservation agriculture, alley cropping, noble weeds

Financial support: Corporación Universitaria del Meta, Unimeta, Villavicencio, Colombia

(8543 - 1068) Distribution characteristics of soil aggregates and its organic carbon ingravel-mulched land with different cultivation years

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The distribution characteristics of soil aggregates and its organic carbon in gravel-mulched land with different planting years (5, 10, 15, 20 and 30 years) were studied based on a long-term field trial. The results showed that the soil aggregate fractions showed a fluctuation (down-up-down) trend with the decrease of soil aggregate size. The soil aggregates were distributed mainly in the size of >5 mm for less than 10 years cultivation, and 0.05-0.25 mm for more than 15 years. The content of aggregates over 0.25 mm（$R_{0.25}$） and the mean weight diameter (MWD) of soil aggregates all decreased with the increase of cultivation time. The content of organic carbon within soil aggregates was increased with the decrease of soil aggregate size in gravel-mulched land with different planting years. However, the content of organic carbon within soil aggregates, contribution rates of different aggregate fractions to soil organic carbon and soil organic carbon storage of aggregate fractions decreased with planting time extension and soil depth. Soil organic carbon in the aggregate sizes over 1 mm was sensitive to long term gravel–mulched field planting response. Organic carbon storage ofaggregate fractions among 10, 15, 20 and 30 years were decreased by 8.0%, 24.4%, 27.5% and 31.4% in the soil depth of 0-10 cm, and 1.4%, 15.8%, 19.4% and 21.8% in the soil depth of 10-20 cm, respectively. In conclusion, the ability of soil carbon sequestration in arid gravel–mulched field was reduced with planting time extension. Therefore, soil fertility of gravel–mulched fields which are cultivated for more than 15 years needs to be improved.

Keywords: gravel-mulched field; soil aggregate; soil organic carbon; soil organic carbon stock

Financial support: The China Agriculture Research System for Watermelon and Melon (CARS-26-20)

(2984 - 543) Potential of conservation agriculture to mitigate historical and future greenhouse gas emissions in subtropical regions

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Currently the land use and land use change (LULUC) emits 1.3 ± 0.5 Pg carbon (C) $year^{-1}$, equivalent to 8% of the global annual emission. Techniques such as low carbon agriculture has been developed to reduce greenhouse gases (GHG) emissions from LULUC sector. The objectives of this study were to quantify 1) the impact of LULUC on GHG emissions in a subtropical region and 2) the role of conservation agriculture to mitigate GHG emissions. We develop a detailed IPCC Tier 2 GHG inventory for the Campos Gerais region of southern Brazil that has large crop area under long-term conservative management with high crop yields. The inventory accounted for historical and current emissions from fossil fuel combustion, LULUC and other minor sources. Our results showed historical (1930 – 2017) GHG emissions of 412.18 Tg C, in which LULUC contributes 91% (376.2±130 Tg C), the uncertainties range between 13 and 36%. Between 1930 and 1985 LULUC was a major source of GHG emission, however from 1985 to 2015 fossil fuel combustion became the primary source of GHG emission. Forestry sequestered 51.7 ± 23.9 Tg C in 0.6 Mha in 47 years (1.8 Tg C Mha^{-1} $year^{-1}$) and conservative practices sequestered 30.4 ± 23.9 Tg C in 1.9 Mha in 32 years (0.5 Tg C Mha^{-1} $year^{-1}$) being the principal GHG mitigating activities. The regional adoption of the best management practices observed in the region can mitigate 105 years of agriculture, forestry and livestock emissions (40 Tg C in 100 years) in 100 years, making the agriculture sector a net C sink. As most of the future land use change to meet the global food demand is expected in subtropical regions, we hope our methodology can be used as a model to create C inventories for supporting public policies aiming to mitigate GHG emissions.

Keywords: Carbon; Subtropical region; IPCC Tier 2; Agriculture, forestry and land use change

Financial support: CAPES

(2076 - 1269) The relationship between the erodibility factor (K) and parameters of soil fertility in agricultural lands of Gaziantep Province, Turkey

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Public relation is of great importance to raise the awareness about the threat of soil erosion. This is particularly true for Turkey, where protective measures against soil erosion are still not sufficiently addressed and applied. The knowledge of the spatial distribution of soils that are prone to erosion as well as their respective physical and chemical condition is a basic prerequisite to deduce recommendations for measures of applied soil protection, which can be implemented by local farmers.Within the present study, the susceptibility of agricultural lands in Gaziantep province to water erosion was examined on the basis of the parameters soil texture, soil organic matter content, soil aggregation and water permeability. Moreover, the nutrient supply of soils was investigated in order to further elucidate the impact of soil erosion on soil fertility. The study revealed that all investigated soils had

to be categorized as threatened by erosion due to a high to extremely high erodibility potential, with K-factors ranging between 0.33 and 0.79. According to these results, there is a generally high risk of erosion for the investigated soils and future erosion events might also be followed by a measurable loss of nutrients and consequently also soil fertility in general. As a major outcome of the present survey, the development of a regional soil protection concept was recommended. The effects of erosion on soil fertility could be illustrated to farmers within the scope of information sessions to implement appropriate soil protection measures.

Keywords: soil erodibility, soil fertility, nutrients, farmer education
Financial support: We would like to thank the Gaziantep University for funding the project (BAPB FEF0808)

(7898 - 2433) Using humified organic matter from lignite, as plant biostimulant of *Brachiaria decumbens* in post coal mining land reclamation in a semiarid zone

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In the open-cast coal mining, low rank coals (LRC) and carbonaceous waste are generated, these materials are enriched in humified organic matter (HOM) due to the vegetal origin of the coal and a incomplete coalification process; on the other hand, in post-mining land rehabilitation processes, a key factor for the quality of the new soil is the content of organic matter, which among other aspects contributes to the the soil aggregation, exhibith a phytostimulating effect and stimulates the microbial activity of the soil. In this research, several strategies to take advantage of HOM present in LRC were evaluated through an field-level experiment, in the area of land reclamation of an open pit coal mine in Colombia, in order to promote the establishment of a grass as a pioneer plant in a constructed soil in the early stages of land reclamation, this in a semi-arid tropical environment where endogenous sources of organic matter are scarce; then, experimental plots with *Brachiaria decumbens* were established and the following treatments were evaluated during a year: 1) direct application of a lignite type LRC as humic amendment for the topsoil, 2) a humic bioconditioner designed with LRC and an inoculum of bacteria that biotransform this carbon and release HOM, and 3) humic acids (HA) extracted from LRC, applied as biostimulants of plant growth. The microbial activity in the rhizosphere (enzymatic activity and respiration), the production of plant biomass, and the changes in the metabolic profile of the soil microbial community were determined. The treatments evaluated had significant effects on the evaluated variables; the effect of the phytostimulation treatment with HA stood out, enhanced important increases in the production of biomass and root system development. Results suggest that in this mining area it is possible to use the HOM contained in the residual LRCs, as a strategy to support the establishment of plants and improve some soil properties, in the early stages of land reclamation through constructed soils.

Keywords: *Brachiaria decumbens; lignite; humic biostimulants, humic amendments; constructed soils.*
Financial support: COLCIENCIAS – Colombia, agreement- RC 0424 de 2013, Project code: 111557635893

(8968 - 1073) Wheat yield and soil carbon, nitrogen and phosphorus reveal legacy effects of artificial erosion and amendments on a Dark Brown Chernozem

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Topsoil removal (simulated or artificial erosion, de-surfacing), whereby incremental depths of topsoil are mechanically removed with an excavator, is a recognized method of quantifying erosion effects on soil productivity. The ability of soil amendments (e.g. manure, fertilizer, crop residues) to restore productivity to variously 'eroded' surfaces may also be studied with this approach. The oldest artificial erosion experiment in Alberta dates to 1957 at the Agriculture & Agri-Food Canada Research Centre, Lethbridge. Various sub-studies, aimed at restoring soil productivity, were imposed on the site including one which ran from 1980–85 and one from 1987–91. Legacy effects of erosion (which occurred in 1957) and manure amendments (applied in the 1980s) were still evident on wheat yield in 2010 as well as on soil organic carbon, total nitrogen, and available phosphorus in 2011. For example, in 2011, across all levels of erosion, soil organic C (10.9 vs. $\bar{x}$ = 9.8 g kg^{-1}, or +11%) and total N (1.13 vs. $\bar{x}$ = 1.00 g kg^{-1}, or +13%) were significantly higher (0–15 cm depth) where manure vs. check or fertilizer was applied in 1980–85. Our findings showed that in the absence of amendments, recovery of artificially eroded soils was only partial, to a point below the level of non-eroded soil. Our study identified maximum legacy effect timelines of 54 yr for soil erosion and 31 yr for soil amendments.

Keywords: Soil erosion, carbon, manure
Financial support:

WG12 Paddy Soils: Mitigating GHG emission and enhancing productivity in rice-based systems

(1629 - 1856) Fertility re-evaluation of paddy soils in tropical Asia after 50 years of the Green Revolution (FREPS 50): Case studies in Thailand and the Philippines

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Understanding the long-term trend of soil fertility in paddy would be essential to establish rational and sustainable management for rice production. Kawaguchi & Kyuma (1977) investigated 410 paddy fields in 10 tropical Asian countries to evaluate soil fertility during 1960s to 70s, i.e. at the initiation of the "Green Revolution (GR)". It is obviously recognized that the GR contributed to the dramatic increase of the rice yield but the long-term effect of the GR on fertility status of the tropical paddy soils is not fully understood. The objective of this research was, therefore, to evaluate the effect of the GR on the changes of soil fertility status in the past 50 years, as case studies in Thailand and the Philippines. In 2015, 2016 and 2017 (named as 2010s), 65 and 31 soil samples were collected from the plow layers of paddy fields in Thailand (i.e. the northeastern region, the northern region, the central plain and the Bangkok plain) and in the Philippines (i.e. the Luzon, Panay and Leyte islands), respectively. The sampling sites were placed at the same or close locations of the original during 1964 to 1972 (named as 1960s). The following properties of the 2010s samples were analyzed; pH, EC, total carbon (TC), total nitrogen (TN), available phosphorus (P) (Bray No.2 method), exchangeable bases (Ca, Mg, K, Na), CEC, particle size distribution and available silicon (Si). The data in 2010s were then compared with those in 1960s. In Thailand, significant increase in pH and the contents of TC, TN, available P and exchangeable K and significant decrease in exchangeable Mg and clay contents were observed for the last 50 years. In the Philippines, significant increase in pH and available P content and significant decrease in exchangeable Na and clay contents were observed. Among them the increase of available P content was most prominent. These changes would be ascribed to a higher input of chemical fertilizers and possibly the increased organic matter input due to the GR. In addition, more pronounced increment in the fertility status was found in Thailand partly because its original fertility status in 1960s

was much lower than that of the Philippines with volcanic activities. Furthermore, there are still considerable regional differences such as very low fertility status in the northeastern region of Thailand with very sandy texture. In conclusion, these findings should be used to establish more sustainable and productive rice production in tropical Asia.
Keywords: fertility status; Green Revolution; paddy soil; phosphorus; tropical Asia
Financial support: JSPS-Kakenhi (No 15H05247).

(2204 - 1731) Impact of water management on greenhouse gas production and soil fertility during rice production in southern Florida

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Production of rice in high organic matter soils have the potential to produce methane, and may increase overall greenhouse gas (GHG) emissions. Presently, after three years of sugarcane growth, farmers in the Everglades Agricultural Area (EAA) of southern Florida will rotate either flooded rice, flooded fallow or dry fallow during the summer months. Following drainage of the former sawgrass marsh in the early 1900s for agricultural production, the EAA has experiencing substantial subsidence due to organic matter oxidation of the organic soils (Order: histosol). Flooded fallow and rice fields both have the potential to reduce soil subsidence by slowing the oxidation of soil organic matter and release of carbon dioxide (CO_2) to the atmosphere. Prolonged flooding of these organic soils, however, may produce methane (CH_4). The objectives of this study were to evaluate differences in GHG production, nutrient availability and uptake, and rice yields, by manipulating water management in an effort to aerate soils and mitigate CH_4 production. Treatments were grown in 291 L pots, in quadruplicate, in a randomized block design. Each pot contained either 51 cm (deep) or 25 cm (shallow) of soil, and were subjected to one of three water treatments: (i) flooded, (ii) alternating (one week flooded, one week drained), or (iii) unflooded (top-half soil moist and aerated, bottom-half soil flooded) in comparison to dry fallow and flooded fallows. Gas measurements were taken in clear acrylic chambers to include both soil and plant flux. Mean CH_4 flux was low from all treatments (0.12 - 0.93 mg/d/m^2); however, deep soil-flooded rice was the highest. Relative global warming potentials demonstrated high overall GHG consumption by rice treatments (-648 to -926 mg CO_2 equiv./d/m^2), low GHG consumption in flooded fallow (-29 to -68 mg CO_2 equiv./d/m^2, and net production in dry fallow (100 - 139 mg CO_2 equiv./d/m^2). Following the growing season, 2-week alternating rice had the greatest increase in plant available soil Mn (5.7 g/cm^3), Fe had the greatest increase in flooded rice (137 g/cm^3), and P had the greatest increase in flooded fallow (5.8 lbs/acre). While Si and K decreased in all treatments, there was the greatest retention of Si (-2 ppm) in dry fallow, and K (-18 lbs/acre) in 2-week alternating rice. Our results suggest that alternative water treatments in rice may alter GHG production and soil nutrient availability.
Keywords: rice, greenhouse gases, soil nutrients, water management
Financial support: Florida Everglades Agricultural Area - Environmental Protection District

(6605 - 1096) Nitrogen loss from anammox and denitrification for different fertilization managements in paddy soils

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The anaerobic oxidation of ammonium (anammox) process has been observed in rice soils. However, the contribution of anammox to N2 production under viable fertilization managements is not well documented. In this study, soil denitrification and anammox activity, together with the abundance and diversity of anammox bacteria and denitrifying microorganisms were investigated for different fertilization and straw managements in paddy soils. The anammox rates measured by the isotope-pairing technique ranged from 0.22 to 0.53 nmol N per gram of soil per hour in paddy soils, which contributed 8.56 to 12.24% to soil N2 production. Soil denitrification rate ranged from 1.58 to 5.80 nmol N per gram of soil per hour. Anammox bacteria related to “Candidatus Brocadia” and “Candidatus Kuenenia” and “Candidatus Scalindua” and other clusters were detected, “Candidatus Kuenenia” comprising 55.46% of the anammox population and “Candidatus Brocadia” comprising 27.83% of the anammox population. The prevalence of the anammox was confirmed by the quantitative PCR results based on anammox bacterial(AMX) genes, which showed that the abundance ranged from 3.73×105 to 5.01×105 copies per gram of dry weight. The denitrification rate and anammox rate of NPKS were significantly higher than other three treatments. Results indicated that both fertilization and straw stimulated denitrification and anammox. N lost via anammox is an important way in paddy soils.
Keywords: anammox; denitrification; fertilization; paddy soils; nitrogen loss
Financial support: This research was financially supported by the National Natural Science Foundation of China (No. 41671232, 41271267).

(7563 - 843) Temporal trends of rice yield in a long-term paddy field experiment and their relations with climate warming

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We investigated rice yield in a long-term paddy field experiment on three elements (nitrogen, phosphorus and potassium) and application of rice straw compost conducted over four decades at Tohoku Agricultural Research Center, National Agriculture and Food Research Organization, located in the cool climate region of Japan. In most treatment plots, the yield of rice significantly increased over time. Total nitrogen and carbon contents of the soils in the plots with repeated application of rice straw compost increased, whereas those were almost constant or tended to slightly decrease in the three elements plots. Then, the trend of temporal increase of rice yield under the application of repeated rice straw compost can be partly attributed to the increase of soil fertility. However, in the three element plots without the application of rice straw compost, the increasing trend of rice yield was irrelevant to the soil fertility. Mean air temperature during rice growth period tended to increase during the experimental period over four decades. The trend of increase in temperature was greater after heading stage than that before the heading stage. Significant positive correlations were observed between yield and mean air temperature during growth period in most plots. The increasing trend of yield with temperature was raised by the repeated application of rice straw compost at the rate of 2 kg m^{-2} or more. Harvest indexes also increased with the temperature. In the yield component, kernel weight was main influential factor on the variation of yield in relation to the temperature. The quality of rice based on external appearance tended to decrease with temperature after heading. The application of rice straw compost alleviated the decreasing trend of rice quality.
Keywords: Climate warming long-term field experiment paddy soil rice
Financial support: The Ministry of Agriculture, Forestry and Fisheries, Japan through the research project "Development of agricultural production technologies for adaptation to global warming"

WG13 SUITMA: Soils of Urban, Industrial, Traffic, Mining and Military Areas

(2928 - 2866) Biochar-assisted phytoextraction of cadmium and zinc in contaminated soils

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Amendments of biochar, the residual solid of biomass pyrolysis, have been investigated in metal-contaminated soils, mostly in order to reduce soil metal mobility and availability to plants. However, biochar can influence plant metal uptake in metal-contaminated soils in various ways. In particular, biochars may enhance phytoextraction with metal-hyperaccumulating plants. Three successive plant growth experiments were conducted in order to understand the effect of one biochar on the amount of metals extracted by the species *Noccaea caerulescens*, a hyperaccumulator of Cd and Zn. One wood-derived biochar obtained from slow pyrolysis at 450°C was tested together with one acidic soil (A) and two alkaline soils (B and C) contaminated with Zn, Pb and Cd by smelter activities. In Experiment 1, various doses of biochar from 0 to 10 % (w/w) were tested with soil A and B in 800-ml pots, in which rhizon samplers were inserted to extract soil solution over the 9 weeks of plant growth. In Experiment 2, rhizoboxes filled with soil A or B amended with 0% or 5% biochar were used to assess the influence of biochar on root growth in similar conditions as in Experiment 1. In Experiment 3, two lysimeters containing undisturbed columns of soil C (1-m^2 wide, 2-m deep) were used to test the effect of biochar on plant growth and metal uptake over four successive years in real climatic conditions. In all three experiments, biochar was shown to improve the germination of *N. caerulescens*. A higher concentration of Cd and Zn in the shoots of the hyperaccumulator was generally found when biochar was present in the soil at a dose of 5%. Experiment 1 suggested that this increase in metal uptake was associated to a decrease in competition between the targeted metals and calcium ions. Experiment 2 showed that the higher uptake of metals was systematically associated to an increase in root surface. Finally, Experiment 3 showed that the positive effect of biochar on shoot metal concentrations decreased over the successive harvests of *N. caerulescens*, but that the presence of biochar increased plant resistance to harsh climatic conditions. In conclusion, biochar amendments can be used to favor plant installation in contaminated soils and to increase metal uptake with hyperaccumulating plants, but further investigations are necessary to assess their long-term effects.

Keywords: biochar, metals, hyperaccumulators, phytoremediation, agromining
Financial support: GISFI (www.gisfi.fr), France; Région Grand Est & EU (Feder), LORVER project

(8222 - 1170) Characteristics of edifisols of Shanxi Province, China

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The largest human impact on the soils is observed in urban areas. Many authors studied urban soils, however researches about the initial soils forming processes occurring on technogenic substrates on artificial structures are scarce. This process in such cases is relatively natural, apart of technogenic parent rock, and leads to the formation of so called edifisols. This type of soil was described by few authors only. The present study aimed to enrich knowledge in this field, thus the goal of this study was to examine the properties of soils forming on buildings in Shanxi Province with focus on assessment of the climate impact on the process of their formation. The research was conducted in China, in the Shanxi province, which lies in the east part of the loess plateau. The study sites were located in three cities and surrounding areas (central parts of municipalities and townships in direct vicinities of main cities): Datong, Taiyuan and Yuncheng, which lies in the northern, middle and the southern part of province, respectively. Those three cities were representative for the different climate conditions. The samples (40) were collected in June 2016 from abandoned buildings, where the soil material was mainly gathered by wind blow deposition from surrounding areas and weathering of technogenic substrate. In all studied soils content of following elements: C, N, P; heavy metals (Cd, Cr, Pb, Hg, As, Se, Cu, Mn, Fe, Zn) and pH, $CaCO_3$, texture were determined. Additionally, number of culturable bacteria, Actinomycetes and fungi was estimated in selected samples. Edifisols collected in the central part of metropolises are characterized by higher contamination of heavy metals than samples from suburban townships around. Value of the C:N ratio was the lowest in samples from southern part of province (mean C:N ratio value – 14), while the highest was observed for samples from northern part of province (mean C:N ratio value – 34). Number of culturable bacteria, Actinomycetes and fungi was not correlated with the climate factors. Climate could affects forming edifisols - initial soils on buildings, however evidence for this is not unequivocal. This subject needs more detailed research.

Keywords: Edifisols, initial soils, SUITMAs, Technosols, China
Financial support:

(1819 - 1741) Global soil sealing in urban reduce carbon storages

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Global Urbanization has deeply altered earth ecosystem. It is estimated that by 2030 the urban population will be more than 60%. Soil sealing in urban is a serious problem across the world. This study assumes that the organic carbon sequestration in soil will continue to decomposition due to blocking of the fresh organic material. Yet Studies have shown that soil organic carbon may reduce by 40-60%, it remains unclear how much carbon loss is caused by the global urbanization. To assess the impact of global urbanization on global soil carbon losses since the industrial revolution, we combined meta-analysis and process-based model to reveal soil organic carbon dynamic under anthropogenic sealed soil in global urban. In order to deal with the high spatial heterogeneity of urban soil, we divide the urban soil into four types: in-situ direct closed soil, surface soil removal, closed soil, normal open soil and open soil with foreign soil. The results showed that carbon density loss mostly depended on the initial carbon density and urban history. We also collected investigation soil carbon data about soil sealing from peer reviewed publications Soil carbon density in sealed soil had a good linear relationship with initial carbon density (*Carbon density* $_{sealed\ soil}$=0.57·Initial carbon density-0.68; r^2=0.67). the results implicated that we can us the simple relationship between sealed soil and initial soil to assess the carbon loss under impervious surface. The history of soil sealing was reconstructed based on HYDY data from 1900 to 2015. Now about 600, 000km^2 land, equals to area of French Republic, was sealing by urban. Soil sealing areal increased 5 times area from 1900 to 2015. Global soil sealing derived over the net loss about 1.3 PgC, about 0.013PgC yr^{-1}. We also predicted global soil sealing area using scenarios methods. The total of global soil sealing area may reach a range from 1000,000 km^2 to 1400,000 km^2 in 2050. The potential carbon loss will be up to 4.8 ~8 PgC. The carbon loss due to soil sealing are largely irreversible. Reducing soil sealing degree is an important approach for a sustainable earth.

Keywords: Soil sealing, Urbanization, Cabon, global, land use
Financial support: National Natural Science Foundation of China(41671085)

(9320 - 2643) Impact of nature-based solution on urban soil quality in different urban areas of Europe

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Improving soil management in the urban area required to modify soil use policy. Urban planning requires prior knowledge of soil quality, generally acquired through a set of diagnostics (geotechnics and analysis). The capitalization of these data, often collected and exploited by different actors, is a major stake in a logical implementation of a consistent, reasoned and sustainable use of the soil for planning purposes. Optimized management of urban soil (US) involves the use of specific techniques and tools adapted to the urban context (compilation into databases, interpretation of data and taking into account uncertainties). It is crucial to sustain the information in a usable format and make it available and accessible. Nowadays, the use of innovative procedures will help to promote the social acceptability of soil challenge by the city users. Nature-based solutions (NBS) can be defined as the use of nature in tackling urban challenges and conserve biodiversity in a sustainable manner. NBS may support to reform the approach of urban planning in EU countries. NBS are a new way to deliver multiple environmental, social and economic benefits especially for in urban space management and biodiversity through proposing and implementing a new toolkit based on natural resources. In the Horizon 2020 project, Nature4Cities besides multi-thematic and multi-scalar evaluation of all the nature-based solutions and their capability in addressing different urban challenges on a platform used by urban planners. Our work aimed at showing the relations between the fertility and quality of USs and the provided ecosystem services (regulation, provisioning, and habitat). Theses relations were assessed for all NBSs listed in the project. It was based on an analysis of the NBS performance using physical, chemical and biological indicators. We identified 21 candidate indicators relating to environmental issues, covering seven soil threats: erosion; organic matter decline; compaction; contamination; sealing; biodiversity and land use. The selected indicators were linked to threshold values and baselines and were tested on in situ experimental platforms in three cities in Europe under various climates (Alcala de Henares, Spain; Milan, Italy and Szeged, Hungary). The outcome is a set of proposals and recommendations for reference values for the selected indicators. The objective is to define new threshold values adapted to urban context.

Keywords: Nature-based solution; urban soil; biodiversity; fertility
Financial support: Nature4Cities project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468.

(7831 - 1265) Integration of organohalide-respiring bacteria and nanoscale zero-valent iron (Bio-nZVI-RD): A perfect marriage for the *in situ* soil remediation of organohalide pollutants

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Due to massive production and improper handling, organohalide compounds are widely distributed in soil, especially electronic waste (e-waste) recycling sites. Compared to traditional pump-and-treat or dredging-and-disposal treatments, *in situ* soil remediation employing abiotic or biotic reductive dehalogenation represents a sustainable and economic solution for the removal of organohalide pollutants. Both nanoscale zero-valent iron (nZVI) and organohalide-respiring bacteria remove halogens through reductive dehalogenation and have been extensively studied and successfully applied for the *in situ* soil remediation of chloroethenes and other organohalide pollutants. nZVI and microbial reductive dehalogenation (Bio-RD) complement each other to boost reductive dehalogenation efficiency, suggesting that the integration of nZVI with Bio-RD (Bio-nZVI-RD) may constitute an even more promising strategy for the *in situ* soil remediation of organohalide pollutants. In this review, we first provide an overview of the current literature pertaining to nZVI- and organohalide-respiring bacteria-mediated reductive dehalogenation of organohalide pollutants and compare the pros and cons of individual treatment methods. We then highlight recent studies investigating the implementation of Bio-nZVI-RD to achieve rapid and complete dehalogenation and discuss the halogen removal mechanism of Bio-nZVI-RD and its prospects for future soil remediation applications. In summary, the use of Bio-nZVI-RD facilitates opportunities for the effective *in situ* soil remediation of a wide range of organohalide pollutants.

Keywords: Nanoscale zero-valent iron (nZVI); Organohalide-respiring bacteria; Organohalide pollutants; *In situ* soil remediation.
Financial support: National Science Foundation for Distinguished Young Scholars of China, No. 41225004; Special Fund of Environmental Protection Research for Public Welfare from the Ministry of Environmental Protection of the People's Republic of China, No. 20150937.

(5855 - 2314) Monitoring of soil ecological functions of an urbic Technosol after applying biochar and compost.

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City parks and gardens are often established on excavated materials containing rubble and garbage. In order to support plants, the porosity and the nutrient contents of these materials need to be improved. This can be achieved by adding compost or biochar, two amendments made out of organic wastes, which are produced in large quantities in cities. We set up a field experiment in an inner garden of a research institute filled up with construction debris, where we applied three treatments in six-fold replication to 1 m^2 plots, namely compost, biochar and control. On each plot we planted 4 plants of *Rosmarinus officinalis* and 4 plants of *Lavandula angustifolia*. The organic amendments were applied in doses of 4 kg m^{-2} mixed in 0-10 cm depth. For 2 years we monitored the soil temperature, water tension, volumetric water content and CO_2 emissions and the height and coverage of the plants. After 2 years we sampled the upper 10 cm and determined aggregate size distribution, organic C content, bulk density, and water infiltration and evaluated the improvement of soil functions due to the addition of the amendments. Both treatments improved soil functioning in comparison to the control, but the effects of the compost and biochar differed in the short term (3 months) vs. the medium term (2 years). Compost enhanced CO_2 emissions in the short term, but improved plant growth, while biochar improved the available water holding capacity of the soils, especially in the short term. Our experiment shows that it is worth to follow these kinds of experiments over several years to differentiate between short,

medium and long-term effects of the organic amendments.
Keywords: urban soil, organic amendment, water retention, CO_2-emission, soil aggregation
Financial support: CONACYT

(6051 - 3008) Soils within Cities Global approaches to their sustainable management - composition, properties, and functions of soils of the urban environment

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As the proportion of people living in urban areas has been and still is increasing, the recently published book, “Soils within Cities: Global approaches to their sustainable management”, undertakes to shed light on the role and importance of soils in cities, by stressing the need to consider and manage this unique component of the urban ecosystem on our way to build sustainable cities. Edited on behalf of the International Union of Soil Sciences, this book is the result of a joint effort of the international SUITMA (Soils of the Urban, Industrial, Traffic, Mining and Military Areas) working group of the International Union of Soil Sciences IUSS. Thirty-four short contributions comprehensively highlight key aspects and characteristics of soils of the urban ecosystem and the problems and challenges associated with them. This symposium will highlight major topics emphasized in this new IUSS publication. The authors lay out the fundamentals of soil science applied to anthropized environments (environments degraded by human activity), including composition, properties, and functions of soils of the urban environment, their pedogenic evolution, classification and mapping. Furthermore, contributions present examples of actual urban soil surveys conducted in the US, Poland, Germany and Russia. Approaches to managing soils of the urban environment with focus on brownfields, soil sealing and urban agriculture, and the management of soil sealing are described. A separate chapter is dedicated to the ecosystem services urban soils can provide, including sustaining and controlling water quality and quantity, providing C and P storage capacity, supporting biodiversity, pollution problems, and pointing out ecosystem services that even contaminated industrial and mine soils are able to provide. “Soils within Cities” is aimed at expanding our view of soils of our planet, and having them taken into consideration for human well-being. It provides city planners and managers with a special reference that can serve to offer citizens a better life in a sustainable city-environment.
Keywords: urban soils; anthropogenic soils; ecosystem services
Financial support:

(1128 - 1258) SUITMAs as hotspots of anthropogenic carbon accumulation

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Globally, urbanization is progressing rapidly and coincides with substantial changes in vegetation and soils. Soils are a key component of urban ecosystems, responsible for multiple functions and services, contributing to environment and quality of life in cities. Soils of Urban, Industrial, Traffic, Mining and Military Areas (SUITMAs) represent a relatively novel and rapidly developing direction in environmental and ecosystem sciences. Traditional views of urban ecology stress the negative anthropogenic impacts on SUITMAs (e.g. contamination, salinization and over-compaction). However, the recent views on sustainable urban development highlight capacity of SUITMAs to provide important functions and services, including substrate and support for greenery, water purification, transport and storage, habitat for microorganisms, carbon (C) sequestration and climate mitigation. SUITMAs and undelying cultural layers accumulate C over centuries, however, processes and mechanisms leading to high C accumulation in these soils remain unknown. The processes specific for C accumulation in SUITMAs were analyzed and the C sequestration rates were assessed based on the data from 118 cities worldwide. For the whole range of climatic conditions, 1.5-3 times higher C content and much deeper C accumulation in SUITMAs resulted in 3-5 times larger C stocks compared to natural soils. Soil organic carbon (SOC) and black carbon (BC) increased with latitude, whereas soil inorganic carbon (SIC) was less affected by climate. The city size and age were the main factors controlling intra-city C stocks with higher stocks in small cities compared to megapolises, and in medieval compared to young cities, whereas the inter-city variability was dominated by functional zoning. Substantial amounts of SOC, SIC and N were sequestered for long-term in the subsoils, cultural layers and sealed soils, underlining the importance of these ‘hidden’ stocks for C assessments. Despite small city areas, SUITMAs are hotspots of long-term belowground C sequestration worldwide, and the importance of SUITMAs will increase in future with global urbanization
Keywords: urban soils, carbon sequestration, carbon emission, soil functions, ecosystem services
Financial support: RUDN 5-100 Project

(8185 - 2944) Visualising the Soil Platform Function – A Cultural Critique of Anthropogenic Soils

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Not all soil functions are understood or protected equally and nor should they be. The protection of the function of soil as platform for human structures appears at first as counter-intuitive to the goals of soil protection. Practitioners of soil mechanics and civil engineering calculate soil properties in order to plan a human universe of concrete and steel upon the porous architecture of the ground below. Buildings, bridges, highways, plazas, retaining walls, dams, dumps, subways, sewers, and power and communication lines could not exist if the soil failed to provide space and stability for their construction. But these structures are usually erected at the detriment of habitat, filtering, and food production functions of the soil. An interminable game of material displacement, soil sealing, and mitigation ensues beyond the framweworks of soil ecoystem services and functions. Inspired by ongoing research within the SUITMA working group, the following paper looks at the platform function of the soil from the lens of cultural critique. Drawing on several examples from the book publication, “Field to Palette – Soil and Art in the Anthropocene” (Toland, Noller & Wessolek, 2018, CRC Press), the presentation examines how visual artists, arhitects and designers question, critique, and envision hybrid alternatives of this conflicted but necessary soil function. Soils of Urban, Industrial, Traffic and Military areas are seen here not only as epicenters of anthropogenic change but as social stabilizers, literally the rock on which all human civilization stands. By embedding the predicament of the platform function within a larger cultural context of the archive and cultural heritage functions of the soil, new visions of the soil as platform emerge, new allies for the protection of anthropogenic soils arise, and interdisciplinary collaboration is encouraged.
Keywords: soil functions Anthropocene soil art
Financial support:

WG15 Cultural Patterns of Soil Understanding A: Anthropological, psychological, religious and spiritual perspectives on soils

(3294 - 2399) Deep culture related to soil ecosystems

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Long time before the emergence of agronomy and soil science, people interacted with soils as a part of landscape, as a source of food, as an object of labor application in agriculture, and as the final destination of humans after death in many cultures. The perception of soils in ancient times was mythological as well as rational, and some echoes of its perception in a mythic context still exist in human culture. Recently the ecosystem services concept became popular in the studies of the nexus between humans and nature, and so-called "cultural ecosystem services" have been declared as an integral component of the value of ecosystems. But the importance of soil for the cultural heritage of our civilization is still not properly addressed. There is a common belief that spiritual and religious soil functions were important at the early stages of the development of humankind, or in present "primitive" cultures. However, also present world religions are partly based on the early generic beliefs, and contain some rituals related to soil. The soil is the place where dead people are buried. It was considered being the place of chthonic gods/goddesses, ancestor souls, local spirits, and uncanny creatures, but also of the not yet born life: the inner earth is in this regard a symbol of the deep netherworld. Because of this archetypal and ambivalent web of meaning which persists in known religious traditions as well as unconsciously in humans, many people have a rather negative attitude to soils. On the other hand side, the imaginary of a Great Mother who spends food from the deep earth and soil to humans, got a new meaning, when agricultural civilizations emerged in the Neolithic revolution. The dual, ambivalent mother godhead, giving and taking life, was considered to show its cruel face especially when not respected as she should, when there was no offering and no sacrifice to her: Then she sent illness or madness, starvation and death. The mythological understanding of soils has not only historical value; it is still alive in human culture. Unfortunately, in the modern urban subcultures people do not regard soil as "Mother Earth" and a cradle of food; in contrast, soil is either associated with dirt, dust, death and diseases, or just "functionalized" in a superficial way as a service provider. Strong efforts are needed to bring understanding of the importance of soils for humans, and old fairy tales and myths may touch people where popular science books do not.
Keywords: Agrarian and soil myths; the history of agriculture; burial traditions; types of knowledge; soil communication
Financial support:

(9405 - 511) Soil in Rumi's thought

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As a divine creation, soil is a site where all natural beings of the solid earth develop and grow and eventually return to it in the process of decomposition and restoration of the natural world. The quality and the way of human interaction with the natural world is one of the most important issues in human life. Therefore, epistemic schools of thought seek to provide a model for the universe and its explanation, including a self-conceptualization of human beings and how they connect with the universe and its components. Since its birth on, Persian literature has dealt with nature, too; and its poets referred to the full range from art to science. . One of these poets is Rumi whose writings reveal the connection and relation of human being with the natural world. The study of his poems confirms also Rumi's knowledge of topics related to the concept of soil. One of the ways to make a connection between human beings and the soil is human soil-eating (*khak-khwari-e ensan*). The issue of geophagy that Rumi proposes is the basis of creating a constructive approach to linking man with the universe; an approach in which the soil is the main substance of all natural beings and the context of development and the only source of their nutritional power. The objective of the present paper is to investigate and analysis the above-mentioned issue in Rumi's thought and to what extent his sayings are adopt our modern science.
Keywords: Soil, Geophagy (*Khak-Khwari-e Ensan*), Rumi, Persian Literature
Financial support:

(1312 - 1824) *Soils within the Yoruba mythology: an example of a modern conceptualization from an ancient mythology.*

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Myths can be powerful tools for soil education and awareness. That is so due to their potential to cope with the "unsaid" obviousness of crucial aspects of our connection with the environment and the feelings we have about it. In the case of non-traditional communities, myths could be even more useful for soil scientists and extension agents to "give voice" to the soil and "speak to the soul" of the general public, since the place of soils in the landscape, as well as our existential dependence of it, can both be veiled and/or ignored, even within rural communities. It is agreed that soils are arguably the most important compartment of terrestrial ecosystems: life as we know it would not be possible without the pedosphere. This relevance of soils can be difficult to be understood, even more difficult to be felt, by the general public. After all, it's just dirt! Amongst the Yoruba people as well as their descendants over the Americas – understood herein as both biological as those who adopted their religion – this paradoxical aspect of the pedosphere (i.e. unbelievable powers and deafening silence), is translated into their mythology, structuring their cosmology, and therefore, their territoriality. Olodumare (the supreme creator) one day distributed to his sons and daughters (the orishas) the powers over the forces of nature, before leaving the world forever, under their care. In a given occasion each orisha was given the domain over the items they were using for a dress – they have chosen what they liked the most from nature to compose their vestment. Onilé, the timidest and most demure of his children, dug a hole in the soil and hid at the bottom of it during every party at Olodumare's court to avoid noisy music and the crowd. Since she was "dressed with the soil", she received the power over its domain: Onile became the goddess of the pedosphere. Once all the orishas and humans, both dead or alive, were now connected to the "soil", Onile should be propitiated so the world of humans would never be destroyed. In other words, the most powerful and fundamental orisha, to whom all natural forces of the Earth are somehow connected, is also the most silent one. To help us as soil scientists to deal with and communicate the silence of the pedosphere and its implications on human territoriality, such myths can be a very nice way to integrate both reason and emotional responses towards building value to soils: the aim of any soil education and awareness activity.
Keywords: Ethnopedology, Yoruba culture, Orishas, Onile.
Financial support:

WG16 Cultural Patterns of Soil Understanding B: Dialogues between traditional and scientific knowledge and perceptions of soils by different stakeholders

(9049 - 2809) Cultural and scientific roots of soil perceptions by university and secondary school´s students in Minas Gerais, Brazil.

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The Soil Education Programme (PES) of the Earth Sciences Museum Alexis Dorofeef was created in 2000 and since them has developed a wide array of activities and has involved more than 2000 people. It also became a reference in the country. Throughout its existence, the Programme has undergone several changes related to concepts and methodologies driven by practice and experience as well as by the perceptions of the limits of communication of our soil science. From a basic soil properties approach the programme enlarged to encompass agroecology, art and culture. To further enhance it, it was decided to seek a closer look into soil perceptions among its current and potential users. An enquiry was built to be done individually in an open dialogue using elements of Paulo Freire´s pedagogy. Main groups approached were university and secondary school students. They were asked to express the first idea that comes to their mind about the term soil and to explain it afterwards. The answers were analysed together with further personal information as rural or urban origin, parent's occupations, etc. The results showed that perception of soils is mostly linked to affective memories and subjective experience. This means that to increase awareness about the importance of soils it is necessary to consider those dimensions and roots of soil understanding. The results and discussion of the objective and subjective, rational and emotional roots of soil perception among students will be presented and discussed in this presentation.

Keywords: Soil education, soil museum, constructivism, agroecology
Financial support: UFV

(2185 - 2870) Experience in an afrodescending rural community using humic acids as a vegetal biostimulant for the promotion of family agriculture

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The rural community of the village of Guacoche (Colombia) is an Afro-descendant community, where the food was easily cultivated before and generated good productivity. Nowadays the productivity of the crops has decreased, this is due to the reduction of the productive capacity of the soil and the adverse effects of climatic phenomena have been accentuated, this situation is worrying given that these soils are located in a semi-arid zone, under saline conditions and with a high risk of desertification. To carry out reconversion programs of family farming under agroecological production models, it is necessary to create a paradigm shift that leads to acceptance and confidence in the use of biological and organic inputs. Through this work we wanted to develop educational strategies to explain the phytostimulating effect of biological inputs such as humic acids (AH), on the growth and development of crop plants, across participatory research for food production through family farming, this work was carried out in conjunction with the Afro-descendant rural community. The project was presented previously to the communal council, who gave endorsement to execute it. Methodological aspects were selected from the dialogue and respect of the knowledge of the rural community according to their needs and interests based on the model of family farming and a work plan was drawn up jointly with the people interested in participating in the experiments. Ten participants decided to join the experimental development of the use of biological inputs in small plots in their yards, to verify the effect of this input, in comparison with the traditional farming method. In each backyard two plots were established and seeds of certified corn were planted, one plot was planted without any treatment, and the other one was planted with regular addition of biological supplies and subsequently three periodic applications of AH were made by foliar spray, the trial was maintained for ninety days. The parameters to be measured were agreed with the group of participants.Through the experience the community was able to establish the differences between treatments, improvements in growth and production were observed in plants treated with AH, taking into account parameters such as number of established plants, number of ears harvested, size, perimeter and fresh weight of the ears, as well as the number of rows and grains of maize, as well as the health of the ears in the treated plots.

Keywords: Participatory research, phytostimulants, agroecological production.
Financial support: Universidad Popular del Cesar

(2804 - 451) Stakeholders' Mental Models of Soil Food Value Chain in South Florida

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Once an exporter of fruits and vegetables, the United States (US) is now a net importer of both fruits and vegetables. As the US increasingly relies on imported fruits and vegetables concerns over food safety and food security increase. Maintaining and supporting American production of fruit and vegetables is essential to food safety and security in the US. This study used mental models to explore extension communication of sustainable soil management with farmers, extension agents, and scientists to maintain food security. The study site is located in Miami-Dade County, Florida, which is a major producer of tropical fruits and vegetables ($800 million annually) for the United States. Miami-Dade County, with a population of 2.7 million places pressure (eg. land availability, labor availability, raising land value etc.) on the agricultural land to urbanize. Interviews and transect walks are used to collect data on the soil management belief systems of farmers (n=19), extension agents, and scientists (n=20). Mental models of the soil food value chain emerged from this data. All stakeholders perceive urbanization as the major barrier to their ability to contribute to America's food security and maintaining soil health. However, the mental models of farmers show that their ability to continue farming is reliant on their capacity to build and maintain a sustainable system—the soil food value chain. In this system, top quality products are sold on low risk markets, and second quality products and culls are recycled into farm capital. This farm capital may include value added products sold at the local market or composted. However, scientists and extension agents did not perceive their role as maintaining a system, rather only improving production. With research focused on improving product quality, increasing yield, decreasing cost of production, and minimizing the environmental impact of production. The mental models of farmers suggest that research and extension related exclusively to improving production has limited effectiveness, and that building and maintaining the entire soil food value chain would enable the farmers to survive and better care for their soil. This research contributes to the literature by recognizing the importance of examining barriers to soil communication between stakeholders beyond specific soil characteristics to also examine barriers to understanding soil within a system context.

Keywords: Mental Models, Soil Food Value Chain, Ethnopedology, Soil Health, Food Security
Financial support: Internally Funded by University of Florida

EXCURSIONS

Technical Tours of the 21stWCSS

The 21st WCSS promoted six technical tours, giving participants the opportunity to acquire greater knowledge of the soils of Brazil. Check out short summaries of how these tours (before, during, and after the event) went in this sequence of descriptions.
Coordenator: Raphael B.A. Fernandes (UFV/BR)

Pre congress

Western Amazon region - Indian black earth
Organizer: Paulo Wadt (EMBRAPA/BR)

The 21st World Congress of Soil Science (WCSS) began with the second step of the XII Reunião Brasileira de Classificação e Correlação de Solos (RCC) [XII Brazilian Soil Classification and Correlation Conference] in Rondônia. The first tour took place from September 9 to 16, 2017, and the second, from August 1 to 8, 2018, just before to the opening date of the WCSS. Considering 15 described soil profiles available, 14 profiles were visited in the tour of 2017 and 12 profiles in the tour of 2018. A total of 126 participants were registered (82 in the first tour and 44 in the second). In addition to representatives from the main Brazilian institutions of higher education and research related to Soil Science, there were also participants from Germany, Australia, Colombia, the United States, Estonia, Hungary, Italy, Japan, and Russia. Each tour traveled approximately 2500 km of roads in Rondônia with the aim of presenting some of the main interactions between topography and soil formation processes in the region. The last day of the trip, in the second tour, was dedicated specially to visiting some examples of *Terras Preta de Índio* (Indian Black Earth) that occur in Rondônia. These lands originated from the interaction of pre-Columbian populations with the regional environment. It is extremely difficult to assess the impact of an RCC on the process of building up knowledge regarding Brazilian soils but, undoubtedly, not only the RCC of Rondônia, but also those of Acre and Roraima, in combination, will have an impact on the cumulative understanding of the Amazon and its soils in decades to come. What many scientists learned about Amazon soils from 2010 to 2018 exceeded the most optimistic expectations. The states and profiles visited led to knowledge of a range of soils and environments, which go far beyond the image of an Amazon dominated by poor and weathered soils. They were able to recognize a richness and diversity of edaphic environments that were unimaginable only a few years ago. This has only been possible through the coalescing role of the Sociedade Brasileira de Ciência do Solo (Brazilian Society of Soil Science).

Congress

Landscape and soil in the metropolitan area of the city of Rio de Janeiro
Organizer: Ademir Fontana (EMBRAPA/BR)

This tour, on August 15, took place in the metropolitan region of the city of Rio de Janeiro, in the Serra do Mar mountain region, and parts of the municipalities of Guamirim, Nova Friburgo, and Teresópolis. Around 80 participants, especially from abroad, were able to see a wide variety of landscapes and soils in a small space, as well as large and expressive agricultural production based on vegetable growing. The aim was to show the soil and its occurrence in different environments, as well as the predominant vegetation and the land use made by humans through agriculture. To begin, professor Carlos Ernesto Schaefer (UFV) described the formation and evolution of the landscape, as well as land use of the Dedo de Deus region in Teresópolis. In the region of the Associação de Pequenos Agricultores da Fazenda Rio Grande (a small farmers' association), near Ceasa (Conquista district), the fruit and vegetable marketing center, the conversation and presentation was directed toward both the formation and occurrence of soils in the region and land use and agricultural production, based on vegetable growing. Within the specific soil profile, professor Carlos Ernesto showed genetic aspects, classification, and land use suitability. In this profile, a surface horizon was highlighted that is quite thick and dark and has variations in depth and shades from brown to black; the horizon was classified as humic A by the SiBCS. Discussions regarding its potential and limitations, and even its formation, generated an enthusiastic response from participants. In a location not far away, in an area of intense vegetable crop production, Alessandro Samuel Rosa from the Universidade Tecnológica Federal do Paraná and the researcher Renato Linhares de Assis from Embrapa Agrobiologia spoke about production in all its aspects, such as cultivated species, management, and agricultural practices, as well as the commercialization and destination of these products.

Recovered landscape and fruit plantation in the mountains of the State of Rio de Janeiro
Organizer: Cláudio Lucas Capeche and Fernando Gregio (EMBRAPRA/BR)

The technical tour, organized by Embrapa Solos on August 15, led 35 researchers (from 17 countries and 5 continents) to the Caboclos Farm in Teresópolis, in the mountainous region of Rio de Janeiro. There they got to know the work of recovery of a hillside that underwent landslides during a natural environmental disaster on January 11, 2011, brought about by torrential rains. The rural property was affected in various areas, especially near the main farmhouse, where two one-hectare forested hillsides suffered landslides. The owners then decided to take on the challenge of recovering the affected areas. They sought the assistance of Embrapa Solos for technical agronomic orientation, due to its history in recovery of degraded areas, and they contracted a civil engineering company for containment and surface drainage work. The recovery work associated sustainable agronomic techniques with those of civil engineering, making it possible to increase the safety of the work and reduce economic costs. During the technical tour, the participants visited the recovered hillsides and observed the procedures performed, in detail. They also got to know another area of the farm directed to setting up a citrus orchard through use of conservationist practices (contour farming, terraces, and retention basins). In addition, they received the explanation of Embrapa researchers regarding the soils of the region, with a profile of a *Latossolo Vermelho Amarelo* available for morphological observations. The organizers evaluated that an optimal response was obtained from the participants in the tour. For the Embrapa Solos team, the information/knowledge provided will be remembered in work abroad and can be replicated by technicians and scientists that participated in the tour in their countries of origin.

Post congress

Brazilian highland soils and oxisols from deep-weathered saprolites
Organizer: Carlos Schaefer (UFV/BR)

The team of professor Carlos Ernesto Schaefer, from UFV, prepared a video with details of the tour "Brazilian Highland Soils", which was part of the program of the 21st World Congress of Soil Science. The tour traveled around 1,250 km, beginning with the tectonic depression of Rio de Janeiro, passing through the mountain massif of Itatiaia (2700 meters), extending to the *quadrilátero ferrífero* (quadrilateral iron ore region], and ending in the Sete Lagoas region, where the "Rei do Mato" limestone grotto was visited. *Latossolos* developed from saprolites of shales, gneisses, limestones, and itabirites in highlands of the Brazilian Plateau in the state of Minas Gerais were studied.
Check out the video at: https://goo.gl/CHg6JX

Agroecological transition within the Atlantic forest biome
Organizer: Cristina Muggler (UFV/BR)

The tour was carried out soon after the 21st WCSS by professor Cristine Muggler and by the students Martin Meyer, Leonardo Abud, and Heitor Mancini Teixeira of the Soil and Agroecology research group of the Soil Department of UFV. In all, 23 researchers from various countries, such as Hungary, Slovenia, Australia, the United States, and Russia traveled across the Zona da Mata region of Minas Gerais to get to know tropical soils and their interactions with crops, the environment, and people. On the way, after departure from Rio de Janeiro, they visited an MST

(agrarian reform movement) settlement in Goiânia, two agroecological properties, a family agriculture school, and the Serra do Brigadeiro State Park in Araponga, as well as Viçosa and UFV. On the trip, in addition to observation and discussion of soil profiles, the participants were able to enjoy the natural and cultural landscape of the Mares de Morros and got to know the history of land use and loss of the Atlantic Forest and the current challenges for agriculture and sustainable soil management. The conceptual, methodological proposal was to build knowledge regarding the landscape, vegetation, and agroecology with the participants, going deeper into soil genesis and classification from the perspective of the three classification systems (SiBCS, WRB, and Soil Taxonomy). In addition, the participants were able to experience the Brazilian agrarian reality and agroecological practices of family agriculture. The agroecological transition in the Zona da Mata is fruit of the work carried out in partnership with organizations of civil society such as the Centro de Tecnologias Alternativas - CTA-ZM (Alternative Technologies Center), farming organizations, and UFV. Experience shows the potential of agroecology in access to the land and the autonomy of farmers, in generating income and building field education, and in conserving biodiversity and promoting food independence and security. The trip and the study group, among other initiatives, are organized in partnership with the Organização Cooperativa de Agroecologia – OCA (Agroecology Cooperative Organization) and the International and Inter-Institutional Research Program FOREFRONT.

Paddy soils of the south of Brazil

Organizers: Alberto V. Inda Junior (UFRGS/BR), Filipe S. Carlos (UFPel) and Flávio A.O. Camargo (UFRGS/BR)

The field trip to visit the irrigated rice soils in the state of Rio Grande do Sul took place from August 19 to 21, soon after the end of the WCSS. Traveling across 1250 km, efforts were made to get to know the main institutions involved in research of rice under flooded conditions, the producers and their production systems, and soils under the rice crop from the pedological perspective. The organizers emphasized the pedological perspective of *Planossolos* because rice growing in the state only begins in September. Participants were all Japanese, with professor KazuyukiI Nubushi, president of the Japanese Society of Soil Science, as head of the delegation. Professor Alberto Inda Vasconcellos of UFRGS was responsible for pedological explanation of the *Planossolos*. Professor Felipe Selau Carlos, of UFPel, was responsible for organizing the tour and contacts, and professor Flávio Camargo (UFRGS) was responsible for logistical support.

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