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2023 BOOK OF ABSTRACTS

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Tuesday

Plenary

Keynote lecture: Soils for Society

Peter Groffman

We appear to be at a shining moment for interactions between soils and society. Popular interest in soils has increased along with interests in urban gardening, carbon sequestration, recognition of the vast biodiversity in soils, and the realization that soils are a finite resource whose degradation has serious consequences. This increase in interest creates both opportunities and challenges for Soil Science. While there is great potential for increasing the diversity and inclusion of people involved with Soil Science, key scientific and communication challenges need to be addressed for interactions between soils and society to be useful and productive. Key issues include the need to understand the mechanisms and limitations of carbon sequestration in soils, the capacity to restore and/or create new soils for specific uses, the use of different kinds of inputs to address different kinds of problems in different places, and the complex effects of environmental change on soil processes. Addressing and communicating about these challenges will require advances in both basic and applied aspects of Soil Science as well as interactions with other disciplines.

Carbon farming: Are soil carbon certificates a suitable tool for climate change mitigation?

Carsten Paul, Bartosz Bartkowski, Cenk Doenmez, Axel Don, Stefanie Mayer, Markus Steffens, Sebastian Weigl, Martin Wiesmeier, Andre Wolf and Katharina Helming

Increasing the soil organic carbon (SOC) stock of agricultural soils can make a significant contribution to climate change mitigation. Across Europe, markets for soil-based carbon certificates are emerging. These certificates are sold as voluntary emission offsets. They constitute a form of private governance that may motivate farmers to implement carbon farming measures. However, despite a high interest from farmers and industry, the suitability of these certificates as a tool for climate change mitigation is under debate. To address existing knowledge gaps and create a comprehensive assessment, we analyzed soil carbon certificates under the perspectives of soil science, agricultural management, and governance. We focused on certification schemes within Europe and used German certification providers as examples. While carbon farming measures increase SOC stock and cause multiple synergies with climate change adaptation and soil health, the analyzed certificates were found to be unsuitable for offsetting greenhouse gas emissions. Certification providers could not guarantee the permanence of carbon removals, and re-emission of unspecified amounts of CO2 after the contracting period are very likely. Furthermore, long-time monitoring was typically lacking, additionality not ensured, and safeguards against leakage effects insufficient. We conclude that current soil carbon certificates are unlikely to provide the climate change mitigation they promise and that limited fund for climate change mitigation would be more effective if spent elsewhere. Alternative public and private governance tools should be developed to motivate lasting management changes that increase soil organic carbon stocks and unlock synergies with climate change mitigation, -adaptation, and biodiversity preservation.

Climate-robust nitrogen management in agricultural fields

Tom Coussement, Sophie Nawara, Vincent Wolfs and Mia Tits

Climate change results in less predictable and more extreme weather conditions, which makes it even more challenging for farmers to minimise nitrogen losses and at the same time maintain or improve soil quality and crop profitability by good cropping practices. The aim of this study is to determine how farmers can respond to weather conditions and optimise nitrogen management in their fields by adjusting the timing of manure spreading and sowing catch crops. First, a number of indicators for good nitrogen management are defined. Some examples are the soil mineral nitrogen content at the end of the growing season, nitrogen uptake by catch crops, ammonia volatilisation after manure spreading, yield losses, etc. Cut-off values are assigned to these indicators based on literature and model simulations. The goal is to adjust the timing of the cultivation practices in function of weather conditions in such a way that these cut-off values are not exceeded. Next, a number of weather indices are defined that likely affect the indicators for good nitrogen management. These indices can be simple (e.g. average temperature) or complex (e.g. combinations of temperature and precipitation). With respect to the cropping practices, the indices can be retroactive (past weather conditions) or proactive (weather forecasts) or a combination of both. Finally, a correlation analysis is performed to determine the most relevant weather indices to predict the nitrogen management indicators. For this, a crop and soil dataset of more than 70 field trials in Flanders (1997-2022 including different soil textures) is used.

A composite index of field-scale sustainability to support farm to fork efforts

Shai Sela, Uria Luzon and Sagi Katz

The food supply chain, from farm to fork, was responsible for 31% of human-caused net greenhouse gas emissions in 2020, with half of these emissions are at the farm gate. The ability to quantify production sustainability at the field scale is of interest to many stakeholders, including farmers, governmental agencies and food and beverage companies. To account for this, a new composite index was developed to track and quantify field-scale sustainability levels. It is a holistic index encompassing different aspects of environmental sustainability. The index is composed of two scores: i) the efforts farmers are doing (optimizing 4R's of nutrients, precision insecticides, fungicides and herbicides applications, irrigation management (both quantity and delivery method) and more); and ii) the respective measured outcomes (annual N and P balance, annual water footprint, yield-scaled CO2 losses, trends of SOM% accumulation and more). The data sources for the index are farm management data, plant and soil testing, climatic data, and remote sensing. To enable the calculation of a field-specific score, we have used an Analytical Hierarchy Process (AHP) approach to assign weights using inputs from both industry and academia experts. The scores of each sub-index are reported for the user to relate management decisions with the resulting scores, better understanding of management options and overall pathways for improvements. The presentation will present the value of such a holistic approach, with an application of the framework and analysis of the scores to Table Grapes in 45 vineyards in Maharashtra, India.

How to use soil threats bundles to assess the effects of climate change and land use changes at EU scale

João Coblinski, Jessica Reyes-Rojas, Sylwia Pindral, Rodrigo Antón, Isabelle Cousin, Lubos Boruvka, Chiara Piccini, Nicolas Saby and Sophie Cornu

In Europe, 70% of soils are degraded and subject to threats. These threats can apply individually or simultaneously on soils, one way to imagine this is to present them as bundles. In addition, threats depend on climate or land use for many of them, they may thus to evolve in the future depending on the scenario

experienced. We aim here to evaluate the effects of different scenarios, such as climate change and land use changes, on the evolution of ST bundles at European scale. In this work we evaluated four individuals STs, soil erosion, soil sealing, soil compaction and Soil Organic Carbon (SOC) losses, using the following indicators: soil losses by water, sealing, bulk density changes and SOC losses. We assessed the impacts of climate change using two Shared Socio-economic Pathways (SSPs): 1-2.6 and 5-8.5. Concerning land use change, we used the projections provided by the LUISA (Land Use-based Integrated Sustainability Assessment) modeling platform. The projection year of the two scenarios is 2050. ST bundles were finally assessed by employing clustering approaches such as model-based algorithms. In this research, we propose to utilize the spatial distribution of bundles as an indicator of the co-occurrence of STs that can reduce the cultivated areas decreasing soil health. The presented approach allows identifying hotspots where soil threats deteriorate soil health, influenced by climate and land use changes. Therefore, the proposed approach is one of the solutions that can help to achieve the goals of the Green Deal and the Soil Strategy for 2050.

Parallel Session

S1: Soil & land degradation and development

Recovery and resistance of soil fungal communities in ecological and conventional grasslands under altered rain regimes

Laura Martínez-García, Gabin Piton, Davide Francioli, Eduardo Nascimento, Filipa Reis, Jose Paulo Sousa, Lijbert Brussaard and Gerlinde De Deyn

Climate extremes, including droughts and floods cause major fluctuations in the functioning of ecosystems. With this research we assess the role of soil fungal communities in the resistance and the recovery of conventional and organic managed grasslands. Intact monoliths were extracted from conventional and organic grasslands in three Europen countries and exposed to three rain regimes (dry, wet and intermittent wet/dry) compared to a normal regime. Total soil fungal communities and arbuscular mycorrhizal fungal communities were characterized across the experiment using high throughput sequencing (Illumina MiSeq). Subsequently, the resistance and recovery of total soil fungal communities, soil fungal pathogens, saprotrophs and symbionts (mycorrhizal fungi) to the rain regimes were calculated. Organic and conventional managed grasslands had different soil fungal communities. Ecological management enhanced the recovery of the soil fungal communities to altered rain regimes. However, independently to the grassland management, soil fungal communities were less resistant to the intermittent wet/dry regime than to the dry or wet rain regimes. Changes on the recovery and the resilience of the overall fungal community related to changes on the saprotrophic fungal community. Whereas, the resistance and the recovery of the arbuscular mycorrhizal fungal communities was not affected by rain regimes or management. We conclude that organic management of grasslands is a better option than conventional management to increase the recovery of soil fungal communities to climate change. Among soil fungal functional groups, saprotrophs are main drivers of resistance and recovery patterns.

Microbial communities in soils of Russian Arctic

Maria Korneykova, Viacheslav Vasenev and Dmitry Nikitin

Russian Arctic is a unique research area where severe climatic conditions coincide with high anthropogenic pressure resulting to remarkable consequences for soil health. Soil microbial communities are sensitive to anthropogenic pressures and therefore microbial activity and diversity are widely used indicator of soil

health. So far, the effects of urbanization and industrial development on soil microbial communities in the Russian Arctic region remain overlooked. This research aimed to quantify soil microbial indicators in the industrial non-ferrous metallurgy plant emissions zone and in cities (Apatity, Murmansk) located on the Kola Peninsula. Microbial biomass and number of ribosomal genes copies, soil microbial activity were studied. It was shown that industrial plant emissions reduced biomass, functional and species diversity of soil microbial communities and altered their structure and activity. The number of ribosomal genes copies of different groups of microorganisms was less sensitive to pollution, compared to their biomass and the number of culturable forms. Fungi were more resistant to technogenic pollution than bacteria and actinomycetes. In the cities, the combination of urban heat island, land use, and anthropogenic pressure created a new ecological niche for the development and functioning of soil microbial communities. The biomass and the number of ribosomal gene copies of microorganisms in urban soils more than doubled compared to background soil. Such a niche for microbial development was observed not only in the topsoil, but also in the subsoil horizons, where soil physical and chemical properties (neutral pH, high content of carbon and nutrients and low concentration of pollutants) created favorable conditions for soil microbial community.

Soil degradation in response to more persistent precipitation regimes

Olga Vindušková, Gaby Deckmyn, Simon Reynaert, Karen Vancampenhout, Jan Frouz, Hans De Boeck and Ivan Nijs

In mid-latitudes, climate is changing towards more persistent precipitation regimes, i.e. longer duration of both dry and wet periods. We investigated the effect of such shift on soil-water relationships in an 18-month field mesocosm experiment. The simulated precipitation regimes (PRs) differed in persistence, i.e. the duration of alternating dry and wet periods of 1, 6, 15, and 60 days, and in timing (either starting with a dry or a wet period), resulting in 8 different treatments. By the end of the experiment, all treatments had received the same total amount of water, i.e., dry periods were followed by wet periods of equal duration. Aboveground and belowground plant biomass followed similar patterns: it decreased with more persistent PR and the timing of the dry and wet periods were important in the most extreme (60-day) treatments. Accordingly, bulk density decreased with more persistent PRs but was not significantly affected by timing. Water retention at full saturation and field capacity were also negatively affected. Aggregate stability was also decreased by more persistent PR, without a similar trend present in total carbon, suggesting that soil organic matter quality is more important for soil aggregation than its quantity. Furthermore in more persistent PRs, studied soils had a higher chance of becoming water repellent (with a build-up period of 7 days) and this reduced infiltration rates. Overall, the experimentally simulated shift in precipitation regime led to degradation in soil properties and we discuss how these may exacerbate effects of future climate change on temperate grasslands.

The role of soils in carbon sequestration by urban green infrastructures: a university campus case study

Robin van Velthuijsen, Slava Vasenev and Marcel Hoosbeek

Urban green infrastructures (UGI) are considered among the main nature-based solutions to reach carbon (C) neutrality and support climate mitigation strategies in cities. City governments have high expectations from C sequestration by UGI, however, the role of soils remains overlooked. Lack of information on C stocks and fluxes in urban soils increases uncertainty in C accounting and probably overestimates the real potential for C sequestration. Soil organic carbon (SOC) stocks and CO2 emissions are highly variable in space and time. It is important to understand the factors driving this variability to support C-smart solutions in UGI planning and management. This study aimed to explore the effect of UGI typology and age on SOC stocks and soil respiration by using the Wageningen University campus as a living lab. The campus is dominated by

lawns, herbaceous meadows, shrubs and trees with well-documented management practices. To study the effect of time since construction, the vegetation was further classified according to their age. Overall, the topsoil SOC stocks were quite low (3.01 kg m-2). Soils under trees (3.27 kg m-2) and shrubs (3.14 kg m-2) had higher SOC stocks compared to lawns (2.93 kg m-2) and herbs (2.74 kg m-2). SOC stocks of recently constructed sites were higher compared to older ones. Carbon fractionation further determined the quality of the SOC stocks. Lawns showed the highest respiration rates indicating that lawns in urban greenspace are less favourable for climate change mitigation. Temperature sensitivity analysis of respiration indicated how the soils respond to increasing temperatures.

Nature-Based Solutions for Addressing Salt Intrusion and Accumulation on Boro Crop Fields: Innovations by a Local Community through Research and Practices in Southern Bangladesh

Md Zakir Hossain

At the beginning of the 21st century, the farming community of "East Sujonkathi" in Bangladesh, located 130 km along the Bay of Bengal coast, faced the escalating risks of salt intrusion due to climate change. As one of the champion communities of UN Disaster Risk Reduction and committed to ecological farming, they sought alternative natural solutions to address salt accumulation in Boro (winter) crop fields, instead of relying on conventional zinc fertilizers as recommended by traditional support systems. Through a process of trial and error, the community's local research identified ash from traditional cooking ovens as an effective solution to mitigate salt accumulation. The results were demonstrated and disseminated through local information and knowledge sharing networks. The community is now in communication with Bangladesh Agricultural Research Institute to scientifically validate their locally innovated solution, with the aim of contributing to soil management in the context of changing climate scenarios and ensuring food security. This community-led initiative has empowered the farmers to shift from being passive beneficiaries to proactive agents of change in their own development trajectory. This oral presentation will showcase the research pathways, process, and results of the community's nature-based solution to salt intrusion and accumulation on Boro crop fields. It will also highlight the next steps for further exploration and validation of this innovative approach. For the world-class soil scientists and practitioners, this presentation will provide insights into locally-driven solutions and community-based adaptation strategies for addressing the challenges of salt intrusion in coastal agricultural systems, with potential implications for enhancing resilience and sustainable soil management in the face of climate change.

S2: Soil quality and health

A new pedoclimatic-context-aware soil health diagnosis methodology to evaluate the impact of management practices

Christophe Calvaruso, Aurélie Bacq-Labreuil, Lorenza Pacini, Pierre Arbelet and Eva Lopez Fornieles

Soil fulfils many functions essential for the environment and thus for humanity. E.g., as an essential component of terrestrial ecosystems, soil contributes to food production and fibre supply and serves as a habitat for biodiversity. However soil is a fragile environment that is now threatened in many places, mainly due to human activities: fires, forestry routes, inappropriate land use, agricultural practices, atmospheric deposition, pollution, etc. Because soils are very diverse in their intrinsic characteristics, their potential to provide services (for example carbon sequestration and climate attenuation) and their sensibilities to external pressures (for example drought) are highly variable. In order to define sustainable practices in a specific context, soil diagnosis is essential. To this aim, lots of physical, chemical and biological indicators were recently developed to measure soil health. These indicators are very diverse, more or less robust, but the main limitation is

the lack of a referential to interpret the measurements in a soil health perspective. What are the critical and reference values for a given indicator? What is the link between the soil measurement and the status of the soil functions? The start-up Genesis is developing a new methodology to answer these questions in order to evaluate soil health status and dynamics, and quantify environmental impacts (i.e., carbon dynamics, water and nutrient cycles...) of different practices at different land scales. Its approach is based on the development of a referential built upon pedoclimatic clusters (contextualization of soil health measures) and by using reference soils to quantify soil functions.

Impacts of Diverse Cover Crop Mixtures on Soil Health and Soil Microbial Communities in East Central Ontario

Mykhailo Rangaiev, Kaileigh Wright and Karen A. Thompson

Considering the current shortage of synthetic fertilizers and the Canadian government's target to achieve a 30% reduction in fertilizer emissions by 2030, integration of multifunctional cover crop (CC) mixtures and alternative biological nitrogen (N) sources into cash crop systems may represent a substantial return on investment while contributing to environmental stewardship goals. In 2022, a randomized complete block design field trial was established in East Central Ontario. Blocks (n = 3, 1750 m2 each) were split into 16 plots and seeded with different combinations of CC mixtures (oats, barley, sorghum, peas, and radish) to study the effect of CC functional diversity on soil health indicators and soil microbial functioning. A split-plot factor of N sources (biological, synthetic, or no N) was also applied, resulting in 144 plots. Soil health indicators (e.g., pH, % water stable aggregates (WSA), electrical conductivity, bulk density), soil C and N dynamics (total and C, soil organic matter, plant available N), and microbial functioning (extracellular enzyme assays) were characterized. Preliminary results indicate key species of CCs may outperform some highly diverse CC mixtures in improvement of soil health and production of large biomass yields. Increased CC functional diversity resulted in 26% higher biomass yields vs. monocultures and increased % WSA ($p<0.05$). Characterization of CC's impact on soil N-cycling and soil nitrifying and denitrifying communities will be further explored.

Let's get real on regenerative agriculture: How do we assess soil health?

Mirjam Pulleman, Giulia Bongiorno and Ken Giller

The concept of regenerative agriculture has rapidly gained momentum among agri-food companies, governments, NGO's and farmers. Although there is no widely accepted definition, different interpretations of this concept emphasize the importance of restoring and enhancing soil to generate multiple benefits for society and for farmers. The premise is that regenerative agriculture, by strengthening soil health and associated ecosystem services, helps to make agroecosystems more productive and resilient, while improving farmers' livelihoods. A focus on regenerative agriculture further creates important opportunities to mitigate greenhouse gasses, thereby helping agrifood companies to meet their ambitious targets towards achieving "net zero" supply chains. The popularity of regenerative agriculture has created an overwhelming demand for indicators that can be used to assess and monitor soil health in robust and cost-effective ways, while obtaining evidence of the links between regenerative practices, soil health and the assumed benefits (agronomic, environmental, social). Conceptually a focus on soil health, considering biological, physical and chemical soil properties and processes and their importance for multiple soil functions, has proven to be attractive for practitioners. Yet, there are many challenges associated with the measurement of soil health and the interpretation of indicator values in terms of soil functionality. Based on literature review and our experiences working with key stakeholders in the cocoa and coffee sectors, we discuss progress and challenges for the development of soil health indicator frameworks and their application at scale. Special emphasis is on biological soil indicators, given their potential to respond quickly to management interventions, as well as

the key role of soil biota for soil functions. Yet, how can they be assessed at scale, and how are they interpreted?

Unlocking the Potential of Knowledge Graphs for Soil Health Monitoring and Management

Bojan Blažica, Vid Podpečan and Marko Debeljak

Soil health has a significant impact on food production and the quality of the environment, thus playing a central role in ecosystem functioning. However, the assessment and management of soil health is complex and involves data and knowledge about the spatiotemporal dynamic interactions between different soil properties (soil biology, processes and functions) which are under the influence of environmental and human impacts. As a result, current knowledge on soil health is dispersed across different domains, scales and actors, making it difficult to obtain and make available for application. In this research, we propose a knowledge graph-based approach to gain new knowledge on soil health. Knowledge graphs belong to the field of artificial intelligence and are a type of knowledge representation that captures knowledge as a graph of nodes and edges. Such a semantic network allows us to integrate multiple soil data and knowledge sources and helps us discover new knowledge about specific soil functions and soil health in general. Furthermore, it facilitates the development of decision support systems providing farmers with i) an assessment of soil health and ii) personalised soil management recommendations to improve soil health. Additionally, the knowledge graph also helps us identify knowledge gaps in soil health and prioritize areas for new research.

Soilguard Project to assess and safeguard Mediterranean agro-environments

Luis D. Olivares-Martínez, Fuensanta García-Orenes, Victoria Arcenegui Baldo, Minerva García-Carmona and Jorge Mataix-Solera

Unsustainable management in food production has led to the degradation of fertile and biodiverse soils in agricultural and forestry areas of the planet, reducing the supply of ecosystem services and the quality of human life. Therefore, it is a priority to establish policy that promote productivity, as well as the stability and biodiversity of agricultural soils, in congruence with their regional and local geographic conditions. The Horizon 2020 SOILGUARD project arose to assess the soil biodiversity status in different countries and the effects of climate change, this work shows part of the Spanish case under different degradation and management scenarios. Using a raster model of soil degradation obtained through the LUCAS soil information repository, and verification in field though visual soil assessments, plots with two levels of degradation were identified. We worked on 10 plots with traditional management and 10 with organic management, in agricultural Mediterranean area (Murcia, Spain) being considered organic those without using inorganic fertilization for more than five years. Soil samples were taken from each plot and analyzed for the following soil properties: organic matter content, microbial biomass carbon, basal soil respiration and some enzymatic activities, also available phosphorus, bulk density, and coarse fragments. One of the main SOILGUARD hypothesis is that soils under organic management have more biodiversity and this makes then more resilient to the climate change. By understanding the changes in soil quality and health, it will be possible to establish more precise recommendations for the establishment of agricultural management policies for Mediterranean environments.

S3: Soil and land management

Edafoagroclimatic evaluation of typical argiustol and typical ustipsament in the argentine semi-arid chaco

Prieto Daniel and Cristina Angueira

Given the agricultural expansion in the Argentine semi-arid Chaco ecosystem, the fragility of its soils, the annual and interannual variability of rainfall, the classification of soil by Land Capability and the average climatic data are not sufficient to zone edapho-agro-climatic units by crops. In Sachayoj, Santiago del Estero, Argentina, the probability of water deficit (DH) and yield deficit (DR) was studied, with water balances by crops, which are better than the climatic ones considering the vulnerability of the crop, in a typical Argiustol with AU 173 mm and a typical Ustipsament AU 114 mm, estimated with Pedotransference Functions (FPT). The water balance of Soybean sown on 10/15 (Sj-15/10) and 10/12 (Sj-10/12) and Wheat on 10/06 (Tr-10/06) was simulated with Cropwat. Monthly means of Temperature and 54 years of monthly Precipitation were used. Initial AU (DI) deficits of 40%, 60% and 80% were assumed and the empirical frequency of the DH and DR series was calculated to assess variability. The results showed that DH and DR are more affected by AU than by DI. The difference of 59 mm of AU between the soils produced DR differences of 3 to 7% in Sj-15/10, from 0 to 7% in Sj-10/12 and from 8 to 13% in Tr-10/06, while the DR differences between extreme DI (40 and 80%) were only between 0 and 5% with the highest values and coefficients of variation in wheat, suggesting not to include DI levels in future studies.

Optimization of manure allocation in view of crop requirements and environmental impacts in Chinese agriculture

Weikang Sun, Gerard H. Ros, Qichao Zhu, Donghao Xu, Yong Hou and Wim de Vries

The average manure recycling ratio in China is lower than 40%, implying that over half of the nutrients in manure are lost to the environment. Enhanced manure recycling by recoupling crop and livestock production is an important option to reduce soil acidification and environmental pollution caused by nitrogen (N) and phosphorus (P) losses to air and water in China. However, the optimal amount of manure to reduce soil acidification differs considering the need to stay below an acceptable P input depending on the soil P status and an acceptable N surplus in view of water quality. This study aims to identify optimal manure recycling strategies for six counties in the Chinese city Quzhou, by calculating the required nitrogen (N), phosphorus (P), sulphur (S), potassium (K), calcium (Ca) and magnesium (Mg) input to fulfil their crop demand using current crop yields, while accounting for the need to minimize soil nutrient surpluses and soil acidification. The current nutrient balance in Quzhou city indicated that under current manure and straw recycling rates, extra mineral fertilizer is needed in view of remaining nutrient demands of N (-11630 tonnes), K (-3800 tonnes), P (-550 tonnes), and S (-380 tonnes). However, at full manure and straw recycling, nutrients from livestock manure can meet crop demands at city level except for N (-6300 tonnes), with some counties having a deficit in N and also K, and other counties having an excess implying the need for manure transport out of the county.

Using random forest to determine the importance of soils in influencing yields in rice-wheat systems in the Indo-Gangetic Plain

Kavya Krishnan, Harold van Es and Andrew McDonald

Warming climates, changing labor markets, declining groundwater and soil degradation are widely considered as the causes for declining productivity in rice (Oryza sativa L.) - wheat (Triticum aestivum L.) systems in the Eastern Indo-Gangetic Plain (IGP). Understanding the management and agro-ecological factors that

significantly influence (and can improve) yields is therefore crucial to food security. To determine the drivers of rice and wheat yields in Bihar, we used surveyed data and soil sampling and analysis across eight districts in Bihar to analyze the effect of a combination of factors like soil quality, management, fertilizer application etc. Random Forest models were used to evaluate importance of all variables to crop yield. Models predicted yield relatively accurately, with a root mean square error (RMSE) of 0.32 tons/ha for wheat yields and 0.38 tons/ha for rice yields. However, the amount of variation explained by the models was low (32% for wheat and 33% for rice) and yield gain due to improved management was low. Planting date, crop duration and N and P fertilization appeared to be the most important drivers of both rice and wheat yields. Soil chemical indicators like pH, available Fe, Mn and electrical conductivity (EC) were also fairly significant. Comparing farms with low yields vs high yields suggests that agronomic management factors are more important in lower yielding farms. Once management practices are optimized, future yield gains appear come from improvements in soil health.

Drivers and pathways for future soil management and soil health

Katharina Helming, Lukas Bayer, Arndt Marie, Bandru Keerthi and Alevtina Evgrafova

Soil management is a crucial determinant of soil health. Decisions on soil management are subject to multiple external driving forces, technological, social, cultural, economic, and environmental. Their interactive dynamics are site specific and they determine the room for manoeuvre in which farmers may be able to implement soil improving management practices. We developed a typology of drivers and we assessed future pathways for soil management by downscaling and specifying European Agricultural Pathways (Eur-Agri-SSPs) for the case of Germany. These are consistent with the Shared Socioeconomic Pathways (SSP) used in IPP assessments. The method was participatory in nature and included a total of five national workshops with stakeholders from practice, science, policy, civil society and administration. Results showed, inter alia, that technological advance including digitalisation may leverage soil improving management, but only if governance mechanisms are in place that regulate data property rights and that guide decisions towards supporting public interest and ecosystem services. Results also showed that value chain properties and dietary choices strongly influence the financial scope for farmers' decision-making with regard to soil management. Taking action along the value chain may therefore remove barriers for soil improving management at farm level. Building upon the experience with soil management pathways we developed a protocol for European regional specification and assessment of future driving forces for land use and soil management that builds upon a generic typology and that should therefore allow for a comparative analysis. We conclude that systemic assessments of soil management and soil health dynamics needs to consider such future frame conditions.

Land use change overrides the effect of management type on soil microorganisms

Heitor Mancini Teixeira, Marcio Leite, Marielos Peña-Claros, Felix J.J.A. Bianchi, Irene Maria Cardoso and Eiko E. Kuramae

Despite the key role of soil microorganisms for regulating ecosystem functions, the relationships among: (i) soil microorganisms, (ii) agricultural management practices (iii) vegetation and (iv) soil quality, remain poorly understood. In this study, we used DNA extraction and sequencing to assess soil fungi and bacteria communities in twelve pastures and twelve coffee fields in Zona da Mata, Minas Gerais, Brazil. The pastures and coffee fields belong to three different farm types and represent a gradient of management intensity from conventional to agroecological. In addition, we recorded 41 quantitative variables related to vegetation, soil quality and management practices in each field. Our main objectives are (i) to understand the effects of management type and land use change on soil microbial communities and (ii) to identify specific drivers of change in soil microbiota. We found that changes in land use between coffee and pastures overrides the effect of management type on soil microorganisms. The main specific soil factor driving microbial communities was

bare soil, which was negatively correlated with many groups of microorganisms. No specific management practice had significant correlations with microbial abundance. The only specific vegetation variable correlated with the abundance of microorganisms was variance in height, which was positively correlated with several microbial OTU's. Our findings suggest that land use change can drastically modify soil microbiota, and therefore, the associated ecosystem functions performed by microorganisms. Furthermore, our results suggest that soil cover and structural diversity are important drivers of soil microbiota and therefore, should be considered for the design of more sustainable agroecosystems.

S4: Soils in decision-making and policies

Carbon for soils, not soils for carbon

Gabriel Moinet, Renske Hijbeek, Detlef van Vuuren and Ken Giller

Soil organic carbon (SOC) sequestration is increasingly promoted as a 'win-win' solution to address both climate change and food security, arguably two of the most pressing and complex contemporary global threats. Current enthusiasm is very high in the science community as well as in the public media and increasingly in policy initiatives. Our objective is to bring nuance in the discussion and to reflect on the true potential of SOC sequestration in science and policy. To do so, we first summarise the findings of our recently published paper (Glob Change Biol. 2023;29:2384–2398). We re-emphasise that only specific management options in specific conditions hold the promise of SOC sequestration as a win-win, and that, even where and when a win-win outcome is possible, conflicts will arise when setting out to maximise both food production and SOC sequestration. We argue that the existing knowledge base does not justify the current trend to set global agendas focusing first and foremost on SOC sequestration and contend that the rapid development of largely unregulated voluntary carbon markets, wherein farmers get paid per ton of sequestered CO2, is unlikely to lead to fair and effective incentives for a transition to more sustainable farming systems. Finally, we advocate for soil carbon research and policy to fall in line behind the wealth of knowledge showing the importance of local context, of developing locally suited adaptative methods focusing on a wide set of environmental outcomes, and calling attention to social acceptability and economic viability.

Building a hospital for soil health diagnosis and treatment: a modelling approach

Yizan Li, Carmen Vazquez Martin, Ron de Goede, Junling Zhang and Rachel Creamer

With the extensive discussion of soil health, more attention has been paid to the contribution of soil to ecosystem services, that is, soil functions, including: primary productivity; water purification & regulation; climate regulation & carbon sequestration; soil biodiversity & habitat provision; and nutrient cycling. Enhancing soil multifunctionality requires evaluation of the current soil function status and optimized soil management practices. In this study, we developed models specific to the North China Plain agroecosystem to assess soil health and suggest interventions for farm management on a field scale, building upon the framework of the EU Soil Navigator models. Qualitative multi-attribute decision models in a hierarchy tree structure for each soil function were established using the Decision EXpert (DEX) integrative methods, based on the knowledge extracted from literature review, expert opinions, and data mining. A soil health dataset was collected from long-term field experiments and the Science and Technology Backyard in Quzhou County to provide data support for model calibration and validation. The models incorporate soil properties, climate conditions, and field management data as model input to assess the performance of the five soil functions at Low, Medium, and High levels and provide a list of soil health mitigation measures. The models will serve as a practical tool for end-users like farmers, land-owners and researchers to evaluate and optimize the soil conditions in their

fields, and would ideally be organized like a hospital for soil health diagnosis and treatment.

Using a pathways approach to provide policy support for sustainable and profitable agriculture

Hedwig van Delden, Luuk Fleskens, Melanie Muro, Tugce Tugran, Iris Vanermen, Jantiene Baartman, Jane Mills, João Pedro Nunes, Guna Salputra, Lilian O'Sullivan, Julie Ingram, Charlotte Chivers, Simone Verzandvoort, Rudi Hessel and Roel Vanhout

European agriculture is confronted with many uncertainties regarding its future development. Some of these are linked to changing climatic and environmental conditions, while others are the result of our behaviour. Within the SoilCare project we aimed to explore different pathways for European agriculture, from now until 2050, as this will help to support the development of policies that are future proof. Main questions this research aimed to answer were: 1) How can policies support soil-improving farming practices under different future pathways? 2) Are some policy actions more robust under a range of future pathways? To answer these questions we developed a storyline, simulation and policy support approach that includes a combination of qualitative and quantitative techniques in a multi-actor setting. First, together with European level stakeholders, we developed scenarios that capture diverse pathways for European agriculture. Next, we used the SoilCare Integrated Assessment model to quantify these scenarios and assess how sustainability options can contribute to sustainable and profitable future within these pathways. Finally, we discussed what is needed to enable adoption and implementation of relevant options. Quantitative assessment results indicated that different options score differently across Europe on selected indicators (soil erosion, soil organic matter, yield and production) because the combination of drivers plays out differently in different parts of Europe - indicating the complexity of the issue and the importance of understanding local dynamics. The participatory identification of actions highlighted that better understanding plausible futures helps to design actions that target specific developments or are robust across developments.

PRESS II project – from soil data towards sustainable land use planning

Elisabeth Zocpe, Patrick Mounoumeck, Patrice Nsegbe, Cédrick Nguemezi, Lydia Krauß, Britta Greenshields, Annette Lisy, Guy Debok Nghemning, Francis Ngome and Clemens Romankiewicz

The public increasingly recognizes the importance of soil health. Stopping world hunger as one of the UN sustainability goals cannot be reached with the threat of soil degradation through climate change and mismanagement of soils. The Cameroonian government aims to integrate soil information into planning processes to secure the country's socioeconomic future. To support Cameroon in its efforts, the Federal Institute of Geosciences and Natural Resources, Germany (BGR) cooperates with the Ministry of Economy, Planning, and Regional Development (MINEPAT) and the Agricultural Research Institute for Development (IRAD) on generating soil information. The pillars of the bilateral technical cooperation project include fieldwork and field equipment supply, equipping the national soil laboratory, building up and equipping a unit for managing the country's soil data, and, most important of all, supporting the development of capacities in field methods, laboratory methods, soil data management and processing spatial soil information to share that knowledge with future generations. So far, the project has succeeded in initiating all pillars. The first project results are integrated into planning processes with a high positive impact potential on the expected land use plans regarding their sustainability.

Soil and Water Conservation in China: Challenges and Innovations

Guobin Liu, Sha Xue, Mingxiang Xu, Guoliang Wang, Bing Wang, Chao Zhang, Ying Liu and Xiaomei Yang

Soil erosion has been a major problem in China for many years. However, the country has made significant progress in reducing water erosion through various soil and water conservation projects, such as the "Grain for Green" program. Despite these great efforts have been done for years, soil conservation areas are still imbalanced, and the ecological stability and functions of soil erosion areas need improvement to meet the demands of high-quality green development. To address these challenges, the this study proposed three strategies with different levels of concern based on scientific-research and practical management. First, the concept of soil and water conservation should be innovated in order to enhance ecological functions systematically, including improving soil protection, water conservation, ecological product supply, carbon sequestration, and biodiversity which is integrated with ecology, economy, and society together. Second, the promising design technologies of watershed should be explored in order to change the previous methods from simply intercepting sediment to improving soil quality, and from increasing vegetation cover to increasing carbon sequestration and biodiversity. Finally, more attention should be paid to coordinate the development of ecological economy based on the watershed unit. Successful explorations on the Loess Plateau offer a reference for constructing ecological barriers in China's future called "Three Regions and Four Belts." Overall, these strategies will help China to achieve sustainable development and enhance the ecological stability in soil erosion areas.

Poster

BreakThru (wetting agent) and Fontelis (fungicide) change the life-history of Folsomia candida (Collembola) and affect soil respiration in different climate scenarios

Borbála Szabó and Juliane Filser

Most of the world agriculture still uses conventional chemical plant protection, whereas soil pollution is one of the main factors negatively affecting biodiversity. Springtails (Collembola) are accepted model animals in ecotoxicology as they are cosmopolitan animals with diverse roles in the soil, e.g. shredding organic material, microbial regulation or moss pollination. BreakThru is a trisiloxan wetting agent that decreases the surface tension, therefore allowing plant-protection agents to cover more even and better adhere to plants. We have no toxicity data from BreakThru, and barely any from trisiloxan materials. Fontelis is a fungicide with penthiopyrad as an active ingredient (succinyl dehydrogenase inhibitor). We aimed to examine the toxicity of BreakThru and Fontelis on mortality, juvenile number, egg size, egg number, egg shape, hatching success, growth, and compensatory growth of Folsomia candida (Collembola). These life-history parameters allow extrapolating more accurately the long-effects of a toxicant or stress factor. Furthermore, we investigated the effects of both compounds on soil respiration under different climate scenarios (increased temperature, drought, heat shock, cold shock, extreme rain). Currently we are testing interactions of life-history and different climatic scenarios. Both toxicants significantly decreased the reproduction of F. candida. The soil respiration increased with increasing concentration, most probably because of the dead microbes providing resources to a simplified saprophytic community. Upon heat or cold shock treatments at lower concentrations the effects on respiration diverged into diverse directions in the, but the high concentration treatment showed stable increase in oxygen consumption.

Temporal evolution of soil salinity in Bas-Cheliff -Algeria.

Mouloud Ait Mechedal, Karim Ali Ouamer, Kaddour Djili and Youcef Daoud

Salinization is a generic term characterizing a progressive increase in the concentration of soluble salts in soils. Salt transfer is consistent with water dynamics and vertical and temporal variations in water stress. This work shows the temporal evolution of salinity between 1956 and 2012 by comparing the saline profiles to determine the direction and intensity of the variation in the state of salinity of the soils of the perimeter of Hmadena located in Bas-Cheliff. This work focused on the analysis and exploitation of data obtained on the solution of 20 samples from 5 profiles. The observation of saline profiles makes it possible to highlight a temporal evolution of salinity specific to two categories of situations:- profiles A495, B163, B217 record desalination between 1956 and 2012 at a rate of around 0.13 to 0.27 dS/m per year,- profiles A567 and A503 recorded salinization between 1956 and 2012 at a rate of 0.06 dS/m per year. The observation of salinization gradients at each horizon for the different profiles shows a heterogeneous variation in salinity between 1956 and 2012. This observation also reveals the presence of relatively greater salinization at depth for the 2 profiles A503 and A567, and a relatively greater desalination at depth for the 3 profiles A 495, B 163 and B 217 between 1956 and 2012. This variation in salinity would be due to the specific morphological characteristics of each horizon. The evolution of soil salinity over an episode of 57 years highlights the importance of the efficiency of the drainage network in determining the direction of variation in the level of salinity of the soils of Bas-Cheliff.

Sustainable Carbon Management in Urban Soils for promoting Soil Ecosystem Services and Soil Health

Atefeh Movassagh, Bibiana Betancur-Corredor and Martin Hamer

The current rise in atmospheric carbon is caused by a disruption in the balance of carbon fluxes between the atmosphere and other reservoirs, particularly the terrestrial ecosystem. Urbanization intensifies this imbalance through construction, industry, mining activities, and unsustainable soil management. Many factors, such as soil type and climate fluctuations influence soil organic carbon (SOC). However, on a local scale land use and management practices can have a more significant impact on SOC. The present study determines the impact of various soil management practices on (i) urban soil carbon storage (ii) soil health and (iii) its potential to provide climate regulating ecosystem services in the Bonn/Rhein-Sieg region (Germany). We conducted a survey on different management practices followed by the gardeners for each vegetation type (e.g., lawn, ornamental, and vegetable) in private and public gardens. Furthermore, in the autumn and winter of 2022, 248 composite soil samples were collected from topsoil (0-20 cm) in 30 private, 30 allotment, and 35 public green areas for physicochemical analyses. With these results, we expect to assess the most prevalent urban soil management practices and their effects on urban soils. The results of this study will help to identify a set of best management practices that would enhance the SOC content and, ultimately, soil health and ecosystem services.

Environment-relevant concentrations of lithium influence soybean development via metabolic reprogramming

Noman Shakoor, Muhammad Adeel and Rui Yukui

Lithium (Li) production has attracted global attention in recent years due to unprecedented demand in modern industry. The effect of lithium exposure on plant subcellular distribution, mineral homeostasis and root metabolomic is rarely reported. Herein, soybean plants as a model were exposed to Li at low (25 mg kg-1), medium (50 mg kg-1), and high (100 and 200 mg kg-1) concentrations for 28 days. The current study shows that the lethal concentration of the physiological and photosynthetic indicator was 146-177

mg kg-1. The higher mobility of Li was observed in shoots (383 fold) relative to the root (4.2 fold). Li was mainly deposited in the vacuole (103-320%) followed by cell wall (78-203%), mitochondria (46-303%), nucleus (21-298%) and plastid (26-298%), which suggested that both compartments (vacuole and cell wall) act as crucial defensive barriers against Li stress in soybean. Additionally, high concentrations of Li (100 and 200 mg kg-1) in soil dramatically altered and down-regulated the specific root metabolites in ABC transporters, ascorbate metabolism, aminoacyl-tRNA biosynthesis and pentose phosphate pathways leading to poor soybean growth and development. Li exposure at 100-200 mg kg-1 decreased Ca 27-43% and Mg 25-71% relative to control. These results provide valuable information for mechanistic understanding of the biological impact of Li on plant physiology and root metabolites; such understanding pave a way forward for the execution of emerging Li issues in agriculture.

Flexible framework for soil health indicator selection

Carmen Vazquez and Rachel Creamer

With an increasing interest in sustainable and regenerative agricultural schemes, stakeholders are increasingly seeking to monitor the effects of newly implemented farming practices on soil health. However, soil health, understood as the capacity of the soil to deliver several soil functions simultaneously is often difficult to understand, as most soil health assessments focus on monitoring a number of physical, chemical and more recently biological parameters that are often disconnected from soil functioning. At best, these parameters are compared to target values established using standards that fail to properly contextualise the pedo-climatic and management conditions of the soils of interest. Finally, any monitoring of soil health needs to be in line with the stakeholder's perspective, farmers may need to monitor parameters to guide management decisions in the shorter term or in specific conditions, while law makers will be more interested in landscape level dynamics in soil health. To meet these differing needs for soil health monitoring, the EC funded project BENCHAMRKS will develop a flexible framework for indicator selection that starts from the ground up. This framework defines which soil properties and environmental co-variates can be used to define soil functioning, and how this can be linked to soil management practices for a range of different climatic and land use contexts across Europe. The outcome will provide relevant indicators for soil health assessment, which considers the stakeholder's perspective, climatic conditions, land use and spatial scale under consideration. In this talk, we present two case studies for the use of this flexible framework.

Evaluation of soil quality through arthropod bioindicators

Mário Duarte, Elsa Valério, Rosa Coelho and Maria Godinho

Healthy soil is a foundation for agriculture and an essential resource to ensure human needs. That said, the need to assess the aspects of its degradation, becomes a priority, in line with the sustainability politics outlined for the 21ST century. Several studies have been conducted to quantify the impacts that agriculture have on the ecosystems and have shown that the use of conservative practices, such as cover crops, can have positive effects on the soil fauna. An essential part of this fauna, the soil arthro-pods, have been used as bioindicators of soil quality. This study aimed to monitor soil Arthropoda biodiversity, in an intensive horticultural system, where a cover crop was installed and compared with a control modality. It has been conducted since 2022, in a test field, located in Chamusca - Portugal, where a mix-ture of legumes and grasses was installed as cover crop, preceding a processing tomato crop. Two monitoring methods were used: (i) arthropod capture with pitfall traps and (ii) deep soil collection, applying the QBS-ar methodology. In the laboratory, the arthropods col-lected by the traps were quantified, sorted by morphotypes, and taxonomically identified. The soil samples were placed in a Berlese-Tüllgren extractor for arthropod separation and posterior classification. The data obtained in the first year, showed that the plot where the cover crop was in-stalled, presented a greater number and diversity of arthropods as well as a higher soil quality index. The data

regarding the present cultural campaign as been demonstrating the same tendency, so far.

The effect of soil properties on the overgrowth of dominant tree species on former agricultural land in the southeast region of Latvia

Kristīne Afanasjeva, Raimonds Kasparinskis, Imants Kukuļs, Oļgerts Nikodemus and Aivars Lukevics

The aim of the study was to investigate the relationship between the physical and chemical properties of soil and the dominant tree species during the overgrowth process, as the ecological knowledge is limited regards to link of soil properties and the afforestation former agricultural lands. The study was conducted in a 310-hectare area that had been abandoned and subsequently overgrown by Alnus incana, Salix caprea, Betula pendula, Populus tremula, and Picea abies. Over a span of 60 years (1954-2014), the forested area increased considerably from 11% to 62%, while the area of arable land and grassland significantly decreased. The study's results suggest that soil properties may not have a significant role in the process of succession. Nevertheless, the presence of loam and sandy loam soils in the study area had a significant influence on the overgrowth of farmland, which resulted in land use transformation and development of ecological processes. Additionally, the study found that new forest stands in the area affected the soil properties. The statistical analyses revealed that the total carbon content was significantly lower in the Betula pendula forest than in the overgrown grassland with different tree species. Furthermore, the concentration of exchangeable cations (Al3+ and Fe3+) in the soil was higher in Betula pendula and Alnus incana forests than in grasslands overgrown with Alnus incana or Salix caprea.

Soil acidification and declining soil health- major constraints of sugarcane productivity improvement in China

Ting Luo, Xiao-Yan Liu, Rui Yan, Kejun Huang and Prakash Lakshmanan

China is the fourth largest sugarcane producing and the second largest sugar importing country globally. Sugarcane is cultivated mostly in the sub-tropical regions of Southern China, with an estimated cane production area of 1.16 Mha in 2021 cropping season. Decades of continuous monoculture without fallow, large input of chemical fertilisers, especially nitrogen applied as urea (average 551 kg N ha-1), relatively low input of organic matter, heavy tilling and export of large quantities of base cations through harvested cane caused substantial soil acidification in most of the production regions. A recent detailed soil survey of sugarcane production regions found 62% of the surveyed farms have soil pH between 3.0-4.9. This has greatly altered soil chemical properties, soil biota and nutrient mineralization unfavourably with lasting adverse effects on greenhouse gas emissions and cane and sugar yield. This is further evidenced by the low sugarcane productivity gain in the past two decades despite releasing 30 varieties in the past 15 years for the surveyed regions. Gradual spreading of sugarcane ratoon chlorosis caused by low soil pH-induced manganese toxicity indicates continued deterioration of soil quality. Development and implementation of science-based, regionally targeted nutrition management and optimisation of cropping system are critical for the long-term sustainability of the Chinese sugarcane industry, and it will be discussed in this paper.

Impacts of different cacao (theobroma cacao l.) Agroforestry arrangements and farming systems on soil biodiversity in the ecuadorian amazon

Matilde Maria Bragadini, Giulia Bongiorno, Mirjam Pulleman and Lisbeth Espinoza-Lozano

In the last 15 years, the market for cacao and its by-products has been facing an increasing demand that is leading to agricultural intensification. The typical shade production of cacao has been replaced by high

input monoculture system, causing soil degradation, including soil erosion and soil biodiversity loss. Cacao Agroforestry Farming Systems (CAFS) represent a valid solution in terms of soil health and biodiversity preservation. The objective of this study is to assess the effects of different farming management practices and different agroforestry systems on soil biodiversity. Free-living nematodes, earthworms, macroarthropods, and microbial communities have been characterized in a long-term field experiment from five different CAFS in the Ecuadorian Amazon region, from both organic and conventional treatments. Nematodes, earthworms, and macroarthropods were extracted from the soil and morphologically identified and quantified. The overall structure and diversity of the soil microbial communities were studied through Phospholipids Fatty Acids (PLFAs) and Neutral Lipids Fatty Acids analysis (NLFAs). Nematode-based indices (NBIs) (i.e., maturity index (MI), maturity index 2-5 (MI 2-5), structure index (SI), enrichment index (EI), channel index (CI), basal index (BI)) were calculated to assess the complexity of the soil food web and the resource flow into the soil webs. The arthropods-based index of biological soil quality (QBS) was used as an indicator for soil health. These parameters were related to soil chemical parameters, such as C: N ratio in the soil and the soil total available carbon, indicators for soil quality. The data are currently being analyzed; results will be presented during the conference.

Understanding biological measurement of Soil Health

Felix David, Carmen Vazquez Martin and Rachel Creamer

Increasing anthropogenic activities such as urbanization or intensive agricultural practices put strong pressure on soils and lead to degradation and loss of biodiversity. Soil health monitoring is high on the agenda of the European Commission with the ambition to restore or maintain soil health in 75% of soils across Europe by 2030. Therefore, the assessment depends on a reliable cost-effective framework for measuring soil health. Current soil health monitoring systems are, in many cases, applying a traditional minimum soil dataset approach focused on key agronomic soil chemical indicators, with a few easy-to-measure but not very informative soil biological and physical measurements. Hence, understanding the role of soil biota and quantifying their contribution to soil processes is crucial to make analyzing soil biological properties more interpretable and useful for monitoring. Soil aggregation is a key parameter for soil sustainability. To explore the role of biological actors in forming stable aggregates in agricultural soils different management practices (tillage vs no-tillage, organic manure vs. mineral fertilizer, and strip cropping) will be assessed regarding their 1) soil structural properties and 2) their impact on the (functional) biodiversity in three well-replicated long term field experiments in Switzerland and The Netherlands. Based on these results, contribution of selected soil biota, i.e., enchytraeids, microbial communities, and plant roots to soil aggregation and macropore formation will be quantified in laboratory experiments. These findings will thereby help to develop a European soil health monitoring scheme and improve recommendations of management practices to support soil health.

Characteristics and functioning of grassland peat soils in Friesland, The Netherlands

Clarisse Kraamwinkel, Ruth Howison and Anne Beaulieu

Healthy soils have the ability to provide a wide range of soil functions and can help address a multitude of present-day societal challenges such as climate change, biodiversity loss, and the nitrogen crisis while ensuring food security for a growing population. Here, we aim to investigate the characteristics of different types of grassland peat soils in Friesland, The Netherlands, and evaluate how well these soils perform the main soil functions including climate regulation, water storage and purification, biomass production, and nutrient recycling. We collected a wide range of soil physical, chemical, and biological variables complemented with measurements of hydrological and environmental conditions and detailed accounts of past and present management practices from thirty grassland fields in Friesland with different peat types and management intensities. Ordination and between-group comparison of the main peat types (no cover, clay cover, and

loam cover) reveal that peat soils without a sediment cover are generally managed more extensively and have: relatively slow nutrient recycling, low biomass production and habitat provision, and high carbon and water storage as opposed to soils with a sediment cover of clay or loam. Understanding the differences in characteristics and functioning of the different types of peat soils is an important first step in the transition towards more sustainable land management.

Diversity of carabids in two intensive crop systems in Portugal (Ribatejo region): monoculture vs crop succession

Elsa Valério, Maria Godinho, Mario Duarte and Elisabete Figueiredo

Soil is a main resource to ensure food production and security. It's a living system wherein arthropods ensure critical functions and represent a large percentage of its fauna. They provide fundamental ecosystem services, being their presence and interactions dependent of the chosen technical profile. In the present study, the abundance of different taxa of arthropod soil quality bioindicators were evaluated along 2018-2021, in Portugal, in an intensive agricultural area (Ribatejo region). The sampling protocol was applied in two fields with different crop systems: (i) cover crop - potato and maize rotation (Golegã) and (ii) processing tomato monoculture (Vila Franca de Xira). Sixteen pitfall traps with ethylene glycol were installed for 7 days at each sampling time/sites, both during the cover crop and the main crop periods. The captured arthropods were separated into morphotypes and identified. During the 4 years of sampling the field with a monoculture system revealed a lower arthropod biodiversity, compared to the field with crop rotation. Regarding an important arthropod group, the carabids, in the field with crop rotation, the number of morphotypes was 9 and 13, in 2019 and 2020, respectively. In the monocultural field only 3 and no morphotypes were found in 2019 and 2020, respectively. The study shows a clear trend towards a greater biodiversity and more balanced Carabid populations with the practice of cultural rotations and cover crops.

Improving soil health through sustainable practices in rice-wheat systems in the Indo-Gangetic plain

Kavya Krishnan, Harold van Es and Andrew McDonald

The dominant cropping system of the Indo-Gangetic Plain, rice (Oryza sativa L.) – wheat (Triticum aestivum L.) has seen increasing risks in recent years due to a variety of environmental and socio-economic factors like changing climates, scarcity of water and soil degradation. Diversifying cropping systems, coupled with zero-till (ZT) and residue addition, have been proposed to address the negative impact of years of intensive cultivation by improving soil health, increasing soil organic carbon (SOC) and system yields. The main objective of this study is to determine the effect of crop diversity, residue management and tillage on soil health and yield. Soils were analyzed from various long-term experiments, located at Bihar, India. Trials involved various combinations of tillage, crop establishment and residue management practices in a rice–wheat rotation. Three trials considered different crops in rotation including maize, chickpea, soybean and mustard. Soil Health was determined using the comprehensive assessment of soil health (CASH) approach which measures 15 biological, physical and chemical indicators. Crop residue addition had a positive effect on biological properties while reduced tillage largely affected soil physical properties. Overall soil health (measured as a composite soil health index), biological indicators notably, were strongly correlated to both rice and wheat yields. We found divergent responses to soil properties and yields with the addition to or replacement of crop to a conventional RW system – with the effect being strongly dependent on the mix of crops selected.

Capability of selected indicators for soil organic carbon stability to explain soil functions

Guusje Koorneef, Ron de Goede, Sophie van Rijssel, Pierre Barré, Mirjam Pulleman, Francois Baudin and Rob Comans

There is no doubt that total organic carbon (OC) is a valuable indicator for various soil functions. The stability of OC influences all soil functions that depend on microbial decomposition and might therefore have strong added value in soil health assessments. Starting from OC content, we investigated the added value of including one or more OC stability parameters measured by different techniques in explaining soil functioning. In 74 arable fields in the Netherlands, 3 soil samples were collected (n=222). We measured 3 soil functions, i.e. element cycling, biological population regulation, and the regulation of soil structure and water with 5 different indicators per function. Besides, we measured total OC content and OC stability with 3 different techniques (i.e. POX-C, Rock-Eval, and POM-MAOM fractionation) resulting in 20 OC parameters. Multiple linear regression was used to determine how much variation in each soil function indicator was explained by the OC parameters, and additionally by other measured intrinsic soil properties (e.g. texture and pH).We found that total OC content explained 9 ± 15% of the variation in soil functions, and that including OC stability parameters increased this to 26 ± 21%. Additionally including intrinsic soil properties explained 31 ± 23% of the variation in soil functions, so the majority (82 ± 22%) was explained by OC parameters. None of the 3 measuring techniques provided a single OC stability parameter that, in addition to total OC content, explained significantly more variation in soil functions than total OC content only. OC parameters from different measuring techniques were complementary and the explanatory power of different techniques was comparable. This study present novel inputs for including OC stability in soil health assessments to evaluate land management.

Characterization of soil bacterial profiles in extremely acidic forest soils

Mélody Rousseau, Arjen de Groot, Andjin Siegenthaler and Andrew Skidmore

Soil bacterial communities respond to their biotic and abiotic environment. Two key drivers, soil biochemical properties and forest type, are known to correlate with the composition of specific communities. The humus-type concept captures these drivers along a gradient of soil nutrient availability, quality, and pH. For example, deciduous forests (mull-like soils) often have nutrient-rich and alkaline soils compared with coniferous forests (mor-like soils). While climate change might favor deciduous forests over coniferous forests in temperate regions and further acidification of soils is expected, essential ecosystem services such as nutrient cycling and carbon storage might be threatened. Our study aims at 1) characterizing soil bacterial community characteristics under coniferous and deciduous stands in an acidic-stress environment and 2) exploring the effect of extreme acidification on soil bacterial community profiles. We collected 147 soil samples in two European temperate forests in The Netherlands and in Germany, measured their biochemical properties, and used in-depth next-generation sequencing to produce bacterial profiles. We found distinct bacterial profiles between forest types, with mull-like soils having a higher bacterial richness and diversity. In addition, extreme acidification of soils emphasized a bacterial diversity loss and a shift in community composition associated with changes in the soil functional profile. Our study is the first to demonstrate strong changes along an extremely acidic soil pH gradient. The results of this study not only highlight the relevance of metabarcoding for biodiversity assessment and monitoring but also provide a baseline for soil microbial functions at large spatial scales.

Implications of Sustainable Soil Management Practices on Energy Use

Mona Aghabeygi, Veronika Strauss, Lukas Bayer, Carsten Paul and Katharina Helming

Rising energy prices following the Russian attack on the Ukraine have raised awareness about energy consumption across all sectors, including agriculture. In a previous study, we identified sustainable Soil Management

Practices (SMPs) with high approval rates among Germany stakeholder groups. Now, we analysed the implications of selected SMPs on the use of total energy, total fertilizer energy, total pesticide energy, and on a field's contribution margin. Using Germany as a test case, we assessed diversified crop sequences (SMP1), comparing three crop rotations with different degrees of complexity, use of organic fertilization, (SMP2), comparing mineral fertilization with green manure or liquid manure fertilization, and conservation tillage (SMP3), comparing conventional tillage with reduced till and no-till systems. To account for the diversity of local conditions, we differentiated between high, medium and low yields, light, medium, and heavy soils, as well as between conventional and organic farming systems. Our results show that shifting to more complex crop rotations is associated with small energy savings while substituting mineral fertilizer with organic fertilizers or shifting to reduced-till or no-till systems strongly reduces total energy use. From the point of view of farm economics, diversifying the crop rotation slightly reduced the contribution margin while the use of organic fertilizers, especially green manure, led to stronger reductions. We conclude that the assessed SMPs are associated with energy savings. Should energy prices further increase in the future, this would raise the economic attractiveness of the SMPs and could motivate a more widespread adoption.

Vertical carbon distribution and soil profile changes under different compost application rates over time in oil palm plantations

Yu Yang Chang, Siti Aishah Abd Wahid, Choon Cheak Sim and Samsudin Amit

Soil degradation is a growing concern worldwide, with negative impacts on agricultural productivity. One approach to mitigating soil degradation and improving soil quality is the application of organic amendments, such as compost. In this context, this study aims to determine the effect of different compost application rates on the vertical carbon distribution and soil profile changes under different compost application rates over a five-year period in oil palm plantations. The experiment was conducted in a randomized complete block design with four compost application rates: control (no compost), low (50 kgpalm-1year-1), medium (100 kgpalm-1year-1), and high (150 kgpalm-1year-1). Soil samples were collected from the depths of 0-15, 15-30, and 30-45 cm annually and analysed for their organic carbon, macronutrient, pH, and CEC. The results showed that compost application at a rate of 150 kgpalm-1year-1 was the most effective at increasing soil carbon and nutrient levels over a five-year period. It was found that soil organic carbon, nitrogen, total phosphorus, and CEC was increased primarily at the soil surface (up to 30 cm). Meanwhile, the increase in soil pH and exchangeable potassium was observed at all soil depths after the application of compost. One noteworthy finding of the study is that the soil carbon and nutrient levels did not reach a plateau stage even after five years of compost application. This observation suggests that the application of compost can result in sustained improvements in soil quality and nutrient levels over an extended period.

Effect of leguminous green manure crops on soil health, tomato production, and nutritional quality

Lukas Pawera, Lourena Maxwell, Mei-Ying Lin and Srinivasan Ramasamy

Excessive amounts of chemical pesticides and fertilizers are used in intensive vegetable production, increasing human and environmental health risks. Synthetic fertilizers do not replenish organic matter and reduce the interactions of plants with soil microorganisms. Green manures (GM) are crops incorporated into the soil to provide organic matter and nutrients. This field experiment aims to identify suitable GM for improving soil health and increasing tomato production and quality. Four GM treatments (Sesbania, Sunn hemp, Mungbean at flowering and after the harvesting stage) and an untreated control were arranged in a randomized complete block design with three replications. In the second year, the main plots were split into two sub-plots with and without compound fertilizer. The data on soil nutrients, microbiomes,

pest and disease incidence, yield, and nutrient composition of tomato are being compared. Results from the first year indicated that Sesbania and Sunn hemp showed the highest increase across soil nutrients. Green manuring recruited specific microbial functional groups. The incidence of common tomato pests and diseases did not differ significantly. The total tomato yield was significantly higher in GM plots compared to the control (p=0.05). The yield was highest in Sunn hemp (41.12±6.12 kg/plot) and lowest in control (26.87±4.62 kg/plot). From tomato nutritional qualities, only pH and soluble solids significantly differed from the control. These preliminary results suggest that GM may contribute to vegetable production systems by increasing the level of soil nutrients. The data from the second year are being analyzed and will be presented.

Effects of sustainable management practices on health and biodiversity soil in agricultural ecosystems

Sandra Tienda, Javier Gonzalez, Oscar Gavira, Ana Lia Gayan, Marina Lopez, Jose Antonio Guiterrez-Barranquero, Estefania Santos, Victor Carrion, Jose Damian Ruiz, Francisco M. Cazorla, Raimundo Real, Michael Schade, F. Javier Peris-Felipo and Gina Swart

This research was carried out within the framework of the international LivinGro® project, promoted by Syngenta, and focuses on the effect of best sustainable management soil practices from different farming systems that could preserve health and biodiversity soil. Several parameters were evaluated, such as soil characteristics, soil microbial biodiversity and insect biodiversity. This study was performed on selected plots of stone fruit and olive trees allocated in different geographical areas of Spain. In each area, soil samples were collected during the two-years' experiments to unravel the soil characteristics such as the organic matter, basal respiration, nitrates and porosity. Furthermore, was also obtained from the same soil samples the microbial biodiversity. The alpha- and beta-diversity was obtained by the relative abundance of Prokaryotic and Eukaryotic microorganisms, and putative microbial indicators of specific ecological management soil were proposed. For arthropods biodiversity, surface pitfall traps and subterranean sampling devices (SSD) were used. More than 28,000 organisms have been examined from pitfall traps and more than 39,000 from SSD. The results indicate that soil management could be an effect on soil characteristics, with an increase in nitrate, basal respiration, and total nitrogen, related to an increase in the relative abundance of some specific microbial genera that could have a potential beneficial role for soil and plants. In addition, the results reflect zonal differences due to geographical location, with different climatic conditions, relief, and lithology, which can affect soil quality. Finally, an effect of soil management on arthropod biodiversity was also observed, increasing the number of insects.

Ground cover management and climatic conditions affect soil fauna abundance and community structure in stone fruit orchards

Sara Acconcia, Andres Valdezate, Oscar Aguado, Luis Miranda, Ana Lia Gayan, F. Javier Peris-Felipo and Maria Jesus Briones

The LivinGro® project focuses on implementing sustainable practices to create optimal conditions for enhancing above- and below-ground biodiversity. The experimental design included six fruit orchards located in three different Spanish regions: olives in Rioseco and Pozaldez (Valladolid, NW Spain); olives in Alzamen and peaches in Almonacid (Zaragoza, NE Spain); peaches in Yechar and plums in El Ciruelo (Murcia, SE Spain). At each farm the soil between tree rows was either planted with a mixture of flowers (ecologically friendly treatment) or left as bare soil (conventional treatment). Replicate (n=3) soil fauna samples (earthworms and microarthropods) were collected in winter (December 2022-January 2023).The highest average earthworm abundance was observed in Valladolid (23.7 ind. m-2), whereas the lowest ones were recorded in Zaragoza (1 ind. m-2) and Murcia (4 ind. m-2). Unlike Valladolid, the winter period in these two latter locations

is dry and explains why at the warmest site (Murcia) earthworms were only found under the protecting vegetation cover.In contrast, microarthropods were particularly abundant in Murcia (1334 ind. m-2), more so under the vegetated soils, with their communities being dominated by mites (Oribatida, Prostigmata, and Mesostigmata). Despite their lower abundance in Valladolid and Zaragoza (534 and 433 ind. m-2, respectively), microarthropod communities were more diverse and consisted of Collembola, Acari (Prostigmata), Myriapoda (Pauropoda, Symphyla) and Hexapoda (Diptera, Coleoptera).These results suggest a strong climatic influence on soil communities, and with the ground vegetation cover having a beneficial effect on soil fauna densities, in particular in dry soils.

Cover crops improve stabilization of soil structure and their associated organic carbon in dry woody agroecosystems

Noelia García-Franco, María Almagro, Cristina Férnandez Soler, Luis Carlos Colocho, Martin Wiesmeier, María Martínez-Mena and Antonio Sánchez

Regenerative and sustainable farming efforts are widely promoted and picked up by motivated farmers all over Europe, with the promise to restore soil health and biodiversity as well as capture carbon, while maintaining high crop yields and avoiding soil degradation or water pollution. In the last years, the implementation of cover crops in rainfed woody agroecosystems as almond orchards have spread, as a sustainable practice in semi-arid areas. In our study, we assess the effectiveness of cover crops for carbon sequestration and aggregate formation in three rainfed almond farms located in SE Spain. Two types of cover crops (native and seeded) incorporated into the soil by reduced tillage are compared to conventional tillage where the soil is bare most of the year. Our results showed that the soil structure improves through the formation of 29% more macroaggregates and 9% more microaggregates under the seeded cover. In addition, the OC stock associated with macroaggregates and microaggregates was higher (0.8 ± 0.3 and 0.8 ± 0.2 t ha-1, respectively) under the seeded cover crop than spontaneous cover crop and conventional tillage (0.5 ± 0.1 and 0.6 ± 0.1 t ha-1). The quality of the used sown vegetation displayed a significantly higher proportion of N-O-Alkyl compounds (55.3 ± 9.3%) and less decomposed than the spontaneous vegetation (49.1 ± 2.3%). We assume that the quantity and the quality of the vegetation material that the farmers used as a cover crop in dry woody agroecosystems are one of the main controlling factors in OC stabilization within soil aggregates.

Sensational Reduction of Ammonia Volatilization Loss by Organic and Mineral Soil Covering Systems in Potato Cultivated Soil

Eun Mi Lee, Him Chan Choi, Yeomyeong Lee and Sang Yoon Kim

Ammonia (NH3) volatilization is a major nitrogen (N) loss from agricultural soils, which can deteriorate air quality and eliminate soil N, resulting in significant reduction of soil productivity. Soil covering systems (SCs) may effectively reduce NH3 volatilization due to increased NH4+-N adsorption and moisture content. However, it remains unclear. To evaluate the effects of soil covering systems on reducing NH3 volatilization and enhancing potato (Solanum tuberosum) yield, organic (rice hull biochar, RHB) or mineral (bentonite, vermiculite, zeolite) soil covers were installed on the surface of the pot with different covering depths (low 0.5 cm or high: 1.0 cm) under the recommended fertilization including PK treatment (control, excluded N fertilization) by investigating potential NH3 reduction, potato yield, and soil properties. NH3 volatilization was significantly mitigated by SCS during the cultivation, showing the effective reduction (13-87% over NPK treatment). Among all the covering materials, zeolite (1.5-1.7 kg N ha-1) was sensational to suppress total NH3 volatilization (approximately 85% reduction over the NPK) and followed by RHB (6.6 kg N ha-1, 42%) > bentonite (6.7 kg N ha-1, 41%) > vermiculite (9.8 kg N ha-1, 13%). Irrespective of treatments, NH3

volatilization was gradually reduced with increasing the covering depth. However, zeolite was more effective on reducing NH3 volatilization than biochar treatments. SCs effectively reduced NH3 volatilization from agricultural soils, due to potentially blocking NH3 penetration as an environmental filter without significant reduction of potato yield. Conclusively, SCs could be a sensational strategy for mitigating NH3 loss and increasing productivity in agricultural soils.

Biochar Application as A Sustainable Strategy for Enhancing Carbon Balance, Soil Properties and Fruit Productivity in Red Pepper Cultivated Upland Soils

Sohee Yoon, Juhee Lee, Yeomyeong Lee, Hyerin An and Sang Yoon Kim

Incorporation of soil organic matter (SOM) is crucial to enhance soil organic carbon (SOC) stock, tackling global climate changes. However, there is lack on SOC balance in soils with different organic amendments. To evaluate the effects of organic amendments on increasing SOC balance, red pepper (Capsicum annuum) productivity, soil properties including SOM fractionation, six treatments (no fertilizer and red pepper residue (R), compost (Com), rice hull biochar (RB), and wood biochar (WB) at a rate of 0 and 5 Mg d.w ha-1 under the recommended NPK fertilization) were set up in the field. SOC balance between input (organic amendments) and output (CO2 and CH4 fluxes) was investigated. Total C input was the highest at WB treatment (2.83 Mg C ha-1), and then followed by RB (2.81) > R (2.02) > Com (1.03). CO2 fluxes were the highest at R treatment but was no statistical difference among other treatments. Pepper residue was easy to be decomposed due to consisting of more labile C and light fraction, which might not be a promising option for increasing C stock in soils. CH4 emissions were negligible, showing the highest C balance in RB and WB treatments. Organic amendments enhanced total fruit yield of red pepper, showing the highest productivity at RB treatment (6.78 Mg ha-1), and then followed by WB (6.56) = R (6.54) > sole NPK (6.48) > Com (6.05) = control (6.00). In conclusion, biochar amendment could be a promising way to enhance SOC stock and increase the yield in upland soils.

Organic matter, soil biodiversity and agriculture

Petra van Vliet, Sophie Deelen and Els van der Spek

For optimal agricultural production, climatic conditions and good management are crucial. Soil management is a central point of attention in any agricultural business. Soil can be looked at from a physical, biological and chemical point of view. The interactions between these three aspects are very important. Organic matter stands at the center stage of the three aspects: it is important in soil due to its effect on nutrient availability (short term and long term) (chemical aspects), water holding capacity, workability of the soil, prevention of soil loss, soil structure (physical aspects), and as a food source for soil life (biological aspects). A high activity of soil life will result in a higher breakdown of organic matter, resulting in a higher availability of nutrients, which can result in a lower demand for fertilization. In our study we monitored the presence and activity of soil life (bacteria, fungi, protozoa, predatory nematodes and earthworms) under different management conditions with different organic matter input using the PMN and PLFA method. In another setting we studied the effect of soil texture on soil life. Crop yield and crop quality, fertilization history, crop rotation and weather conditions will also be included in the statistical analysis.These studies will provide more insight into the role of soil life and organic matter in agriculture.

Can agroecological management enhance soil biology and resolve the soil compaction problem in Thailand ? A soil physic parameters study

Emilie Peiffer, Aurore Degré and Chuleemas Boonthai Iwai

Agriculture relies on soil to grow crops and feed the growing population. Unfortunately, the extent and the intensity of agriculture degrade it. As soil is a non-renewable resource, sustainable use of it and its ecosystem services is necessary. Among threats to soil, compaction causes hidden changes in the soil structure and therefore impacts its productivity. A change in soil structure influences the hydraulic properties of the soil and its fauna. Hydraulic properties determine how nutrients, chemicals, water and pollutants move through the soil. Soil biodiversity is the living entity of the soil and it influences and is influenced by the hydrophysic properties of the soil. Soil engineers' ability to create channel can influence the food web and the physical properties of the soil. In this master thesis, hydrophysical parameters and soil biota will be assessed in order to highlight the existence of a relation between soil physical status and biological status in Ultisols in Northeast Thailand. The soil physical parameters studied will be the bulk density as well as soil water retention, measured with a pressure plates apparatus and WP4C dew point. Saturated hydraulic conductivity and field measurements with a Mini-Disk will provide K(h) curves. Soil fauna will be analyzed by microbial respiration and hand-sorting of earthworms. Four land-uses : sugar cane, community forest, paddy rice and cassava, with organic and conventional managements for the latter, will be studied in order to understand how the agricultural system influences biology and hydrophysics of the soil.

Crop yield response to long-term reduced tillage in a conventional and organic farming system on a sandy loam soil

Derk van Balen, Fogelina Cuperus, Wiepie Haagsma, Janjo de Haan, Wim van den Berg and Wijnand Sukkel

Reduced tillage has multiple positive effects on soil properties. However, reduced tillage can also lead to negative effects, such as a decrease in crop productivity. There is limited data on the effects of reduced tillage on root and tuber crop yield in temperate zones. In this study we assessed the effects of reduced tillage on crop yield in the Netherlands with a focus on important cash crops for arable farmers: potato, carrot, onion, and sugar beet. Three tillage treatments were selected including conventional tillage (deep ploughing) and two reduced tillage treatments consisting of shallow non-inversion tillage with (RTS) or without subsoiling (RT). These tillage treatments were tested in a long term experiment with a conventional and organic crop rotation system that included grass and grain crops and important cash crops. We found similar or even higher marketable yields in reduced tillage for 12 (RTS) and 11 (RT) of the 13 crops grown over a 10 year period, compared to conventional tillage. However, yield of onion and cabbage in one or both reduced tillage systems was lower than in conventional tillage. In both cases, yield losses in both RT treatments could be partly related to negative effects of crop residues from the preceding cover crop. Our results provide evidence that yield levels of crops grown in reduced tillage systems can compete with crop yields in deep inversion tillage systems. However, crop residue management and seedbed preparation remain a challenge in reduced tillage systems, requiring further attention in research and dissemination.

Reducing aluminum is the key nutrient management strategy for ameliorating soil acidification and improving root growth in an acidic citrus orchard

Siwen Zhang, Xiaohui Chen, Zongjun Ji, Xiaojun Yan, Kunpeng Kong, Qichao Zhu, Muhammad Atif Muneer, Fusuo Zhang and Liangquan Wu

Aluminum (Al) toxicity is one of the most serious hazards of soil acidification, which limits root formation and hinders crop growth. Soil acidification in orchards has been widely reported, but there is little information

about the effect of Al3+ on citrus roots. We thus conducted soil surveys to analyze the status and characteristics of acidification in orchards of pomelo (Citrus grandis), being the main citrus variety in Southeast China. Subsequently, we explored whether optimized fertilization and liming can effectively reduce Al toxicity in roots and increase yield, including three treatments, i.e. farmer fertilization practice (FFP), NPK optimization (OPT), and OPT combined with lime (OPT+L). Results showed that significant soil acidification occurred in pomelo orchards (with an average pH decrease of 0.81 units, increasing with orchard age). The soil pH and base saturation (BS) at the drip line (DL; i.e., fertilization site) were the lowest, while the concentration of exchangeable acid (Ex.Acid) and exchangeable Al (Ex.Al), and the ratio of Ex.Al to cation exchange capacity (Ex.Al%) were highest compared to other locations away from DL. Random forest analysis indicated that Ex.Al was the most important factor reflecting soil acidification. Under the OPT+L treatment, the concentrations of soil Ex.Acid and Ex.Al decreased, and BS increased, which markedly reduced the Al 3+ concentration in the roots and promoted root growth in terms of an increased root activity, root length, root tips and root surface area by a factor of 1.2, 0.8,1.3 and 1.4, respectively.

Can biochar-amended soils mitigate land degradation from runoff and soil erosion by water? A global scale meta-analysis

Behrouz Gholamahmadi, Simon Jeffery, Oscar Gonzalez-Pelayo, Sergio Prats, Ana Catarina Bastos, Jan Jacob Keizer and Frank Verheijen

Most researchers consider biochar as a nature-based solution. Potentially, biochar application could be a useful contribution to restoring degraded soils from erosion, especially for vulnerable soils. It has the potential to affect soil and vegetation properties that are key for the processes of runoff and soil erosion. We conducted the first systematic meta-analysis aiming to quantify and interpret the impacts of biochar on runoff and soil erosion. The developed dataset consists of 184 pairwise observations for soil erosion from 30 independent studies, 22 of which included runoff, from four continents. Both field and pot experiments show a range of effects, from strong reductions to strong increases in runoff and/or soil erosion. Our results showed a significant grand mean reduction in the runoff by 25% and in erosion by 16%. Mitigation of soil erosion in the tropics was approximately three times stronger (30%) than at temperate latitudes (9%); erosion reduction in the subtropical zone was 14%, but not significantly different from either the tropical or temperate zones. At topsoil gravimetric biochar concentrations between 0.6% and 2.5%, significant reductions occurred in soil erosion, with no effect at lower and higher concentrations. Biochar experiments that included a vegetation cover reduced soil erosion more than twice as much as bare soil experiments, i.e. 27% vs 12%, respectively. This suggests that soil infiltration, canopy interception, and soil cohesion mechanisms may have synergistic effects. Our results demonstrated that biochar amendment may be a useful tool to combat land degradation on a global scale.

Impacts of different management practices and site conditions on soil acidification rates in long-term experiments

Xingjuan Zhu, Gerard H. Ros, Donghao Hao, Minggang Xu and Wim de Vries

Excessive mineral fertilizer use has accelerated soil acidification in southern China, while manure application can alleviate this by the associated base cation inputs. However, the impact of (integrated) fertilizer management on soil acidification remain unclear. This study examined soil acidification rates of 13 long-term experimental sites with different fertilization management systems by quantifying the inputs (atmospheric deposition, mineral fertilizer and manure), crop uptake and losses of major elements (base cations, NH4+, NO3-, SO42-, H2PO4-, Cl-, HCO3-), as well as the main driving factors of soil acidification. The study found that the partial substitution of mineral fertilizer by manure resulted in lower acidification rates than mineral fertilizer. The

primary driver of acid production varied depending on the fertilizer treatment and soil type. In non-calcareous soil, nitrogen (N) transformations were the main cause of acidification, while in calcareous soils, HCO3- leaching dominated soil acidification under mineral fertilizer application, while N transformations were more important under manure application. Acid production by N transformation increased with soil N surplus and precipitation surplus (PS), but decreases with higher soil organic carbon content. Acid production by HCO3- leaching showed a strong relation with land use (higher in paddy than in upland) and also increased with an increase in PS. Our research demonstrated that manure can reduce soil acidification by supplying base cation and HCO3-. However, for sustainable agricultural development, it's crucial to regulate the use of mineral fertilizer or manure to lower soil N surplus according to site conditions (including land use, climate, and soil type).

Agronomic drivers and constraints for soil carbon sequestration in Europe

Marti Vidal, Charlotte van Haren, Allard de Wit and Renske Hijbeek

Recent research has highlighted the uncertainties surrounding the mitigation potentials of agricultural soil carbon sequestration and the need for context-specific assessments on carbon sequestering management practices. Many biophysical estimates overlook agronomic and socioeconomic drivers and barriers, which are critical factors for the widespread adoption of these practices. This study aims to bridge this gap and assess the feasibility of adopting specific management practices in arable agriculture in Europe while considering land use, agronomic, and socioeconomic drivers and constraints. Management practices include cover cropping, enhanced rotations, agroforestry, nitrogen input optimisation, erosion control measures, and reduced tillage. The analysis aims to identify under which circumstances win-win situations exist, where adopting such practices may lead to carbon sequestration and enhanced soil functions. To do so, the study will integrate a spatial analysis of European land use cover datasets with empirical data from a survey and semi-structured qualitative interviews with extensionists and farmers gathered in three different case studies (Spain, the Netherlands and Austria). Each management practice will be evaluated for land area requirements and compatibility with other land use demands. At the case study site, management practices will be cross-examined through the lenses of the local producers, experts and extensionists to elucidate context-specific synergies and trade-offs of adoption. In this poster, we will share the proposed research methods of this new study and preliminary findings.

Winter cover crops (WCC) in Santiago del Estero: II water dynamics and soil available water for the next crop

Salvador Prieto Angueira, Maria Clara Berton and Javier Ventura

Cover Crops (CC) in agriculture can contribute to sustainable food production, reducing soil and water degradation. However, winter CC (wCC) in semi-arid, can decrease available water (AW) for the next harvestal crop. To quantify the effect of wCC in the AW for a next maize crop, an experiment was conducted in 2016 and 2017 in Santiago del Estero. Six wCC, short and long cycle wheat, short cycle rye, triticale, hairy vetch, white sweet clover and a control (fallow –F) were evaluated. AW (0-100, 100-200 cm and whole profile) was measured at sowing, drying of each wCC (flowering), drying of the longer wCC cycle and sowing of maize. At this moment the difference between the AW in each wCC and F were calculated and express as soil water cost (SWC, mm). AW at 0-100 cm and to a lesser extent at 100-200 decreased significantly ($p<0.05$) as wCC killing was delayed. All wCC had significantly ($p<0.05$) lower AW than F. On the contrary, in both years at maize sowing date, the AW 0-100 was only significantly ($p<0.05$) lower than the F in 2 of 6 wCC, while the AW 100-200 in 2016 was significantly ($p<0.05$) lower in all wCCs and in 3 of the 6 wCCs in 2017. Consequently, when integrating the AW 0-200, all the wCCs had significantly ($p<0$ .05) lower AW, being the SWC variable but higher with the drying delay. Results show that wCC decreases the AW respect to F and SWC increases with the delay of killing day.

Bokashi promotes general arable soil disease suppressiveness in short term but not in long term

Maartje van der Sloot, Solomon Maerowitz-Mcmahan, Joeke Postma, Juul Limpens and Gerlinde De Deyn

Soil-borne diseases can cause significant crop losses and should be tackled sustainably in current and future agroecosystems. Increasing the capacity of soils to suppress the effects of soil-borne diseases (soil suppressiveness) is an important tool in sustainable crop production. Soil suppressiveness can be improved by adding organic amendments to the soil for multiple years, but the effects vary between the type of amendment (composted, fermented, or fresh material) and timing of application. The objective was therefore to test suppression capacity of sandy arable soil from a multi-year field-experiment where fresh plant cuttings, compost originated from same cuttings, or Bokashi originated from same cuttings were applied across 10 fields. Additionally, the effect of short-term application of the same amendment treatments on soil suppressiveness was tested using control arable sandy soil from 2 field sites. Disease suppressiveness was measured with a bioassay using the Lepidium savitum (cress) – Pythium ultimum model system. Multiple fields showed a strong impact on cress growth independent of the amendment treatment. Additional chemical and biological measurements show evidence of an effect from inherent pathogen load. Focussing on sites with low inherent pathogen load we found no significant impact of long-term amendments on soil suppressiveness. However, short-term application of Bokashi did significantly promote soil suppressiveness. This effect can likely be attributed to the increased metabolic activity of the soil's inherent microorganisms in response to Bokashi, containing more easily-decomposable compounds as compared to the other soil amendments but the longevity of this effect requires further field tests.

Two multi-year public private partnerships support Dutch farmers in the transition toward regenerative agriculture

Michiel In T Zandt, Howard Koster, Mark Manshanden, Margriet Goris, Evelien de Olde, Alfons Beldman, Bert Smit and Rachel Creamer

Driven by personal beliefs, environmental changes, decreasing soil fertility and anticipated changes in legislation, many farmers in the Netherlands are motivated to transition to more sustainable farming practices. The concept of Regenerative Agriculture, with fertile soils as the foundation, is increasingly recognized as a promising pathway. It includes measures that seek not only to mitigate the negative impacts of common practices but also make a positive contribution to nature, environment, climate, food security and socioeconomic conditions. Such changes require a large investment of time and knowledge, and they have significant short-term economic risks for farmers. Results from prior research on the implementation of regenerative agriculture practices in the Netherlands indicate that in conjunction with well-defined farm level business models, there is the need for improved mapping of soil biology and structural monitoring based on a modular, farm-specific set of parameters spanning from soil and biodiversity to economics and social aspects. This is the basis for a new public private partnership (PPP) project in which a number of large agricultural cooperatives, advisory organizations and knowledge institutions will work together to identify successful pathways toward a regenerative system on farm and regional level. This project works together with 50 Dutch arable, dairy and mixed systems farmers who are at different stages in their transition towards more regenerative agriculture. Using soil health as starting point, this project will provide means and support for farmers in the Netherlands who want to take major steps toward regenerative agriculture in the future.

Towards soil classification for sustainable land use planning in the North and Adamawa Regions, Cameroon

Lydia Krauß, Cédrick Nguemezi, Lawrence Tatanah Nanganoa, Patrick Mounoumeck and Elke Fries

Cameroon's large diversity in soil forming factors results in various soil types. Therefore, it is unsurprising that at least 18 WRB (World Reference Base for Soil Resources) soil groups are present in Cameroon. Unfortunately, available information on soil is either rare or outdated. Stakeholders, however, need state-of-the-art soil information for sustainable land use planning. Due to the country's large orientation on agricultural production, climate change is one of the biggest challenges to food security and economic stability. To support Cameroon in its efforts, the Federal Institute of Geosciences and Natural Resources (BGR) cooperates with the Ministry of Economy, Planning and Regional Development (MINEPAT) and the Agricultural Research Institute for Development (IRAD) within the framework of the project "Soil information for sustainable land use in Cameroon" (PRESS II). Together with already existing data, the project aims to build a solid foundation for policymakers to design land use planning sustainably. One irreplaceable first step is fieldwork. Within the project's pilot regions, North and Adamawa communes were selected for WRB 2022 soil classification surveys with a combination of classical soil pit description and sediment coring. The results of the first 31 described and classified soil profiles indicate that at least 11 Reference Soil Groups (RSG) are present within the communes. This emphasizes the large heterogeneity of northern Cameroonian soils and the need for continuing research to provide reliable soil information for planning processes.

Performance: open hands

Cristina Angueira

The Performance began in the 60s, spread internationally, "art that refuses to settle", unrepeatable, actions carried out by the performer or recorded, spontaneous or scripted, answering: if we performatize a meeting, an excursion, a class, a conference, a Soil communication? The objective is to generate a rupture for those who observe, to make the extraordinary appear, the difference that exists below the surface, we are unaware of its diversity, with amazement or not, in some spectators there is no strangeness, they already know its landscape. It is carried out in a rural school in Santiago del Estero, in the patio, with soil samples of four soil profiles from the area in the corners, in the center a large white wooden square. The performer/s with images makes a tour of the local geoforms and each student takes a soil sample, places it in a container, adds water to make mud, plunges their hands into that material, experiments and then rests their hands on the square leaving that mud attached. He walks around the square, stops, looks at his hands, and the others, washes and starts again. Finally, the square is raised showing all the participants the work of art made with the different soils of the area. The scenic event builds on a network of individual and collective possibilities, in a union between, with a dilated scenic power, because it continues in space, in walking the territory, to mentally and fully appropriate the vitality and diversity of the relationship Landscape Soil.

Challenges for soil protection in road construction from the perspective of European road and soil experts

Tim Geiges and Silvia Tobias

Road construction projects have severe negative impacts on soils through soil sealing and earthwork during the construction process. The implementation of soil protection measures is therefore of high relevance. As part of the international project "RoadSoil" funded by CEDR, we assessed the current problems in the implementation of soil protection measures in Europe with an online survey and developed potential solutions in three online workshops with international experts from road and environmental authorities, the private

sector such as planning offices as well as academia. Our results show that most experts, independent of their professional background, experienced negative impacts of road construction on soils. They further emphasised conflicts between waste legislation and the reuse of excavated surplus material as well as insufficient implementation of compensation measures. The experts stressed the need for communication and raising awareness of soil protection amongst stakeholders and the public. All workshop participants appreciated the opportunity to exchange experiences from different European countries and disciplines and wished that international knowledge exchange about soil protection in road construction should be further promoted. The results from the "RoadSoil" project have been synthesised in guidelines for soil protection in road construction. Our poster presents the project and selected results from the survey and the workshops.

Tailoring or tinkering: the theoretical potential for soil-specific crop nutrient adjustments

Joost van Heerwaarden

Supplying nutrients to support plant growth is one of the most important soil functions. Soils can differ considerably in availability of water and nutrients which suggests that supplementation of crop nutrients through mineral fertilisers could be adjusted to individual soil conditions to improve nutrient use efficiency and profitability. This idea is central to many studies and applications involving so-called Site-Specific Nutrient Management, which generally aim to convert empirical or predicted information on soil nutrient and water availability into targeted nutrient recommendations. Despite the considerable history of this idea and its continuing popularity in the realm of data driven and digital agriculture, its true benefits have never been evaluated in practice. In a recent paper, I provide an extensive ex-ante analysis of the potential short-term economic gain from fertilizer adjustments to differences in nutrients and water availability in maize in Sub Saharan Africa. Using a combination of nutrient response models and data from digital maps that capture spatial variation in water and nutrient availability, I calculate the theoretical optimum macro nutrient rates and associated costs and revenue for individual sites across the target area. Under the magnitude of soil fertility variation considered, very little benefit can be expected from matching nutrient levels to indigenous supply, particularly after considering uncertainties in the data. There seems to be greater potential for rate adjustments to water limitations, but improvements in modelling soil water availability may be needed to achieve improvements in this regard. I discuss the limitations and recommendations implied by these results.

Soil health for agricultural fields: a comparison of concepts

Ulrich Menke and Michael Marx

Within the framework of the soil directive with the aim of reaching healthy soils by 2050, the European Union will define criteria to be fulfilled by the different stakeholders that are using or influencing soils. However, defining “soil health” is not straight forward since a definition is very much dependent on the respective habitat properties. For example, the ecosystem services and/or the species composition expected from forest soils, grassland soils or agricultural soils are highly diverse and only partly overlapping, leading to different criteria for defining soil health. Further, the interplay of soil organisms (including microorganisms), plants and animals is strongly dependent on physical and climate parameters that are prevalent in each specific habitat and biogeographic/climatic area. Based on this knowledge, the definition of a healthy soil status must differ depending on the respective habitat/soil use. Especially for agriculturally managed soils, the definition cannot be the same as for e.g. forests mainly intended for nature conservation and recreation. Several concepts for defining healthy agricultural soils were developed and successively refined during the last decades. These concepts often include considerations about soil biodiversity as one of the possible criteria for defining soil health. Some concepts include the necessity to monitor the status of certain focal species in agricultural soils implying a focus on functional diversity when defining properties of a healthy soil. Others describe the biodiversity status of fields using diversity indices and try to define thresholds as minimum biodiversity

implying the opinion that the higher the biodiversity the better the health status. Our poster will discuss important concepts for defining healthy soils and will contribute with further thoughts and conceptual ideas to define healthy agricultural soils using structural and functional resilience as major criteria.

Effect of cover crops in soil carbon storage

Mafalda Pacheco Ferreira, Mário Duarte, Rosa Santos Coelho, Guerreiro Samuel, Ângela Prazeres and Maria Godinho

Assessing the potential of agriculture and effective soil management practices for carbon sequestration is a complex task. However, it is widely believed that including cover crops in the traditional crop rotation practices can have a positive impact on soil organic carbon storage, leading to climate change mitigation and adaptation. The present study, conducted under the HortiCover project: Improvement of monoculture agricultural systems using cover crops, aimed to assess the potential of cover crops for soil organic carbon storage in monoculture plantations in the Ribatejo region of Portugal. The study quantified above-ground biomass, below-ground biomass, and organic carbon stock in two monoculture plantations in Ribatejo during the 2021/22 agricultural year, where a cover crop was sown in the winter. The obtained results were compared with natural plots, which were used as a control. The carbon quantification was conducted following the GSOC MRV (FAO, 2020) and IPCC (2008) protocol. The study showed that the total soil organic carbon stock was significantly higher in plots where cover crops were used (41.4 t ha -1) than in natural practice plots (32.1 t ha -1). Additionally, the below-ground carbon stock (12.0 t ha -1) was higher than the above-ground biomass (1.83 t ha -1) in all the plots. Soil was found to have the highest carbon content, ranging between 48% and 64% of the total. These preliminary findings suggest that including cover crops in monoculture plantations can increase soil carbon inputs and improve soil carbon sequestration.

Decline in soil quality by niche construction by two ectomycorrhizal truffle species

Luis G. Garcia-Montero, Vicente J. Monleón, Inmaculada Valverde-Asenjo, Cristina Menta, Amaya Álvarez-Lafuente, Pilar Pita and Thomas W. Kuyper

Niche construction requires environmental modifications by organisms, which influence selection pressures leading to evolutionary responses in a population. Niche construction has been reported for animals and plants but hardly in fungi, although mutualistic symbioses of mycorrhizal fungi could be excellent examples. So far, there are no studies on soil chemical changes caused by niche construction of ectomycorrhizal fungi, such as T. aestivum and T. melanosporum (truffles), based on long-term observations in natural forests. In the 'Alto Tajo' Natural Park (Central Spain), 263 brûlés have been monitored for at least nine years in three oak forest types in a Mediterranean calcareous region. Brûlés are the sites where these Tuber species grow and inhibit non-host plants, soil organisms, and other mycorrhizal fungal species. The results showed that the development in the brûlé area significantly modified the soil properties and increased both Tuber species' fitness (sporocarp production), albeit in somewhat different ways. Compared to soils outside brûlés, T. aestivum brûlés increases soil pH and decreases total carbonate and total organic carbon (TOC), whereas T. melanosporum brûlés increases active carbonate, active/total carbonate ratio, and exchangeable Ca2+, and decreases total carbonate and TOC. Therefore, the results met the two Matthews criteria that allow us to recognize niche construction by T. aestivum and T. melanosporum. However, enhanced carbonate weathering by truffles decreased soil quality because of increased soil pH, which would reduce Fe availability, and hence, host tree productivity would be limited because of an increased likelihood of chlorosis. This would indicate that mutualistic niche construction does not benefit both partners equally. Moreover, experiments adding Ca salts increased root tips and leaves of the seedlings of host plants, opening new hypotheses on eco-evolutionary mechanisms of mutualism and new approaches to rhizoculture.

SOILGUARD transdisciplinary research: Network of Knowledge and the different approaches for engagement in soils

Ana G. Ramirez-Santos and Cristina Yacoub Lopez

The transdisciplinary SOILGUARD project aims to promote the sustainable use of soil biodiversity to protect its multifunctionality and enhance economic, social and environmental well-being. During the development of the four-year project a process of co-creation of knowledge, is carried out using a Strategic Plan (SP) as an operational guiding tool aiming to boost the main outputs and outcomes co-creating 1) a conceptual and analytical framework with the potential to become the global standard for future assessments of the state of soil biodiversity and its contribution to soil multifunctionality and human well-being; and 2) a predictive tool, the SOILGUARDIANS app. The theoretical basis underpinning the SP in the transdisciplinarity integrates: 1) Analysis of the typologies of knowledge used, 2) Proposed framework to identify the different types of stakeholder involvement, 3) knowledge sharing and integration within and outside the project through the creation of four specific action groups (AGs). All the 4 AGs encompass diverse key stakeholders (farmers, landowners, advisors, policy makers at different levels, civil society organizations and academia among others) related to the main objectives to be co-developed. Then the 4AG are: 1- Cross-biome Network of Sites, 2- Community of Practice, 3- Soil Biodiversity Conservation and Policy recommendations, and 4- Global Soil Assessment Initiatives. Currently (M22), an initial evaluation of the engagement actions carried out per AG is being developed, gaining insights regarding who to develop an engagement strategy in the field of soil biodiversity, as an initial step towards contributing to healthy soils in the society.

Water and yield deficit maps for the rainfed agriculture in santiago del estero, argentina

Daniel Prieto, Gabriel Angella, Cristina Angueira, Howard van Meer, Juana López, Gabriela Barraza and Gustavo Cruzate

In the semi-arid Chaco Americano of Argentina, there has been an expansion of the agricultural frontier since the end of the 20th century with high uncertainty given its negative annual agroclimatic balances and the scarce information on climatic and soil suitability. In order to quantify the risk of agricultural expansion and provide a scientific basis for the land use planning according to its suitability, the risk of water deficit and yield reduction due to water deficit of the predominant crops was studied. A five-step procedure was used to generate maps of water and yield deficit with different probability: i) generation of the Available Water Map (AWM) based on the AW of the three dominant soils of each mapping units estimated by Pedotransfer functions. ii) Definition of 27 "simulation" polygons by superimposing to the AWM, the spatial domain the agrometeorological stations with temperature data and at least 25 years of rainfall information. iii) Simulation of 25 growing seasons of six scenarios (4 crops 2 with 2 planting dates). iv) Determination of the empirical frequency of water and yield deficit from de simulation series. vi) Generation of isolines and continuous maps of water and yield deficits probabilities interpolating assigning values to the each “simulation” polygon. Although a first approximation, the maps probed to be useful for the main stakeholders in land use planning at a regional and local scale (planners and producers). The utility of the Available Soil Water Map also was highlighted.

Reducing the footprint of agriculture: the design of a Soil Footprint Calculator

Bettina Blanka Noszály, Anna Bazzi and Fabian Reichwein

As the increasing uncertainties in food security, extreme weather and soil depletion unfolds, there is a need to change farmland management practices for the better. One of the biggest problems, however, is evaluating different management practices on the scale, due to the high heterogeneity in local landscapes, soil types,

climate, and other parameters. In our research, a calculation methodology was developed to assess different soil management practices and their impact – 'footprint' – on soil health. The methodology relies on a mathematical concept of penalty functions, drawing upon scientific information available describing the dynamics of five chosen soil health indicators: soil pH change rate, organic carbon accumulation rate, artificial input rate (NPK), bulk density change rate and biodiversity change rate. The calculation methodology allows accounting for the differences in the dynamics of each parameter and its optimums. Using the developed framework, we arrive at unitless, relative 'footprint' numbers for each management practice on a certain land, that allows to compare the impact of different management practices on that area. The results of the calculations can be used for decision support by policymakers, government bodies; evaluation and monitoring of (agricultural) activities on different regions or help companies make more informed decisions on their land management plans. In our pilot research done using data from academic papers, we found that the footprint of monocropping (maize) in the Netherlands was the highest, followed by dairy farming, and lastly, agroforestry, which had the smallest footprint of the aforementioned three practices.

Enhancing Resilience of Sandy Soil Landscapes in the Netherlands through Optimized Land Parcel Sizes and Management Practices

Emad Farzanegan

The vulnerability of sandy soil landscapes in the south and east of the Netherlands is increasing due to factors such as intensive use, economic development, and water management. To ensure the productivity and sustainability of these regions in the face of climatic changes, it is crucial to assess their ecological and economic resilience, i.e., their ability to withstand stressors without changing their state. This study aims to investigate the potential effects of optimized land parcel sizes with variability in use and management practices on the future state of the landscape, as opposed to the current situation of a landscape dominated by large-scale homogeneous cropland and pastures with high economic functionality.The study will leverage existing data on biophysical properties and both land management and governance census of the study area to develop a dynamic model as a tool to assess ecosystem functionality that is responsive to environmental stressors, such as changes in precipitation patterns, as well as changes in development and management trajectories that can impact landscape state. Future landscape states will be predicted under different scenarios of parcellation and land use change, accounting for projected biophysical perturbations. The resilience of the scenarios will be comprehensively assessed, providing insights into the best possible future approaches to land management and parcellation for governance and society.

Impact of mechanised sugarcane harvesting on the structural quality and carbon stock in dystrophic red Latosol in Minas Gerais, Brazil

Mayara G. dos S. Gomes, Diego A. A. Esteban, Jeison A. Sanchez, Pedro L. S. Teixeira and Zigomar M. Souza

Sugarcane is a semi-perennial crop that requires the intensive use of agricultural machinery, but this has been a major challenge, as it can affect the structural quality of the soil. The research aimed to evaluate the stage of the mechanized sugarcane harvesting with different transshipment configurations and its influence on the structural quality and quantify the carbon stock in the soil. The research was carried out in a Dystrophic Red Latosol at "Usina Cerradão", Frutal, Minas Gerais, Southeast region of Brazil. The study presents a randomized block design with three treatments and three replications: 2CT/10 - tractor set with 134 kW+ two transshipments with a capacity of 10 Mg each one; 1CT/30 - tractor set 172 kW+ transhipment with a mass of 30 Mg; 1CC/21 - truck + box set with a capacity of 21 Mg. After the mechanized harvesting witch ocorred in the 2020/2021 and 2021/2022 harvests, the soil samples were

collected in the layers of 0.00-0.10 and 0.20-0.30 m in the planting row (PR), and inter-row (IR), for aggregate stability analysis by wet process, and the organic carbon contents by the dry combustion method. Regarding the results, the 2T/10 and 1T/30 treatments showed higher aggregate stability index (ASI) and soil carbon (C) stock for the two evaluated years, while 1C/20 treatment reduced the C values in the PR and IR, despite it has presented a good preservation of soil aggregates (70-86%) in the evaluated layers.

Wednesday

Plenary

Keynote lecture: Measuring and modeling soil carbon and greenhouse gas emissions

Debjani Sihi

Soil is an open dynamic system. Processes of heat, water and substance transfer between solid, liquid, gaseous and life phases drive soil formation and functioning. Soil interactions with plants, biota, groundwater and atmosphere contribute to carbon, nutrient, and energy fluxes. Understanding soil processes is important to support decision-making for rational soil and land management. Advanced measurement techniques and process-based modeling approaches allow the quantification of water, gas and heat transport, carbon turnover, nutrient cycles, and other soil processes. Linking soil processes to land use change and climate change scenarios enables projecting future dynamics in soil health and functionality.

MiNiMAX – Making maximum use of nitrogen mineralisation from soil organic matter

Annemie Elsen, Mia Tits, Gert Van de Ven, Luc De Reycke, Lore Lauwers, Ilse Eeckhout, Jean-Pierre Pellissier, Ellen Truyers and Jeroen De Waele

A good estimate of the amount of nitrogen that the soil provides through mineralisation of organic matter is an important requirement for determining the optimal nitrogen fertilisation and minimising nitrogen leaching. In practice, the actual nitrogen mineralisation can deviate significantly from the expected amounts, because mineralisation is influenced by various factors, which also interact with each other: physical and chemical soil properties, cultivation measures, soil temperature, moisture content, etc. Recently, more attention has been paid to the effects of tillage on mineralisation. Soil tillage breaks up macro-aggregates and exposes the organic matter to air, water and microorganisms, resulting in increased degradation. In this study, the impact of tillage on nitrogen mineralisation is investigated for 3 crops, highly sensitive to nitrate leaching (potatoes, maize, leek). During each year of the 3-year study period, 3 annual field trials are set up, wherein the most common soil tillage practices are compared. During the growing season, nitrogen mineralisation is monitored based on measurements of the nitrogen and moisture content in the soil profile and measurements of the nitrogen uptake by the crops. Before and after specific soil tillage treatments, in situ CO2 measurements are carried out in order to calculate the mineralisation of organic matter and, based on the C:N ratio of the soil organic matter, the N mineralisation. In this way, a solid dataset is generated that will allow us to estimate the impact on nitrogen mineralisation of the most common soil tillage practices, on differing soil types and under different weather conditions.

Can combinations of organic and inorganic amendments effectively reduce potato tuber-Cd?

Yuwei Qin, Yoann Viala, Bert-Jan Groenenberg, Rob Comans and Sheila Alves

Potato tubers contribute to a significant portion of the human dietary cadmium (Cd) intake. Elevated Cd levels in agricultural soils due to the underlying geology have been identified in many regions in Europe, potentially leading to exceedances of Cd levels in foodstuffs, especially potatoes. Despite showing promising results, common soil amendments such as lime and Zn often fail to present consistent results in reducing tuber Cd content among different soil types. Therefore, a greenhouse pot experiment was set up aiming to

identify soil chemical processes that control the bioavailability of Cd in soils and the uptake of Cd by potato plants under different treatments, with an emphasis on monitoring changes in soil parameters, Cd pools and soil- and dissolved organic matter (SOM and DOM) and the humic and hydrophilic fractions therein over time. Paired pots of planted and unplanted soils were given combinations of treatments with various pH levels (lime or nitric acid addition), Zn - and spent mushroom compost doses. During a full growing season, soil samples were taken every month and selectively analyzed for soil characteristics including pH, CEC and iron and aluminum content. Cd in various extracts which operationally represent different Cd pools (e.g. 0.1 M CaCl2, 0.01 M Ca(NO3)2, 0.43 M HNO3) was also analyzed. Soil solution samples were collected every month in situ using Rhizon samplers and selectively analyzed for pH, DOC and Cd. Humic and hydrophilic fractions in SOM and DOM were measured in selected samples. Cd speciation in soil and soil solution were modeled using a mechanistic multi-surface model. The results of this study will provide insights into how applying (combinations of) organic and/or inorganic amendments at different rates will change the distribution and speciation of Cd in soils over time. The mechanisms and effectiveness of the treatments will be revealed by relating changes in soil chemical parameters with tuber-Cd concentrations at harvest.

Traditional versus flux-based plant available water: a stochastic interpretation applied to Brazilian soils

Quirijn de Jong van Lier and Marina Luciana Abreu de Melo

Total available water (TAW) is used in reference to the fraction of soil water available to plants. The upper limit of TAW, field capacity (FC), corresponds to a low drainage rate, discounting the portion of water that quickly drains to deeper layers at water contents higher than FC. The lower limit of TAW, the wilting point (WP), corresponds to a condition in which the rate of water extraction by plant roots in the dry soil is too low for plant survival. Therefore, TAW = FC – WP. At an intermediate condition (limiting point, LP), transpiration turns from its potential sink-limited value into a lower source-limited rate defining readily available water: RAW = FC LP. Traditionally, FC and WP are assumed to correspond to specific matric potentials, respectively 1 and 150 m. LP is calculated proportional to FC and WP, depending on crop type and atmospheric boundary. Recently, a flux-based method (FBM) to quantify FC, LP, and WP was proposed, based on dynamic properties described by water retention and conductivity parameters together with rooting characteristics and atmospheric boundary conditions. We determined these soil hydraulic properties for eight Brazilian soils from several textural classes and processed them in a stochastic platform to yield TAW and RAW together with their respective uncertainties, using the traditional and the FBM method. Results will be discussed and the advantages of the FBM over the traditional method will be highlighted.

Soil colonization of fungal amendments improves soil aggregation and soil physical properties different contrasting moisture conditions

Violeta Angulo, Robert Jan Bleichrodt, Jan Dijksterhuis, Amandine Erktan, Mariet Hefting, Bart Kraak and George Kowalchuk

Soil structure and aggregation status are fundamental for soil functioning, especially under drought conditions. Saprobic soil fungi can often withstand low moisture environments and are known to influence soil aggregate formation and stability. We examined the ability of fungal amendments to improve soil aggregation and hydrological properties across 2 moisture regimes. A selection of 29 fungal isolates recovered from drought-treated soils, varying in colony density and growth rate, was used for single-strain inoculation into sterilized soil microcosms under either low or high moisture conditions (-0.96 and -0.03 MPa, respectively). After 8 weeks, soil aggregate formation and stability were assessed, as were soil properties, including soil water content, water hydrophobicity, sorptivity, total fungal biomass, and water potential. Fungal inoculation altered soil

hydrological properties and improved soil aggregation in a fungal strain and moisture level-dependent manner. Fungal biomass was correlated with enhanced soil aggregate formation and stabilization by connecting soil particles via hyphae and by modifying soil aggregate sorptivity. Water potential improved only when the initial level of moisture was not too low for fungal colonization. Our results show the potential of using fungal inoculation to improve agricultural soil's structure under drought, thereby potentially opening new possibilities in sustainable soil management.

Parallel Session

S1: Soil contamination

Microplastics in a chronosequence of biosolid-amended agricultural soil in Southern Ontario, Canada

Harriet Walker and Julian Aherne

Microplastics, small plastic particles less than 5 mm in size, are emerging environmental contaminants of concern due to their ubiquity in the environment. The contamination of agricultural soil with microplastics has raised public concern due to its proximity to food systems and potential impact on human health. Municipally sourced biosolids are commonly used as cost-effective fertilizers, diverting material from landfills, and contributing to the circular economy. However, biosolids contain high concentrations of microplastics and are a source of microplastic contamination to the environment. Despite this, there is a lack of environmentally relevant field studies. Our research investigates whether microplastics are accumulating in fine textured agricultural soil amended with biosolids, and how this microplastic soil pool changes over time. In 2022, soil samples were collected from seven agricultural fields in Southern Ontario, Canada, representing a chronological sequence of zero to nine years since last biosolid application. Soils were analyzed for microplastic content, particle size, organic matter and bulk density. Further, Samples of biosolids applied in 2022 were analyzed to estimate microplastic loading to the fields. Microplastic particles were extracted from samples by density separation, characterized visually by stereomicroscope and polymers identified using Fourier transform infrared spectroscopy. Here we report on the characteristics, abundance, and polymer type of microplastic particles in the study area to assess their transport and fate in biosolid-amended soils. Quantifying their fate in an agricultural context will help advance our understanding of the extent of microplastic contamination in agricultural soil.

The impact of hormones on below ground interactions

Esmer Jongedijk, Filippo Rey, Gregg Roelofs, Guixin Li, Wim van der Putten and Stefan Geisen

A key requirement for a circular bio-economy is that rest products, e.g. faeces, urine, sewage sludge, are returned to soil for replenishing nutrients for crops. However, a major concern is that these by-products contain hormones, both natural and from medicinal treatments and reproductive manipulations (e.g. estradiol), which might affect soil biodiversity including the most abundant animals: nematodes. Mammalian hormones from surface water are known to negatively impact above-ground invertebrates. We here aimed to study impact of hormones from by-product-fertilizers on the below-ground soil ecosystem, using nematodes as a model. For this, a system approach was chosen, analyzing both fate and effects of hormones in soils. As a starting point our results show that bacterivorous nematode abundance is directly affected by hormones in-vitro, confirming nematode utility as ecotoxicological indicators. Subsequently, in an end-point context in

the food system, in hormone contaminated soil with growing crops, results show that bacterivorous nematode abundance was halved in a three week time span by application of hormones, indicating serious impact on the soil food web. We quantified hormones in soil and crops, which appeared largely metabolized (80%). We found that crops take up and translocate hormones, including higher estrogenic active metabolites, to their edible parts, indicating possible food safety risks. We show that hormones impact soil biodiversity and even end up in plants, which could lead to a circle ending in humans. This calls for a close watch on the ecological impact in soil of pharmaceutically active substances, and hazards originating from circular agricultural practices.

Uncertainty analysis of geochemical multi-surface models for solid-solution partitioning and speciation of heavy metals in soils

Wietse Wiersma, Elise Van Eynde, Rob N.J. Comans and Jan E. Groenenberg

Geochemical models are powerful tools to improve our understanding of the behavior of heavy metals in soils. Especially potent are multi-surface models that predict the binding to various soil reactive surfaces. Nevertheless, to date the uncertainty of such models has not been comprehensively evaluated, thus limiting their applicability. We quantified the uncertainty of the combined NICA-Donnan model for organic matter and the CD-MUSIC model for iron oxides in modelled solid-solution partitioning and speciation of cadmium, zinc and copper. We followed a statistical approach where we randomly sampled model parameters and input values from their normal distributions. A random sample of model parameters (N = 1000) was applied to 25 contrasting samples from background and contaminated soils around the world. A local 'best-case' uncertainty analysis was done by including measured humic and fulvic organic matter fractions, and the reactive surface area of ferrihydrite. A global 'business-as-usual' scenario was included by relying on common assumptions about the reactive surfaces. Model accuracy was evaluated by comparing predicted and measured (0.01 M CaCl2) dissolved metal. The analyses are currently carried out. Relating the resulting uncertainty to soil properties allows for evaluation of the suitability of multi-surface models for certain soil types. Moreover, the analysis will yield practical information regarding how to effectively invest resources to improve model accuracy, i.e. which parameters to optimize or which reactive surfaces to quantify. Overall, our study will improve the applicability of geochemical models to understand the behavior of heavy metals in soils.

Urban Soils and Trace Metal(loid) Contamination by Atmospheric Deposition in Community Vegetable Gardens

Salvatore Engel-Di Mauro

Community gardening has recently spread in cities where it had been marginalised. Notwithstanding ecological and social benefits, such food production faces trace element contamination, among other hazards. Research projects carried out since 2013 in New York State (US) and in Roma (Italy) showed discrepancies between soil and vegetable trace metal(loid) content, leading to studying the role of atmospheric deposition relative to other contaminant sources. Existing research assesses airborne sources indirectly or otherwise lacks controls for other sources. Atmospheric deposition processes and methodologies for its study are briefly discussed, along with implications for urban food production. A research design encompassing multiple sources has been developed to overcome current limits identified in published studies. It combines atmospheric bulk deposition sampling with sampling soils, vegetable, and gardening inputs in field experiment conditions using garden beds under three treatments in three community gardens in Kingston (New York State, USA). The methodology will be discussed along with any results available to date. Legacy contamination in and contaminant sequestration potential of urban soils, especially when appropriate safety measures are implemented, may be less important than atmospheric sources, which remain understudied and poorly understood.

S2: Soil-plant interactions

Temperature dependence of the breakdown of soil aggregate with transport of released particles in soil

Gang Cao

Current conclusions regarding the effect of temperature on the stability of soil aggregates are not consistent because of the lack of quantitative descriptions, either not all variables can be eliminated in the experimental methods. Column experiments were developed to evaluate the stability of soil aggregates at 4, 25, and 45°C. The results indicated that soil particles were released more at 4°C, followed by 25°C and 45°C. The maximum concentration of released particles reached 1232.21 mg L^{-1} at 4°C, and the value was only 55% of the former at 45°C. The average particle size of the released particles was not affected by temperature nor the soil internal forces. The experimental results agreed with the theoretical results. Theoretical calculations revealed that the thickness of the electric double layer that affected key parameters of soil electrochemical properties decreased with increasing temperature, which in turn affected the distribution of soil internal forces and controlled the stability of aggregates. The fundamental reason for the higher stability of soil aggregates at higher temperature was the increase in van der Waals attractive pressures with temperature. These experimental results help to better understand the impact of extreme temperature changes on soil and agriculture under the background of global warming.

Sensitivity analysis and calibration of an upscaled microscopic root water uptake model by inverse modeling

Marina L. A. de Melo, Quirijn de Jong van Lier, Marius Heinen and Jos van Dam

The assessment of limitations to water transfer through the soil-plant-atmosphere continuum allows a better prediction of evapotranspiration fluxes. Microscopic models of root water uptake (RWU) allow the process-based simulation of the involved processes. The objective was to perform a sensitivity analysis and calibration by inverse modeling (IM) of the SWAP model with a process-based microscopic RWU module (MFlux model) for a soybean crop in southeast Brazil. The sensitivity analysis was performed for five Brazilian soils and 32 years of weather data recorded in the municipality of Piracicaba, São Paulo, Brazil (22°43' S, 47°38' W, 524 m a.s.l.). The SWAP model was calibrated using experimental data (actual evapotranspiration and soil water content at two depths) from two seasons (2016/17 and 2017/18) of irrigated soybean in Piracicaba. Results show that the sensitivity of drought stress is high for low values of root length density and radial hydraulic conductivity of root tissue, and low for other parameters of the MFlux model in all considered value ranges. Seasonal and interannual meteorological conditions are more determinant to reductions in biomass production due to drought stress than root hydraulic properties and root geometry. A two-step calibration procedure of SWAP that combines manual calibration of the crop growth module and automatic calibration of the RWU and root distribution modules by IM leads to acceptable model performance in the simulation of evapotranspiration fluxes and soil water dynamics for soybean in southeast Brazil.

Validating the RothC model with long-term experiments in dryland areas of China

Zhibiao Wei, Xiaoxi Xia and Ellis Hoffland

The soil carbon cycle is complex and affected by soil properties, field management, and climate conditions. To simulate this cycle, the Rothamsted Carbon Model (RothC) has been widely used in Europe and around the world, but it is seldomly validated before using. This study validated the RothC model with seven long-term experiments in dryland areas of China. These experiments include 27 fertilizer treatments with

various organic fertilizers, such as crop residues, animal manure, and commercial organic fertilizers. Overall, the model performed well in predicting soil organic carbon (SOC) changes, except for sites with monthly mean air temperature lower than -18.27 °C, which is the lower bound used to calculate the rate modifying factor of temperature in this model. For specific treatments, only 2 out of the 27 were accurately modeled, while the SOC in 24 of the treatments was underestimated. The potential reason is that C inputs from crop rhizodeposition were not considered in our modelling. In addition, the input data for crop root-shoot ratio is highly uncertain according to our literature review, while this parameter saliently affected the model performance based on our sensitive analysis. In summary, the RothC model must be validated and calibrated before used to predict SOC in a specific site of China, although it may perform well in large-scale modelling. An accurate input data for root shoot ratio is crucial to ensure the model accuracy.

Response of root properties and soil enzyme activities to biodegradable microplastic in contaminated soil

Yao Yu, Yanhua Chen, Yan Wang, Sha Xue, Mengjuan Liu, Darrell W.S. Tang, Xiaomei Yang and Violette Geissen

To reduce plastic pollution in soil, biodegradable plastic film is used in agricultural production as an alternative product of conventional plastic. However, there is little known about its residues on plant growth and soil properties. In this study, we investigated the effects of Poly (butylene adipate-co-terephthalate) microplastics (PBAT-MPs) on root properties and soil enzyme activities in soil with soybean (Glycine max (Linn.) Merr.) and maize (Zea mays L.), with the levels of 0% (CK), 0.1%, 0.2%, 0.5% and 1% (w/w). The results showed significant inhibitions of PBAT-MPs on the root properties, including total root length, root surface area, root volume and root biomass of soybean and maize. And the negative effects of PBAT-MPs on the root growth of maize was stronger than that on the root growth of soybean. Furthermore, C-enzyme activities (β-xylosidase, cellobiohydrolase, β-glucosidase) significantly decreased in non-rhizosphere soil with soybean at the harvesting stage and those in rhizosphere and non-rhizosphere soil with maize significantly decreased at the tasseling and harvesting stage. N-enzyme activities (leucine-aminopeptidase, N-acetyl-β-glucosaminidase, alanine aminotransferase) significantly increased in rhizosphere soil with soybean and non-rhizosphere soil with maize at the harvesting stage. In conclusion, PBAT-MPs accumulation could affect root growth negatively and alter soil enzyme activities in soil with soybean and maize differently, which related to soil carbon and nitrogen cycling. To identify the mechanism of effects of biodegradable microplastics on different plant-soil systems, further study should focus on the effects of biodegradable microplastics on soil microbial community.

S3: Nutrients in soil

Modelling nutrient cycle in European agricultural soils including agricultural management scenarios

Anna Muntwyler, Emanuele Lugato, Panos Panagos and Stephan Pfister

Nitrogen (N) and phosphorus (P) are essential nutrients for all crops, yet they negatively affect the environment, public health, and the economy in excess. This context calls for action to assess nutrient management in agricultural soils and find ways to increase nutrient use efficiency. Consequently, numerous agricultural and environmental policies address the nutrient management practices on farms, such as the amount of fertilizers used or switching to organic sources when promoting organic agriculture. To come up with effective solutions, process-based models can help to depict and investigate the effects of land management scenarios that impact the biogeochemistry of the soils. The biogeochemical model DayCent has a recently calibrated and tested P submodel using European long-term experiments on top of the interconnected N and C submodels. We

exemplify the possibility of the model to capture the current dynamic European agricultural nutrient cycles on a high spatial resolution. Additionally, the model is used to project the influence of agricultural management scenarios from 2019 until 2050 compared with a baseline of current agricultural practices. This includes scenarios such as decreasing the nutrient inputs, introducing cover crops, or switching to organic agriculture. Finally, this work showcases a promising model framework for assessing land management policy, which facilitates the projection of the local impacts of policy interventions, making a crucial step toward sustainable agriculture.

Liebig or Mitscherlich?

Renske Hijbeek, Hans van Grinsven, Waldo de Boer, Sofia Delin, Johannes Lund Jensen, Leif Knudsen, Luis Lassaletta, Jørgen Eivind Olesen, Roger Sylvester-Bradley, Miguel Quemada, Jan Rinze van der Schoot, Martin van Ittersum and Hein ten Berge

More efficient use of nutrients, especially nitrogen, is essential for more sustainable agricultural systems. Currently, around half of the nitrogen applied to global cropland is not recovered by the first crop. Besides adoption of improved management practices, reducing the impacts of nitrogen application also requires more fundamental insights into yield response curves to nitrogen, to inform sustainable application rates. Based on data from 25 long term experiments, Grinsven et al. (2022) recently showed that total nitrogen required for a certain fraction of the locally attainable yield, is independent of the size of that attainable yield. This was postulated by Mitscherlich in 1924, but not supported by empirical data, and in contrast with Liebig and others who suggested nitrogen requirements for a given target yield change with the attainable yield. Here, we assessed if these findings hold when tested on a larger dataset of short-term experiments. We compiled data on 532 yield response curves across five European countries (Denmark, Spain, the Netherlands, United Kingdom and Sweden). We show that yield responses follow a Mitscherlich curve with an R2 of 0.88 for spring barley and R2 of 0.90 for winter wheat. These findings highlight the strong dependency of nitrogen requirements on attainable yields, determined by biophysical factors (such as soil and climates) and management (such as irrigation). Our findings give new fundamental insights into yield responses to available nitrogen. This may support differentiation of nitrogen fertilizer recommendations and environmental legislations across agro-ecological zones.

The Phosphorus Saturation Degree as a Universal Agronomic and Environmental Soil P Test

Maarten van Doorn, Debby van Rotterdam, Gerard Ros, Gerwin F. Koopmans, Erik Smolders and Wim de Vries

Phosphorus (P) is an essential nutrient for crop production and is applied to agricultural soil to overcome crop P deficiency, by bringing or keeping the soil at a target soil P level in view of crop yield. However, soil P accumulation up to a target level enhances P losses to the water system threatening water quality objectives. In addition, global food production is dependent on the use of finite P resources, emphasizing the need to use P more sustainably. In this paper, we call for a revision of the current P fertilizer recommendations balancing crop yield, water quality and the use of finite P resources. We show that soil P tests used in routine agronomic soil testing do not provide the required insights for this revision. the acid ammonium oxalate extraction method is identified as a high-potential agri-environmental soil test as it provides a measure for the total pool of reversibly sorbed P that can act as reserve for plant-available P while it also allows for quantifying the maximum soil P sorption capacity from the simultaneous measurement of amorphous iron- and aluminium(hydr)oxides. From these results, the Phosphorus Saturation Degree can be determined. We show that those mechanistic insights are pivotal for the combined assessment of crop response, the risk of P losses to the water system and the amount of P required to reach a target soil P level by combining a literature review with statistical analysis of relationships between the PSD, agronomic soil P tests and crop yields.

Mitigating nitrogen losses from manured agricultural soils: the impact of manure plasma activation

Sebastian Kuśmierz, Chantal M.J. Hendriks, Rene P.J.J. Rietra Rietra, Jan Peter Lesschen and Mart B.H. Ros

Application of manure to agricultural soils can improve soil quality and productivity by maintaining its nutrient status and organic matter (OM) content. Resulting nitrogen (N) emissions in the form of ammonia (NH3) and the greenhouse gas nitrous oxide (N2O) may however lead to substantial environmental pressure. Manure plasma activation has been advertised as an innovative technique that lowers nitrogen losses during and after soil application, although the scientific documentation on its effects is still limited. Here, we conducted a mesocosm study to quantify gaseous losses of NH3 and N2O from plasma activated manure (PAM) and non-treated raw manure (RM) applied to soil. In general, plasma activation caused significant changes in manure characteristics (i.e. OM degradation, pH, NO3- concentration) affecting gaseous N emissions. At a dose of 170 kg N/ha, PAM showed substantial reduction of NH3 volatilization compared to RM, whereas N2O emissions increased significantly. Manure plasma activation resulted in a decrease of total atmospheric N losses. Still, the observed increase in N2O flux raises the question of the environmental impact of PAM application. In line with the elevated NO3- concentrations, N2O fluxes from PAM started shortly after application, whereas highest fluxes were observed for RM after 7 days only. Altogether, the results show an important tradeoff between NH3 and N2O emissions from these manure products and indicate that PAM may be better used as topdress fertilizer instead of a replacement for RM to maximize plant NO3- uptake and minimize gaseous N losses.

S4: Soil carbon

Methane and nitrous oxide emissions from different vegetation communities in three tidal marshes located along the Elbe estuary's salinity gradient.

Fay Lexmond, David Holl and Lars Kutzbach

Tidal marshes are unique ecosystems located at the interface of land and sea. Gradients in salinity, tidal floods and land surface elevation create high spatiotemporal variation in (a)biotic conditions. As a result, a wide range of greenhouse gas (GHG) flux emissions can be expected from these ecosystems. In light of the climate change mitigating potentials of coastal wetlands, it is crucial to improve our understanding of the cycling of major GHGs CH4 and N2O. In this study, CH4 and N2O flux emission magnitudes, their temporal variability as well as dynamics of associated key-environmental conditions are compared between pioneer zone vegetation communities of a salt, brackish and freshwater marsh in the Elbe estuary. Data collection was done using a manual closed chamber method in combination with a portable infrared gas analyzer and a mobile soil-sensors field kit. Preliminary results show average emissions of 0.01 (± 0.05), 0.16 (± 0.37) and 16.1 (±32.1) mg CH4 m-2 h-1 for the respectively salt, brackish and fresh water marshes in the months April till September of 2022. At the conference, this data and data on N2O will be presented, as well as land-atmosphere fluxes of both CH4 and N2O from four vegetation zones (pioneer zone, low-marsh, rewilded high marsh and managed high marsh) within the salt marsh study site. These first results will be discussed according to differences in soil temperature, moisture, electrical conductivity and interpretations from soil classes and morphological properties reported from each study site.

Integrating biological and chemical soil processes towards predicting the climate-carbon feedback at the European scale

Karen M Moran Rivera, Mathilde Hagens, Rob Comans, Rachel Creamer and Gabriel Moinet

Soils represent the largest terrestrial organic carbon stock , storing nearly two times as much carbon (C) as the atmosphere in the top one meter. Under the influence of climate warming, soil organic matter (SOM) decomposition may be stimulated, accelerating the release of carbon dioxide to the atmosphere. Numerous studies have suggested that this will lead to a positive feedback to climate change, as higher temperatures are expected to accelerate C losses through SOM decomposition more than photosynthetic C inputs. Yet, the temperature response of SOM decomposition is still widely debated. Here, we test the hypothesis that separating SOM into particulate organic matter (POM) and mineral associated organic matter (MAOM) can be used to explain the temperature response of SOM decomposition across Europe. We used a European-wide database to identify and collect a large range of samples with varying ratios of POM and MAOM. A total of 132 soil samples were incubated for approximately four hours in a temperature gradient block consisting of 22 discrete temperatures ranging from 4 to 60°C, after which soil respiration rates were measured. We developed and tested an equation based on a combination of Arrhenius and macromolecular rate theories to account for the divergent responses of POM and MAOM to temperature. Preliminary results provide insights on the contributions of POM and MAOM to defining the temperature response of SOM decomposition, and lay the ground for an integration of biological and chemical processes in models predicting the soil carbon-climate feedback.

The effect of landscape position and soil texture on decomposition of added exogenous organic matter via moisture control during a wet summer

Astrid Francoys, Haichao Li, Orly Mendoza, Kevin Dewitte, Samuel Bodé, Pascal Boeckx, Wim Cornelis and Steven Sleutel

Incorporating exogenous organic matter (EOM) in farmland is a potential management practice for preservation of soil organic carbon, and thus it is crucial to have a thorough understanding of various factors controlling this process. Although numerous field studies regarding EOM decomposition are yet conducted, the impact of spatial variability of environmental conditions resulting from landscape position are poorly understood. In this study, a field experiment was set-up with paired locations at contrasting position across gently sloping croplands of three different textures, i.e. loamy sand, (sandy) loam and silt loam soils. Landscape induced differences in soil moisture were assessed and linked to the decomposition of added EOM, with other soil and management factors kept constant. For this, mesocosms with 13C enriched ryegrass were incorporated for ten weeks and afterwards, soil was separated into > 500 µm, < 500 and > 53 µm and < 53 µm fractions. During the experimental period, high amounts of rainfall occurred and lower locations were wetter than higher locations over all textures. Although moisture conditions appeared to be above optimal for lower locations, landscape position did not significantly impact total ryegrass decomposition between contrasting positions for any of the three soil textures. However, it did affect decomposition of the largest size fraction of ryegrass particles (> 500 µm) with more EOM-C remaining in case of the lower landscape locations. We conclude that within-field spatial variability of EOM decomposition was overall limited in the wet summer observation period. However, with increasing summer droughts across Europe it may be expected that spatial variability in soil moisture across the landscape will bear a greater control on OM cycling, pending further experimental proof.

Unexpected high increase of greenhouse gas emissions impact with increasing soil carbon saturation degree in rice paddy

So-Yeong Park, Hyeon Ji Song and Pil Joo Kim

Periodical organic amendment application has been strongly recommended to improve soil quality and mitigate global warming in able lands. However, each soil has its own soil C protective capacity which is generally decided by silt and clay content. It is used to decide the soil C saturation and estimate the soil's capacity to accept additional organic matter into stable form (i.e., mineral-associated organic C). Therefore, amended organic matter can be stabilized into stable under a low soil C saturation degree. However, under a high soil C saturation state, this amendment can increase labile organic C fraction and then increase greenhouse gas (GHG) emission impact, via high methane (CH4) emission in rice paddies. To evaluate the effect of soil C saturation degree on global warming potential (GWP), the same level (4.28 Mg ha-1) of cover crop biomass was applied in different C saturation degrees of soil, and net GWP which was integrated by CH4 and N2O emissions and soil organic carbon (SOC) stock change with CO2 equivalent was characterized during rice cultivation. CH4 emissions were exponentially increased with increasing soil C saturation, but N2O flux was not clearly influenced. Soil C stock increase which was estimated by analyzing net ecosystem carbon budget (NECB) was deceased with increasing soil C saturation degree, mainly due to highly increased mineralized C loss (CO2-C+CH4-C), but the net primary production (NPP) of rice as a C input source was not different among soils. As a result, organic amendment application very highly increased the net GWP under higher soil C saturation. In conclusion, no-stabilized organic amendment like green manure should be carefully managed in highly C-saturated soils. In contrast, its addition can make severe greenhouse gas emission impact in rice paddies.

Poster

Plastic mulch and pesticides residues effects on the lettuce growth

Nicolas Beriot, Raul Zornoza, Esperanza Huerta Lwanga and Violette Geissen

Plastic mulch and pesticide residues are ubiquitous contaminants in agricultural soils. In the field, pesticide residues remain in the soil for months and can accumulate over time. However, most studies investigating the effects of these contaminants use pristine chemicals and test them in lab conditions. We tested 3 plastic mulches and 3 pesticides commonly used by farmers. Low-density polyethylene (LDPE), Pro-oxidant Additive Containing plastic (PAC) and biodegradable plastic (BIO) mulches were laid in a field for 4 months, shredded into micro- and macro-sized plastic pieces and then added to a mesocosm soil experiment along with the pesticides. Plastics and pesticides were left in the mesocosm to incubate for a year in field conditions before lettuce seedlings, Lactuca sativa, were planted. After a 14 week growing period, we measured the basal diameter, number of leaves, leaf area, fresh shoot biomass, dry shoot biomass and shoot water content. We observed decreased leaf area, fresh shoot biomass and dry shoot biomass in plants growing in soil where BIO plastic was present as compared to the control treatments. These results follow previous studies and call for a more detailed testing procedure before BIO mulches are approved for agricultural use and made available on the market.

Impacts of Antibiotics in Manure on Soil Nitrogen Cycling

Zhongchen Yang, Jan Willem van Groenigen, Bjorn J.A. Berendsen, Milou M.G. van de Schans and Gerlinde B. De Deyn

Circular agriculture aims to close elemental cycles, which increases reliance on animal manure to provide nutrients. However, veterinary antibiotics are widely used in the livestock industry, and antibiotics may enter soil through manure application. Antibiotic effects on soil microbial functions related to nutrient cycling and climate regulation are still poorly understood. We hypothesized that antibiotics in manure affect soil nitrogen (N) cycling processes, such as nitrification, nitrous oxide (N2O) emissions, and plant N uptake. We tested these hypotheses with incubation experiments including different drug and soil types, and a greenhouse experiment with grass and clover. In the incubation experiments, we quantified soil N2O fluxes and mineral N pools over time after applying manure with and without antibiotics. In the greenhouse experiment, we harvested and analyzed the aboveground and belowground biomass of grass and clover after eight weeks of manure (with and without antibiotics) application. In the incubation experiments, antibiotic sulfadiazine significantly reduced cumulative N2O emissions compared to manure without antibiotics. In addition, sulfadiazine in manure substantially lowered the soil nitrification rate compared to antibiotic-free manure. In the greenhouse experiment, the belowground biomass of clover was significantly decreased by manure with sulfadiazine or oxytetracycline. Our studies suggest that antibiotics in manure alter soil N cycling by attenuating N transformations and impairing plant root growth. Therefore, antibiotic residues in livestock manure should be removed before fertilization to avoid its perturbation on soil nutrient cycling.

How does microplastic pollution affect plant-soil system under different soil moisture contents?

Alice Wang, Esperanza Huerta Lwanga, Giulia Bongiorno and Paolina Garbeva

Human activities have brought about Microplastic (MP) pollution and climate change into the environment, posing potential threat to plant-soil system. Therefore, we studied the effects of these factors on soil properties and plant growth, as well as compared differences under two soil moisture levels. We conducted a two-month greenhouse pot experiment with 16 treatments. Maize (Zea mays L.) was grown under two soil moisture levels (16.7% and 10.0% w/w) with and without MPs (0.2 % w/w, PLA+PBAT based). The role of soil biota was also considered, for instance, with and without earthworms (Lumbricus terrestris) was included. Generally, we found MP presence impeded plant growth. The presence of MP lowered soil pH under high soil moisture level and raised it under low moisture cases. The measurements of OM content were observed to increase with MP presence. Moreover, the effects of earthworm were found the largest on the plant-soil system. Specifically, dry biomass increased by 130%, fresh biomass and stem width increased by 110%, height increased by 20%, leaf number increased by 10%, while shoot C/N ratio decreased by 20% and pH decreased by 3%. Such effects were independent of the presence of plastic or other factors (e.g., moisture). In conclusion, this study showed the intricate effects associated with plastic pollution on the plant-soil system and they were not always consistent under different soil moisture levels.

A mechanistic understanding of cadmium behavior in tropical cacao soils

Wietse Wiersma, Jan E. Groenenberg, Rob N.J. Comans and Mirjam M. Pulleman

Relatively high levels of cadmium in cacao beans threaten the livelihoods of smallholder cacao farmers in Latin America and the Caribbean (LAC), due to strict food safety regulations in chocolate-producing countries. A potential strategy to reduce bean cadmium concentrations is to apply soil amendments to reduce soil cadmium availability. Nevertheless, the design of such strategies is hampered by a limited

understanding of the biogeochemical behavior of cadmium in tropical soils. We performed a lab incubation study where soils from farms in Ecuador and Colombia with high bean cadmium levels (1.2-4.5 mg kg-1) and contrasting levels of pH and organic matter were amended with four types of compost (30 t ha-1), with or without the addition of lime (CaCO3; 1.75 t ha-1). The objective was to explain the changes in the bioavailability of cadmium in response to those amendments. We measured the amount of reactive surfaces of organic matter and metal oxides. Applying a geochemical multi-surface model including NICA-Donnan and CD-MUSIC, we predicted that 60-100% of cadmium is bound to organic matter. Considering that the dissolved (i.e. bioavailable) cadmium concentration constituted only 1-5% of total soil cadmium, adequate quantification of this pool is essential. Hence, we compared the common 1 mM Ca(NO3)2 extraction method with rhizon samplers that directly sample soil pore water. Rhizon cadmium concentrations were up to an order of magnitude larger than the Ca(NO3)2 extraction. Overall, our results offer a mechanistic understanding of how soil amendments could be used to create sustainable low-cadmium cacao in LAC.

Temporal variability in soil microbial communities in response to microplastics

Giovana P. F. Macan, Manuel Anguita-Maeso and Blanca B. Landa

Over the last years, soil health, defined as the capacity of the soil to function as a vital living ecosystem, has been threatened by a range of factors, including plastic pollution. There is still a lack of knowledge about the potential impacts of these pollutants, especially on soil microbial communities which are crucial for soil functioning. In this context, the long-term effect of different types of microplastics (conventional and biodegradable) on the functional diversity of the soil microbial community has been assessed in a plant pot cycling experiment. Bulk and rhizosphere soil were sampled, and the temporal changes in the microbial community activity and functionality were assessed over time by a community-level physiological microbial profiling approach. The results showed temporal shifts in the bulk soil microbial community activity and carbon (C) use patterns. A transitory reduced microbial metabolic activity, calculated by the average well color development (AWCD), and metabolic richness (S) inferred by the number of different metabolized carbon sources, was observed on the soil exposed to biodegradable microplastic in comparison to the other treatments. These shifts are likely a product of complex interactions between the microorganisms, the plastics and their associated chemical additives, as well as the plastic degradation process over time. Our finding highlights the importance of long-term experiments with assessments over time. It also contributes to a better understanding of the dynamic changes affecting soil microbial communities when exposed to microplastics.

Do microplastics in vineyard soil affect the bioavailability of vine nutrition?

Erika Jez, Eliza Pellegrini and Marco Contin

The first measurement of the microplastic particles in vineyard soils (129 samples) have been done and 20 to 500 microplastic particles were counted in 1 g of dry vineyard soil. Microplastics can alter physico-chemical and biogeochemical processes in the soil, but whether these changes have further effects on soil fertility, and if so, whether these effects vary depending on the type of soil in the vineyard and the type of plastic used in the vineyard was the main question. Knowing what types of plastics are currently used in vineyards in Slovenian viticultural regions as strings to tie vines to the stake, the aim of our study was to assess the effects of microplastic particles from polypropylene (PP) and polyvinyl chloride (PVC) on the availability of macro (potassium (K), Potassium (K), calcium (Ca), magnesium (Mg) and phosphate (P)) and micronutrients (iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn)) in two vineyard soils contrasting in pH and mineralogy. The results show that micro-PVC particles have a more substantial influence on the availability of macronutrients in the soil. The most affected macronutrient was nitrate, as the availability of this element decreased by more than 90% with the presence of micro-PVC particles in

the soil. These results were observed in both soil types (calcareous and acidic soils). On the other hand, the presence of micro-PP particles in the soil had a greater effect on the availability of micronutrients, but not to the same extent as micro-PVC. Although research on the effects of microplastics on nutrient cycling in soils is still in its infancy, microplastics directly affect some soil properties that may also have indirect effects on soil nutrient cycling, e.g. cycling of C, P and according to our results especially to N-cycling.

Wind erosion of microplastics from urban soil surfaces

Inês Leitão, Loes van Schaik, Dirk Goossens, António Ferreira and Violette Geissen

Plastic pollution is a growing concern worldwide, due to the potentially negative impacts on the environment and slow degradation of this material. When in the environment, plastic is fragmented into microplastics (<5mm), which have been found in all environmental compartments at different locations. Research focusing on terrestrial environments is still limited. The main sources of microplastic are linked to the urban environment, where people are concentrated. Microplastics can enter the soil via multiple pathways, but the transport processes contributing to variation of microplastics in the soils are poorly studied. This study investigates the transport of microplastics from the soil surface to the atmosphere through wind erosion, using a Portable In Situ Wind Erosion Laboratory (PI-SWERL). The PI-SWERL creates an increased wind shear near the ground producing wind erosion. The sediments emitted by the PI-SWERL were collected, as well as soil samples around each measurement place. Different urban spaces were tested in Coimbra city, Portugal: green parks; landfills; old dumps; industry places; sidewalks. Microplastics were extracted from the sediments collected from the PI-SWERL and the soil samples, and they were then identified using a stereo-microscope. The data is still under analysis. The results will show the relationship between the concentration of microplastics in soil and transported by wind erosion, which may clarify the role of different types of soil surface both as a sink and a source of diverse microplastic polymers. This data is valuable to understand the processes of microplastics in urban environments, as well as to validate microplastic transport models.

Assessing the plastic contamination in agricultural soils: a protocol from nano to macro implemented in 220 fields across Europe

Nicolas Beriot, Esperanza Huerta Lwanga and Violette Geissen

Plastic use in agriculture has tremendously increased in the past decades resulting in plastic contamination in soils. Several studies intended to quantify the level on the plastic contamination is soil, facing the limitation in size, plastic density and polymer types. For the project MINAGRIS, a monitoring plan is implemented in 11 Case Study Sites (CSS) across Europe, combining four different protocols to quantify nanoplastics, microplastics, mesoplastics and macroplastics contamination in soil. The sampling range to 0.1 m3 of soil searched for macroplastics, 500g soil for mesoplastics, 5g soil for microplastics and nanoplastics. Macroplastics and mesoplastic will be quantified by wheight, area, and single-point ATR-FTIR. Microplastics will be quantified with Vibrational spectroscopy imaging with MCT FTIR (LUMOS II) and FPA FTIR (Cary 620 FTIR). The identification method for nanoplastic is still under development. We will present how combining several sampling strategies and analysis protocol we can assess a wide size distribution of plastic debris in soil.

The MiCoS project: microplastic detection in agricultural soils in relation to soil and plant health

Caroline De Tender, Lisa Joos, Benth Van Buyten, Jane Debode, Bart Vandecasteele and Bavo De Witte

Recent studies have shown that the presence of microplastics (MP) can disrupt key ecosystem services. Whereas plastic pollution in marine and freshwater ecosystems has been studied extensively, information on the effects on the soil ecosystem is severely limited. This is particularly due to the lack of appropriate techniques and methodologies for sampling, extraction and detection which hamper the research efforts to assess MP distribution in soil. As different concentrations, sizes, shapes and polymer types were considered in previous MP studies on the soil ecosystem, knowledge on the role on soil and plant health is fragmented and studies often contradict each other. Within the project MiCoS we will advance the field working in a three step approach. First, we will assess the risk of MP pollution by correlating MP concentrations of 240 agricultural soils in the Benelux with soil health indicators. To measure the MP concentration, a fast, cost effective and standardized method to detect, identify and quantify MP in soils will be developed. This will give novel insights on the MP distribution in agricultural soils in the Benelux. Second, by greenhouse experiments, the correlations between MPs and soil health indicators will be validated. MP induced changes in plant growth, plant disease susceptibility, soil texture, soil chemical composition and the microbial community will be studied. Third, to reduce the introduction and accumulation of MP in soil ecosystems, we will actively search for biodegrading organisms making use of DNA stable isotope probing in combination with metagenomics.

Visual and spectral identification of microplastic particles from soil matrices: a comparison between Stereomicroscope, FTIR and LDIR methods

Suzy Rebisz, Inês Amorim Do Vale Leitao, Davi Munhoz, Nuno Alexandre, Nicolas Beriot and Violette Geissen

The research on microplastic pollution is escalating due to greater awareness and concern about this environmental contaminant. Many methods exist to detect microplastics from different matrices, such as soil or water. However, uncertainties remain on how accurate and efficient the detection and identification of the number and types of microplastic polymers are. Specifically for the soil matrices, microplastic identification is challenging due to the frequent high levels of organic matter content. This study aims to compare and highlight the advantages and disadvantages of the following identification methods: stereo-microscope, μFTIR (4x and 15x magnification) and LDIR. These were tested after the extraction of microplastics from soil matrices. Various types of samples were used per method: 16 environmental from agriculture fields; 8 blank chemicals; 12 virgin microplastic polymers including PE, PLA, PVC and PBAT-PLA blend. Half of the environmental and blank samples were spiked with the same virgin microplastic polymers to test the microplastic limit of detection for each method. Data is still under analysis. Preliminary results suggested that the efficiency of each method depends on different factors such as the type of soil, tested microplastic polymers, and specific information on the number, size or type of microplastic polymer. Hitherto, we conclude that there is no single method capable of identifying a wide variety of microplastics to a high degree of efficiency. A combination of different methods would provide more accurate results than a single method of detection for microplastics.

Aquifer Recharge for Irrigation and Wastewater Treatment

Darrell Tang, Sjoerd van der Zee and Ruud Bartholomeus

Phreatic aquifer recharge with marginal water using existing drainage systems raises the water table and increases water availability for crops. This is a cost-effective method of freshwater conservation and marginal water treatment and disposal, but risks crop and environmental contamination. The fate of contaminants of emerging concern (CECs) within the irrigated water is addressed. We introduce numerical and analytical models, modelled after a pilot experiment supplied with treated domestic wastewater that would otherwise have been discharged directly into rivers. Results show that minimal amounts of CECs are transported to deeper confined aquifers. The root zone is not contaminated, except during dry years where small amounts of mobile CECs may rise to the root zone, but only directly above irrigation drains. Due to the annual precipitation surplus, less mobile solutes are unlikely to ever enter the root zone. The primary mechanism of solute transport is lateral advection within the phreatic aquifer, which we analyze within and beyond the agricultural plot. Mobile and persistent CECs pose the greatest environmental pollution risk, persistency being the more important factor. Despite spatio-temporal heterogeneity in water flux magnitudes and directions, contaminant mobility does not significantly alter its fate, only how fast it gets there. Therefore, to maximize complementarity with the introduced system, future advances in water treatment technologies should focus on mobile and persistent CECs. Overall, environmental and crop contamination risks appear low. However, the system may be unsuitable for climates with annual precipitation shortages, as CECs may migrate to and accumulate in the root zone.

Plastic mulch degradation: Could we optimize plastic degradation in soil?

Davi Renato Munhoz, Jianhua Zhang, Ke Meng, Violette Geissen and Paula Harkes

Low-density polyethylene (LDPE) and polybutylene adipate terephthalate (PBAT) are two of the main polymers composing mulch films. While LDPE is a recalcitrant material, PBAT is labelled as biodegradable. However, biodegradable mulch films are not degrading in agricultural soils as expected. We evaluated the potential of soilborne microorganisms to degrade: LDPE (LDPEp), commercial LDPE (LDPEm) and PBAT-based mulch films. We exposed mulch (1 cm2) to 15 potential treatments in low-carbon media (LC) for six months and selected four microbial treatments (M): M1: Liquid compost extract, M2: Aspergillus spp + Bacillus simplex; M3: Aspergillus Niger; M4: Aspergillus Fumigatus + Pseudomonas spp.. These were inoculated from the plastisphere to either carbon-free media (CF), another LC batch, autoclaved compost (AC), or compost (C). We also tested three abiotic treatments: 1) Non-abiotic treatment (NT); 2) UV-aged films (UV); and 3) 5% mineral oil media (MO). Weight loss (%) (WL) and Attenuated Total Reflection (ATR-FTIR) spectra were assessed. Some LDPEm treatments showed WL above 3% and oxidation signs were UV M1 and UV M2 in C, and both NT M3 and NT M4 in AC. Only MT N1 in C showed over 3% WL and ATR peak shifts for LDPEp. PBAT-based mulch. Controls did not degrade as quickly as claimed. However, UV M1 in CF, NT M4 in LC, NT M1 and NT M3 in AC, and NT M1 in C enhanced WL and showed ester bond hydrolysis, which indicates degradation. Further analyses will verify whether these results are due to fragmentation, depolymerization, and/or degradation.

Sensitivity analysis of transpiration reduction in soybean due to aeration stress under shallow water table scenarios

Laura Raquel Quiñónez Vera and Quirijn de Jong van Lier

A frequently used approach in hydrological models to estimate the reduction of the root water uptake (RWU) caused by oxygen stress is the empirical model of Feddes, describing oxygen stress by a piecewise linear

function defined by two threshold pressure heads (h1 and h2). A more process-based approach was proposed by Bartholomeus et al. (2008) and is based on physical and physiological soil processes to calculate the critical gas-filled porosity of the soil below which oxygen stress occurs, resulting in transpiration reduction. We performed a sensitivity analysis evaluating the relative transpiration under the presence of a shallow water table using the Bartholomeus model and focusing on two parameters, the threshold to stop root growth in case of oxygen stress and the air-filled root porosity. Several combinations of water table depths were combined with the hydraulic properties of five central-Brazilian lowland soil types and a soybean crop. The water table was set as a boundary condition. The results of the sensitivity analysis of the relative transpiration to combinations of parameters used will be shown and discussed.

Changes of soil organic carbon stocks and aggregation in Alpine and pre-alpine grassland soils in a changing climate

Noelia García-Franco, Martin Wiesmeier, Bernd Beauer, Michael Danennmann, Ralf Kiese and Ingrid Köegel-Knabner

Climate and land management changes affect all the ecosystem services provided by alpine and pre-alpine grassland soils. In addition, to the high sensitivity of grassland soil C and N and soil functions of these grassland are also affected by the combination of climate change and land management practices. A promising multi-factorial design combined the translocation of plant-soil mesocosms along an elevation gradient in the Northern Limestone Alps of Germany with climate-adapted management practices (intensive vs. extensive) between 2016 and 2020. In this study, the changes of soil organic carbon (SOC) and total nitrogen (N) stocks and their distribution according to aggregate size classes (large macroaggregates > 2000 μm, small macroaggregates 250–2000 μm, microaggregates 63–250 μm, and silt-/clay-sized particles < 63 μm) were studied in grassland soils along an elevation gradient from 600 to 1260 m a.s.l. The SOC and N stocks decreased after four years in the translocated mesocosms from the higher to the lower elevations in both management treatments. Regarding the aggregate size distribution, we observed a decrease of large macroaggregates in both management treatments, which was more pronounced in the extensive treatment compared to the intensive treatment. For small macroaggregates and microaggregates the opposite trend was found. Our results indicated a transfer of OC associated with large macroaggregates to small macroaggregates and microaggregates. Our study highlights the importance of aggregate-related factors as potential indices to evaluate SOC changes in mountainous grassland soils.

The mechanised sugarcane harvesting and its effects on the soil attributes and root development of the crop.

Mayara G.Dos Santos Gomes, Diego A. A. Esteban, Jeison A.S. Parras, Vitor Fonseca Gomes and Zigomar Souza

The mechanized sugarcane harvesting can results in greater soil compaction, affecting the physical attributes and hindering root development in depth. This work aimed to evaluate different transshipment configurations in the mechanized sugarcane harvesting and verify which configuration may reduce the compaction process that limits root development. The research was carried out in a sugarcane field located at "Usina Cerradão", Frutal, Minas Gerais, Brazil. A randomized block design was adopted, consisting of three treatments and three replications: 2CT/10 - tractor set with 134 kW+ two transshipments with a capacity of 10 Mg each one; 1CT/30 - tractor set 172 kW+ transhipment with a mass of 30 Mg; 1CC/21 - truck + box set with a capacity of 21 Mg. After the mechanized harvesting that occured in the 2020/2021 and 2021/2022 harvests, root samples were collected by the probe method in the layers of 0.10-0.30 m and 0.30-0.70 m in the planting row (PR) and traffic row (TR), to determine the density and root biomass of the crop, besides

collecting undisturbed soil samples to quantify soil penetration resistance (SPR). The density and biomass of the roots obtained greater results in the first year of harvest (2020/2021) with emphasis on treatments 2T/10 and 1C/20, probably this behavior was verified because it was the first year of crop development before planting, that is, it had soil management and preparation. However, in the second year of cultivation (2021/2022), a significant reduction in the density and biomass of the roots was observed along the soil profile.

A novel soil pore three-dimensional segmentation method combining U-Net and LSTM based on computed tomography image

Lei Liu, Qiaoling Han, Yandong Zhao and Yue Zhao

Computed Tomography (CT) has considerably enhanced the comprehension of soil 3D structure through non-invasive research on soil micromorphology. The accurate analysis of soil pore characteristics heavily relies on achieving precision during the conversion of CT images into binary images. However, 2D segmentation often leads to considerable and missing connectivity information in pore space, which affects the accuracy of 3D characteristics analysis. The study presents a novel 3D pore segmentation method, named BDULSTM, which utilizes U-Net and LSTM to improve pore identification precision. The proposed method retains a successful U-shaped architecture for the encoder and decoder. By utilizing skip connections, the encoder and decoder extract image features to generate binary images, ultimately enhancing pore segmentation accuracy. The CLSTM is placed at the base of the U-shaped architecture, connecting the encoder and decoder, and is responsible for fusing sequence image features. Our validation results demonstrated that this architecture can significantly improve soil pore segmentation accuracy in comparison to existing methods, which was demonstrated through the enhanced performance of BDULSTM in soil pore segmentation on CT images of different soil conditions. BDULSTM achieves the highest F1-score of 92.07%, which is 6.97% higher than the second-best performing model, U-Net. The performance of BDULSTM varies depending on the number of sequence images used, with the optimal performance observed at 7 images. In summary, BDULSTM represents a state-of-the-art artificial intelligence approach for 3D segmentation of soil pores, which offers a promising tool for analyzing pore structure and soil quality in the future.

Phosphorus Recovery from Wastewater as a Circular Economy Approach to Enhancing Soil Fertility

Tolulope Ayeyemi, Ramiro Recena, Ana Maria García-López and Antonio Delgado

Phosphorus (P) is a critical macronutrient that is crucial for agriculture and a non-renewable yet strategic resource. However, it is inefficiently used in society. To sustain agricultural production, a circular economy approach with the use of recycled P sources in agriculture is encouraged. To access the potential of two recovered P fertilizer products, we carried out a pot experiment with wheat involving the use of superphosphate, vivianites and struvites from different origins. All fertilizer products were tested at two rates (50 and 100 mg P kg-1). The two struvites tested performed similarly to superphosphate in terms of dry matter yield and P uptake; and were significantly higher when compared to all types of vivianites. One of the vivianites from water purification did not result into increased yields when compared with the control treatment. Industrial effluent and synthetic vivianite performed best among all types of vivianites. These two also led to increased Olsen P in soil after harvesting of the wheat crop relative to non-fertilized control. Phosphorus fertilizer replacement value (PFRVDM) on dry matter basis were in much higher value when compared with PFRVP (P uptake basis) with struvite B having the greatest value (94-154%) and vivianites from industrial effluent with values over 50% (54-75%). Struvites were as efficient as superphosphate in supplying P to plants and increasing P availability in soils. However, with values of 50% PFRVDM for industrial effluent vivianites, a combination of vivianite and soluble P fertilizers may be considered in fertilizer strategies for practical use of vivianite.

Conceptual overview of burrowing animals as actors of landscape change

Marta Loreggian, Annegret Larsen and Jantiene Baartman

Extensive research, ranging from Darwin's work to more recent studies, has demonstrated the significant role burrowing animals play in sediment movement, change of soil structure and water infiltration. This has led to their recognition as ecosystem engineers and key agents in shaping landscape development. Despite this wide knowledge, their role in the erosion-infiltration balance at the landscape scale, especially related to soil hydrological processes, is still unclear. One way of understanding this soil-hydro-biota connection is the use of landscape evolution models (LEM). Therefore, the aim of this conceptual overview is to present a methodological framework used to develop a "soil-hydro-fauna" module, to be then included in a LEM. We conduct a systematic literature review on equations representative of soil movement and water infiltration processes due to burrowing activity. The results are classified according to animal size and behaviour, the spatio-temporal scale of the process, and climatic zone. Then, we bridge the classified processes related to burrowing activity in a virtual experiment to outline the relation between soil-biota activity and hydrology in different landscapes. Finally, we develop a module based on the virtual experiment that can be used to investigate the impact of burrowing animals on soil movement and water infiltration at the landscape scale. Data acquired from rainfall simulation experiments on soils disturbed by burrowing activity, sediment fences and luminescence dating are used to improve, calibrate, and validate the module. With this, we hope to get a better understanding of the impact of burrowing activity on landscapes across scales.

Effects of superhydrophobic sand mulches on steady-state water evaporation fluxes

Amr Al-Zu'Bi, Lisa Exposito, Jiaqi Zheng, Adair Gallo Jr and Himanshu Mishra

Food–water security is a matter of great concern in regions endowed with hot and arid climates., the Middle East, California, western Australia, and northwestern India. Under these conditions, the evaporation of water from the topsoil can be as high as 60% of the total evapotranspiration budget for some cultivars; consequently, irrigation efficiencies are abysmal. In response, our team has pioneered SuperHydrophobic Sand (SHS) mulch technology to reduce the evaporative water loss from the topsoil. Here, we have developed an experimental setup to systematically measure and compare the evaporation fluxes of bare and SHS-mulched soil columns in a steady-state regime as a function of water table depth, surface heat flux, soil-type, and water-retaining materials. Evaporative losses of water were quantified from bare (0 mm) and mulched (5 and 10 mm-thick SHS layers) soils comprised of (i) fine sand, and (ii) silica sand with larger grain size. Remarkably, the use of 10 mm-thick SHS layer reduced the evaporative flux $\approx$80% in comparison with the bare soil. An image analysis software was developed to realize a simple and inexpensive method to analyze results of multiple experiments in parallel. This experimental design and image analysis software present a simple but realistic platform to study heat and mass transfer across soils as a function of soil-amendment technologies. A heat and mass transfer model will also be presented to provide mechanistic insight into these experiments.

ACFTransUNet: a dense-connection multi-category three-dimensional identification model combining Transformer and CNN for soil pores

Meihui Song, Yue Zhao, Yandong Zhao and Qiaoling Han

Soil pore structure is an important component of soil systems that has a significant impact on the exchange and storage of soil water, gas, and nutrients. However, current soil pore identification software such as ImageJ and Image-Pro Plus suffer from problems such as having only a single category identification and low robustness. To address these issues, we proposed a dense-connection multi-category three-dimensional

identification model named ACFTransUNet using UNet as the backbone network for pore identification to assist in digital soil characterization. Specifically, the encoder's top layer is combined with a Transformer module to better extract features of large-volume cracks and tubular pores. The concentrated fusion attention (CFA) module is proposed to fuse adjacent encoding layer information, preserve detail feature information of small-volume irregular pores and inter-aggregate pores. Attention gates are embedded to reduce redundant information and enhance the expression of effective features. Results demonstrate that the ACFTransUNet proposed in this study has the best identification performance on self-build soil pore dataset (including cracks, tubular pores, irregular pores and inter-aggregate pores), with MDice, MPrecision, and MAccurary of 85.48%, 85.30%, and 94.12%, respectively. Especially, for irregular pores, compared to the state-of-the-art model, which are improved by 4.25%, 5.31%, and 1.04% in dice, precision, and accuracy, respectively. This study proposes a multi-category identification method for soil pores for the first time, providing a scientific basis for revealing soil function and ecosystem service provision by soils within a wider, global context.

Combined stress response of indigenous and alien plant species in temperate ecosystems

Morena Rolando, Francesca Secchi, Daniel Said Pullicino, Eleonora Bonifacio and Luisella Celi

The alien species invasion is one driver of ecosystems change, because of their effect on biodiversity and soil environment (e.g. alteration of nutrient cycling). In adverse conditions, non-native species can enhance their invasive potential, implementing the resources use efficiency. The alteration of water regimes due to the climate change may contribute to change the plant performance and nutrient cycling, promoting some resistant species instead of others. In Europe most of Quercus robur L. forests (EO) are invaded by Quercus rubra L. (RO), a Northern American species. Since nutrient and water demands of RO are lower than EO, drought periods may exacerbate the complex interaction between species, especially in nutrient limited soils. To understand the complex response to combined stresses in a phosphorus (P) limited EO forest invaded by RO we performed a microcosm experiment where both species have grown under well-watered and water deficit conditions, and the soil nutrient availability has been modified through addition of nitrogen (N) and P forms alone or in combination. Our results showed that RO tolerates drought conditions better than EO. However, EO recovered faster following P input, highlighting that soil fertility drives the response of the native species to water stress. Interactions of nutrients control N content in EO soils and the competition between species, indicating that a fertility restorage can mitigate water stress and promote the EO competition versus RO.

Wheat-Faba bean intercrops improve plant nutrition, yield, and availability of nitrogen (N) and phosphorus (P) in soil

Ghilès Kaci and Walid Ouaret

In order to promote agroecological practices, this study compares two cropping systems, i.e., intercropping versus sole cropping of a cereal - durum wheat (Triticum durum Desf.) and a nitrogen-fixing legume - faba bean (Vicia faba L.) on plant growth, Efficiency in the use of rhizobial symbiosis (EURS), grain yield and phosphorus (P) and nitrogen (N) accumulation in soil and plant. This study conducted during two cropping seasons in a field trial in the region of Tizi Ouzou, Algeria, shows that shoot dry weight (SDW), nitrogen nutrition index (NNI), phosphorus use efficiency (PUE), land use efficiency (LER), and grain yield were significantly higher for intercropped than for the sole cropped wheat. Furthermore, there was a considerable increase in soil P and N content across the two years of intercropping and sole cropping compared to the unseeded weeded fallow. Intercropping, it is claimed, improves wheat N nutrition by increasing the availability of soil-N for wheat. This increase might be due to reduced interspecific competition between legumes and wheat plants than intraspecific competition between wheat plants due to the legume's ability to compensate by atmospheric nitrogen fixation.

Companion plants influences on soil physicochemical and microbial characteristics in organic raspberry crop

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Intercropping became recently a commonly used practice, as by growing crops close to each other the biological interactions are increased and have a positive impact on light use, nutrient and water uptake, pests and diseases control, crops productivity and farm profitability. The study was conducted at the Rodagria Agricultural Cooperative (Baragan plain, Southeastern part of Romania), in polytunnels cultivated with raspberry Kwanza® variety, in organic system. Three variants of flower strips, Borago officinalis L., annuals and perennials were sown along the poles lines of the polytunnel. In addition, two cover crops were sown in the inter-rows, a mix of Gramineae species and microclover (Trifolium repens L. var. Pirouette). The soil samples were collected in April and October 2022 and the following physicochemical and microbiological parameters were analyzed: pH, electrical conductivity, total carbon and nitrogen and total number of bacteria and fungi. The results highlighted that the number of bacteria in the soil covered with grassy strips and flower strips increased during the vegetation period, being much higher in October compared to April 2022, the highest number of bacteria and fungi being observed in Gramineae strips. The perennials strongly favored the development of bacteria but inhibited the fungi growth. The borage favored fungi development but inhibited bacterial growth. After the first year, no significant differences regarding the soil physicochemical properties between the sampling periods were noticed. Borage proved to be a companion species that inhibit weeds growth successfully and can be used as a weed killer, including in high infestation of Johnsongrass.
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Impact of Different Types of Nitrogen Fertilizers on Greenhouse Gas Emissions and Cabbage Productivity in an Upland Field during Cultivation

Hyerin An, Yeomyeong Lee, Sohee Yoon, Juhee Lee and Sang Yoon Kim

The types of nitrogen (N) fertilizers are diverse so that their chemical characteristics and properties are largely varied, simultaneously affecting greenhouse gas (GHG) emissions and crop yield. The aim of this study was to find out an appropriate N source for minimizing global warming potential (GWP) and maintaining productivity. A field experiment was conducted to investigate effects of different N fertilizers including urea (U), ammonium sulfate (AS), compost (C), liquid fertilizer (LF), and composite fertilizer (CF) with equivalent N rate on GHG emissions, soil properties, and productivity in cabbage (Kimchi cabbage) cultivated soil under the recommended fertilization level except for the control (exclusive N treatments). Overall GHG emissions were significantly varied with different N fertilizations. Particularly, N2O emissions significantly increased in U, LF, and CF treatments as compared to the control. Interestingly, dramatic increase was observed in LF, which was 13-68 times higher than other treatments, indicating LF may provide favorable moist conditions for generating N2O. CO2 emissions were higher in C, LF, and CF treatments than the other treatments. There were no significant differences in CH4 emissions among all treatments. Total GWP was the highest in LF, but was the lowest in AS. Cabbage productivity was significantly higher in the treatment of U, AS, and CF treatments than other treatments. Greenhouse gas intensity (GHGI) as a proxy for sustainability was the lowest in U and AS. Conclusively, the proper selection of N fertilizer should be necessary to mitigate GHGs emissions and to maintain sustainable production for a better agroecosystem.

Flooding-induced N2O fluxes can be attenuated by plant communities

Arlete Simoes Barneze, Jan Willem van Groenigen, Laurent Philippot, David Bru, Diego Abalos and Gerlinde B. De Deyn

Under varying climatic conditions, plant species mixtures with different growth strategies and functional groups could promote stable productivity. The impact of plant community composition on nitrogen (N) cycling, particularly the ability of soil microbial N cycling during floods and their ability to reduce flooding-induced N2O fluxes, is not well understood. This study aimed to determine how mixtures of grasses and legumes can impact N2O fluxes and soil N cycling microbial guilds, and how these would be affected by flooding. In our field experiment, we had monocultures of two grass and two legume species, two-species mixtures and four-species mixture with different growth rates (slow- and fast-growing species) in fertilised sandy soil. We found out that flooding dramatically decreased plant N uptake and increased N2O fluxes due to larger abundances of N cycling microbial guilds. The presence of legumes increased N2O fluxes, but this was not caused by modifications in the N cycling microbial guilds, rather, it was linked to an increase in the nitrate availability of the soil. Grass-legume mixtures increased plant N uptake and decreased N losses, especially when combining slow-growing species and in the four-species combination. Our findings demonstrate that flooding significantly enhanced N leaching, N2O fluxes, N cycling microbial guilds, and lowered plant N uptake. Conversely, mixtures containing slow-growing species showed the lowest relative abundance of nosZII bacteria and ameliorate flooding effects by both reducing N losses and enhancing plant N uptake.

Comparing the performance of P Olsen and P saturation degree in predicting crop yields and P leaching risks using long-term P fertilization experiments

Yu Gu, Gerard H. Ros, Qichao Zhu, Maarten van Doorn, Jianbo Shen and Wim de Vries

In this study, we investigated the effects of long-term phosphorus (P) addition on different soil P pools, crop yield, and environmental risks in wheat-maize rotation systems in China. We examined changes in four soil P pools (PCACL2, POLSEN, POX, and PTOTAL) and evaluated crop yield responses and potential P leaching losses to various P fertilization rates and resources. We also assessed the performance of POLSEN and P saturation degree (PSD) in predicting crop response and environmental risks. Our findings revealed that POLSEN and POX increased linearly with accumulated P input, reaching their maximum values near 3200 kg P ha-1. Continuing P application above that threshold only caused a gradual increase in PTOTAL and a linear increase in PCACL2, implying an increased leaching risk. The majority of the surplus P accumulated in POX before saturation. Moreover, PSD better explained the variation in crop yield and potential P leaching losses than POLSEN. The critical PSD level for enhanced P leaching risk was found to be 0.20, which is near the target level for crop yields when using a cut-off point at 80% of the maximum yield (0.22). Our results suggest that long-term P accumulation can saturate soil-reactive P pools (POX & POLSEN), and additional P inputs will accumulate in more stable P forms or induce a higher leaching risk once the soil is saturated. Additionally, PSD can be used to optimize P management for both crop yields and potential leaching risks.

Modelling nitrogen dynamics of a long-term fertilization agricultural soil to tackle fertilizer losses.

Paula Andrea Rojas Pinzon, Judith Prommer, Lucia Fuchslueger, Petra Pjevac, Christopher J. Sedlacek and Andrew T. Giguere

Current agricultural soils have received approximately 98 Tg y-1 of nitrogen (N) fertilizer in the last years, of which 50% is lost to the environment through nitrate (NO3-) leaching or nitrous oxide (N2O) gas emissions. Fertilizer losses raise a global concern as they not only contribute to water and atmosphere pollution but also

result in low agricultural nitrogen use efficiency. Nitrification, the aerobic oxidation of ammonia (NH3) to NO3-, is one of the pathways leading to substantial nitrogen losses from soils upon fertilization. Soils subjected to controlled long-term fertilization are uniquely suited systems to evaluate the effects of management practices on nitrification and subsequent nitrogen loss dynamics. To investigate this, we used a 15N stable isotope tracing approach and quantified N transformations and losses in whole soil microcosms incubations with soil subjected to four different rates of N fertilization. We found that supplemental NH3 was completely oxidized within 5 days at the lowest N application rates, while NH3 persisted at higher concentrations where nitrification occurred for up to 12 days. We observed that higher fertilization rates led to significantly higher nitrification-derived 15N2O production. Similar microbial and nitrifier communities were found in the different fertilization treatments, and further research aims to determine the role of specific groups of nitrifiers in N2O emissions under distinct fertilization regimes. In conclusion, by having a comprehensive understanding of the fate of N fertilizer in agricultural soils it will be possible to estimate disturbances to nitrogen dynamics and establish early solutions to tackle current fertilizer losses.

The effect water management on iron plaque formation and phosphorus availability to rice

Sara Martinengo, Maria Martin, Angelia Seyfferth, Daniel Said-Pullicino, Michela Schiavon and Luisella Celi

Phosphorus (P) availability (P) to rice plants is influenced by the extent of soil flooding because of its relationship with iron (Fe) redox cycle. The dissolved Fe(II) interact with root oxygen loss causing the formation of Fe-plaque on root surfaces. This surfaces can retain porewater components, such as P. The introduction of dry periods during rice cultivation could affect Fe plaque formation, with an unknown consequence on P availability. To investigate these effects a macrocosm experiment was conducted by comparing three water management: continuous flooding (WFL), alternated wet and dry (AWD), and delayed continuous flooding (DFL), combined with three P fertilization levels: natural soil supply (no-P), 20 kg P ha-1, and 40 kg P ha-1. During rice cultivation, the porewater Fe and P concentrations, P concentration in plant tissues, content of amorphous (AAO) and crystalline (DCB) Fe in root plaque were monitored. A different P and Fe(II) porewater release was observed according to water management. DFL and WFL showed a higher Fe plaque formation compared to AWD. During the early development stages, Fe plaques were mainly composed of AAO-Fe, and the proportion of DCB-Fe increased with plant development. Despite this, the total amount of Fe plaque decreased until harvesting, possibly indicating a consumption of the AAO-Fe in plaques, with a more pronounced effect in no-P plants. Thus, suggesting the role of the plant responses to P-limiting condition to promote Fe plaque dissolution. The positive correlation observed between the AAO-Fe in plaques and plant P uptake, could further corroborates this hypothesis.

Linking manure composition to manured soil emissions of ammonia and greenhouse gases

Sebastian Kuśmierz, Mart B.H. Ros, Nick J.M. van Eekeren, Martine H. Bruinenberg and Gerard L. Velthof

Estimating carbon (C) and nitrogen (N) losses from agricultural soils is crucial to maintain sustainable soil management. Many models that calculate atmospheric fluxes from manured soils depend on emission factors that do not consider differences between manure from different animals, let alone manure composition information within manure type. In a series of mesocosm incubation experiments, we quantified gaseous C and N emissions from 50 different dairy manures with the aim to link emission magnitude to manure composition. In short lab trials, the emission potential of ammonia (NH3) and methane (CH4) from manures was determined, after which NH3, nitrous oxide (N2O), and carbon dioxide (CO2) emissions after manure application at 100 kg N/ha to soil were measured during a 21-day incubation experiment. In both cases gas concentrations were measured using an INNOVA 1512 photoacoustic gas analyser. A combination of principle component analysis and multiple regression with mixed linear models was applied to investigate the relationship between manure composition and gaseous emissions. Results showed that not total or

ammoniacal N, but rather manure pH was the main factor explaining NH3 emissions. The N2O emissions, and to a lesser extent the CO2 emissions, were conditioned by the amount of moisture added with the manure. Other significant factors in the best models were organic C and N, and C/N ratio. This study shows that the variability of emission potential is high within one manure type. Including easily obtainable information on manure composition, such as pH and nutritional content, could provide a way to improve manured soils emission calculations.

Root trait complementarity improves yield of ryegrass (Lolium perenne L.) and tall fescue (Festuca aurundinacea Schreb.) in a low P soil.

Ángel Velasco Sanchez, Laura M.E. Ferron, Nadia Bennegadi-Laurent, Isabelle Trinsoutrot-Gattin, Jan Willem van Groenigen and Gabriel Y.K. Moinet

Phosphorus (P) fertilisation is a key environmental and agronomic issue for grassland management. This motivates the introduction of smart combinations of grasses with the ability to access poorly soluble P pools in soils and decrease reliance on external inputs. In this field experiment, we cultivated Lolium perenne L. and Festuca arundinacea Schreb. in monocultures and in combination, as well as a combination of the latter species with a tetraploid variety of Lolium and Phleum pratense L. Plants were grown in an unfertilized low P sandy soil with and without P fertilization for two growing seasons in Wageningen, The Netherlands. We monitored biomass production through time and measured root traits, nutrient uptake, microbial biomass and enzymatic activities. We observed that, in the unfertilized plots, the combination of Lolium and Festuca generated the highest cumulative yields, relative total yield (RYT) and P nutrition index (PNI). These results can be explained by the complementarity found in root traits between Festuca and Lolium. Festuca showed a significantly higher root biomass at deeper soil layers compared to Lolium. Lolium had finer roots than Festuca through the soil profile. The combination of 4 different grasses did not result in higher yields, but lead to increased soil C, microbial P biomass, alkaline phosphatase and β-glucosidase in the unfertilized plots. Our results show that, in low P soils, combinations of grass species with contrasting root traits could lead to significantly higher yields than monocultures and decrease the need for fertiliser application.

Nutrient bioavailability by weathering process in Cauvery river basin, South India

Deepika Pandey

The study of behaviour of elements in a weathering system was done using the sequential extraction procedure to identify different phases formed in the soil as a result of weathering. The presence of elements in specific fractions provides information about their probable chemical forms in the sample and helps to understand their bioavailability during weathering. The sequential extraction procedure developed by Leleyter and Probst (1998) was adopted for the present study which is a modification of the established sequential extraction method used for sediments by Tessier et al (1979). Bioavailability is a complex function of many factors including total concentration and speciation of elements, mineralogy, pH, redox potential, temperature, total organic content (both particulate and dissolved fractions), and suspended particulate content, as well as the volume of water, water velocity, and duration of water availability, particularly in arid and semi-arid environments (John and Leventhal, 1995). Nutrient elements studied in the present work, such as Ca, K, Mg and Fe, Sr, Mn, Ba, Co, Cu and Zn were found to be distributed among different phases according to their chemical properties, local physical conditions as well as the structural chemistry of the phases. It has been observed that Ca, K and probably Mg are mainly associated with exchangeable fraction, Mg in carbonate fraction, and all the nutrients present in exchangeable fraction are also present in organic fraction. Trace nutrients required by plants in fewer quantities also occur in organic fraction.

Rhizobox studies to investigate rhizosphere processes that lead to yield decline in successive winter wheat crop rotations

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Winter wheat (WW) is one of the most important crops worldwide. Therefore, farmers have been increasing the share of WW in their crop rotations. However, self-succession of WW leads to a significant yield decline. This is often attributed to the soil-borne fungus Gaeumannomyces graminis var. tritici (Ggt; take-all) causing earlier root senescence. This decline is observed even in years without pronounced Ggt presence in the soil. This suggests a moderating role of rotational position-specific microbial community in biomass production of WW. Through a series of experiments, we aimed to improve our understanding of the key rhizosphere processes underlying the loss of productivity in successively grown WW compared to WW after oilseed rape. Here, two rhizobox experiments are presented (one greenhouse experiment on mature and one outdoor experiment on young WW) showing the most important responses of contrasting WW rotational position. State-of-the-art methods have been employed to acquire high-resolution data on nutrient dynamics in bulk and rhizosphere soil, plant N uptake, enzymatic activity, C allocation above and belowground, contribution of different soil depths of plant water uptake. All of these processes were assessed in the context of root plastic responses due to the different rotational positions. Biomass was strongly reduced in both experiments and this effect was related to lower root growth and contrasting growth strategy in successively grown WW. There was evidence of increased competition with the microbial communities that resulted in lower N uptake by successively grown WW. Reduced content of DOC and freshly assimilated C in the soil profile of successive WW rotations further explained the observed yield decline. The implications for plant-soil interactions and management at field level are discussed.

Assessing the effect of arable management practices on carbon storage and -fractions after 24 years in Boreal conditions

Anna-Reetta Salonen, Helena Soinne, Rachel Creamer, Riitta Lemola, Niina Ruoho, Oona Uhlgren, Ron de Goede and Jussi Heinonsalo

Soil organic matter (SOM) is beneficial for soil functions and crucial for ensuring sustainable agriculture. Understanding how agricultural management and soil properties impact on SOM throughout the soil profile would aid in preserving and increasing soil carbon (C) stocks. We sampled a 24 year-old cultivation field experiment on a heavy clay soil with organic and conventional cropping systems, and an adjacent unmanaged meadow to 70 cm soil depth and assessed the total carbon stocks and their distribution into mineral-associated (MAOM) and particulate (POM) organic matter. Throughout the soil profile, >83% of the soil C was in the MAOM fraction. The distribution of C between MAOM and POM was not strongly affected by soil management within a studied soil depth. Largest C stocks (169 t ha-1) together with the largest plant root biomass was found in the unmanaged meadow, which highlights the importance of deep-rooting plants in sequestering C into the soil. We also determined the contribution of clay, and aluminum and iron oxides in explaining the amount of total C, MAOM-C and POM-C. Whereas aluminum and iron oxides correlated with C in all the studied soil layers, clay was not associated to any of the C fractions below the 20 cm depth, suggesting that estimating the C accumulation potential of the deeper soil should not be based on the soil texture alone. Results indicate that aluminum and iron oxides can be important in transporting and stabilizing of C in the soil profile.

Evaluating carbon sequestration of different alternative management practices in the Netherlands

Jonas Schepens, Bart Timmermans, Gabriel Moinet and Chris Koopmans

Purpose: To meet the Paris Agreement targets the Government of the Netherlands aims to sequester 0.14 Mt C per year in clay and sandy soils from 2030 onwards through alternative management practices. Multiple international meta-analyses and modelling studies have been carried out to quantify the soil carbon sequestration potential of alternative management practices. However, the specific impact of such practices for Dutch field conditions have not yet been assessed. In this study, we quantified the potential of a broad range of alternative management practices to sequester carbon in Dutch agricultural clay and sandy soils. Methods: Alternative management practices included altered crop rotations, non-inversion tillage, use of compost and use of animal manure for arable farming and extending pasture age, maize-grass rotation replacing continuous maize cropping, and non-inversion tillage in maize cultivation for livestock farming. Measurements were performed in existing long-term field experiments (LTE's) comparing treatments of the alternative practices to the standard practices. For some practices like altered rotations and extending pasture age no LTE's were available. In those cases the comparison between practices was designed by comparing field plots on farmers' fields based on history of the field and comparable soil conditions. Soil sampling was carried out at the 0-30 cm and 30-60 cm depth layers between 2018-2020 using a standardized protocol including soil density sampling. Results: The variation in carbon sequestration rates appeared to be higher on sandy soil as compared to clay soil. The most promising management practices on clay soil were compost additions (0.4 t C ha-1 year-1), extending pasture age (1.3 t C ha-1 year-1) and non-inversion tillage in maize cultivation (0.7 t C ha-1 year-1). On sandy soils maize-grass rotation significantly increased soil carbon levels (1.8 t C ha-1 year-1) together with liquid manure applications (0.6 t C ha-1 year-1).Conclusion: Our study shows that the potential of alternative management practices under Dutch field conditions to sequester carbon in agricultural soil is largely determined by soil type. In addition, our results show that, based on the investigated management practices, livestock farming has more options to sequester carbon in agricultural soil than arable farming.

A new value of silicate fertilizer as a soil amendment to mitigate greenhouse gas emission impact and improve rice productivity

Snowie Jane C. Galgo and Pil Joo Kim

Silicate fertilizer made from blast furnace slag (BFS) has been utilized as a soil amendment in a rice paddy. Silicate fertilizer which contains electron acceptors was known to reduce methane (CH4) emission. However, the influence of silicate fertilization on global warming remains uncertain. To evaluate the net effect of silicate fertilizer application on global warming, two types of silicate fertilizers were prepared by mixing BFS with 0 (SF0) and 5% (SF5) of iron rust, respectively. Its influence on global warming was compared using net global warming potential (GWP) which was integrated by two GHG fluxes (CH4 and N2O) and soil carbon stock change with CO2 equivalent. Silicate fertilization significantly decreased CH4 and N2O fluxes by 21-30 and 29-47% over the control, respectively. Different from the general understanding of liming which can decrease soil C stock, silicate fertilizer application slightly increased soil C stock by 0.90-1.18 Mg C ha-1 yr-1. Irrespective of fertilization background, net GWP was decided by CH4 flux with 73-96% of the contribution, followed by N2O flux with 11-13%. Therefore, SF0 application significantly decreased net GWP by an average of 40% over the control, but SF5 was more effective, due to the big reduction of CH4 flux. Silicate fertilization increased grain yield by an average of 9%. As a result, SF0 decreased greenhouse gas intensity (GHGI) by 45%, but SF5 more effectively decreased GHGI by 60%. In conclusion, silicate fertilizer could be a good amendment to improve rice productivity and decrease GHG emission impact in the rice paddy.

Evaluation of the effect of biochar on mitigating the net GWP in the whole process of rice cropping

So-Yeong Park, Hyeon Ji Song, Gil Won Kim and Pil Joo Kim

Organic amendments were recommended to improve soil quality and increase soil carbon sequestration. However, in the rice paddy, applying organic amendment induced to increase in greenhouse gas (GHGs) emissions. Biochar with a stable form is recommended to mitigate the GHGs emission. The biochar effect of mitigating GHGs was evaluated within cropping boundaries. A lot of GHGs are expected to be emitted during the biochar producing process (i.e., electricity, fuel, transportation, etc.). To evaluate the substantial biochar effect of mitigating GHGs in the whole process (industrial and cropping), chemical fertilizer (NPK), fresh green manure (Fresh), and green manure biochar (Biochar) were applied in the rice paddy. During the industrial and rice cropping process, the net global warming potential (GWP) was integrated by GHGs (CH4 and N2O) emissions and soil organic carbon (SOC) stock change with CO2 equivalent. As a result of the evaluation of the net GWP in the whole process, Biochar mitigated significantly the net GWP compared to NPK and Fresh. CH4 emissions contributed a large portion of the net GWP followed by Soil C stock change and N2O. GHG emissions in the industrial process were increased to Biochar, NPK, and Fresh. During rice cropping, Biochar mitigated CH4 emissions compared to NPK and Fresh with 21 48% and 64 89%, respectively. Finally, in Biochar, the GHGs emission (especially, CH4) were evaluated as the lowest among the treatments in the whole process. Hence, a stable form of organic matter like biochar was recommended to apply to the rice.

Soil organic matter fractions and soil carbon storage as affected by forest type and climate change

Veronika Jílková, Kateřina Jandová and Olga Vindušková

Soil organic carbon (SOC) is the largest C pool in terrestrial ecosystems, and temperate forest soils in particular have a great potential to store C. Coniferous forest topsoils store more SOC than deciduous forest topsoils. However, less is known about C distribution in subsoils. Also important is the partitioning of SOC into fractions of soil organic matter (SOM), which differ in terms of formation, persistence, and function. Few studies have compared the proportions of C in SOM fractions between deciduous and coniferous forest soils or the influence of C inputs of variable quality and of soil community composition on SOM fraction formation and persistence. Fraction formation and persistence might also be greatly affected by climate change, which includes an increase in temperature and a shift in the distribution of tree species. Here we present preliminary results of our field study focused on the partitioning of SOC into fractions of SOM in temperate forest topsoils and subsoils under spruce, beech, and mixed forest stands and discuss the follow-up experiments focused on the effects of climate change.

Strong Reduction of Greenhouse Gas Emissions by Shifting Transplanting Dates without Significant Loss of Productivity in a Rice Paddy Field

Yeomyeong Lee, Juhee Lee, Sohee Yoon, Hyerin An and Sang Yoon Kim

Shifting rice transplanting dates can directly or indirectly affects greenhouse gas (GHG as CH4, CO2 and N2O) emissions in particular CH4 by influencing the rice growth characteristics and flooding days in paddy ecosystems. However, no such systemic assessment has been conducted so far. The field experiment was conducted to investigate the feasibility of shifting transplanting dates and their influencing factors for reducing GHG emissions and maintaining productivity in rice paddy. Two different rice cultivars (late-maturing and early-maturing) were transplanted at four different dates on May 10 (Time1), May 25 (Time2) as locally recommended transplanting date, June 10 (Time3), and June 25 (Time4). Regardless of rice cultivar,

the highest CH4 emissions was observed in the early transplanting (Time1), and significantly decreased by 38.2-66.7% with delaying transplanting dates. Our results showed CH4 was accounted for approximately 90% over total GHG emissions, while CO2 and N2O were negligible, indicating CH4 as a major contributor to overall global warming. Rice productivity progressively improved as the transplanting was delayed, reaching the highest level at Time3, and then slightly decreased at Time4. However, there was no significant loss as compared to the recommended transplanting date (Time2). The path analysis statistically revealed a strong positive relationship between CH4 emissions and root biomass, which may closely relate to the quantity and quality of root exudate as methanogenic substrates. Conclusively, delaying rice transplanting date could be a promising and pioneering strategy to effectively reduce GHGs emissions without significant productivity loss in paddy field in the era of climate changes.

Effects of plastic film mulching and stover recycling on soil organic carbon stock changes in maize cropping system

Ho Gyeong Chae, Jeong Gu Lee and Pil Joo Kim

Recently, plastic film mulching (PFM) is popularly utilized to enhance crop productivity, via controlling weeds and improving soil properties. However, PFM can increase not only the net primary production (NPP) as a C input source, but also mineralized C loss as a C output source by improving soil temperature and moisture condition. Moreover, the whole maize aboveground was removed in the present maize cultivation system, and it created negative net ecosystem C balance (NECB). Therefore, additional organic amendment is essential to increase SOC stock and stover recycling can increase SOC stock. To determine the effects of PFM and stover recycling on SOC stock changes, PFM and no-mulching (NM) were designed as main treatment. For the sub-treatment, whole maize aboveground removal (Conventional) and stover recycling were installed. In stover recycling, stover was incorporated as fresh (Fresh) and pyrolyzed (Biochar). PFM improved soil temperature and moisture content by an average of 1.4-1.7°C and 11-20%, respectively, compared to NM. The improved soil environmental conditions increased grain yield by 34-51%. In conventional treatment, NPP and respired C loss under NM were 6.3 and 6.0 Mg ha-1, respectively. PFM increased both of NPP and respired C loss by 12-26 and 26-35% respectively. Compared to conventional treatment, fresh stover recycling increased NPP and respired C loss by 22-27 and 11-23%, respectively. However, Biochar stover recycling decreased NPP 4.5-5.3 Mg ha-1 and respired C loss by 3.1-3.8 Mg ha-1. Although, the stover recycling highly increased NECB compared to conventional treatments by 23 and 47% in fresh and biochar, respectively, all the NECB values showed negative values. Our investigation suggests that pyrolyzed stover recycling was very effective to decrease negative impact of PFM on SOC stock but additional organic matter application such as green manure is recommended to increase SOC stock.

Elucidating the interactions between belowground C allocation and iron cycling in the rice rhizosphere and implications for methane emissions

Alexine Ehlinger, Davide Patono, Luisella Celi and Daniel Said Pullicino

Rice paddies have a large potential for climate change mitigation. Indeed, although these agroecosystems are important methane (CH4) emitters, they can also sequester important amounts of carbon (C). In this project, soil processes linking the belowground C allocation to microbial substrate use efficiency as well as its interaction with Fe cycling and methane production under anaerobic conditions will be evaluated. A planted rice microcosm experiment is being setup with two soils having different pedogenetic Fe contents to test the following hypothesis: (1) root C exudation by the rice plants can represent a labile C source for anaerobic Fe-reducing bacteria, thus stimulating the reductive dissolution of Fe(III) oxides and consequently leading to the release of Fe(II) and soil-derived dissolved organic carbon (DOC) into the soil solution, particularly in soils

with a higher content of pedogenetic Fe; (2) microbial growth and use of rhizodeposited C increases with increasing root C exudation; (3) although CH4 emissions increase with increasing belowground C allocation by rice, the contribution of plant-derived C to CH4 does not necessarily increase due to a higher contribution from soil-derived C (i.e. positive priming effect). Root C exudation will be modulated by applying different doses of N fertilisation, while plant C allocation, net C rhizodeposition and its contribution to soil and microbial C pools, and CH4 emissions will be traced by pulse-chase 13CO2 labelling after the rice tillering stage.

Compositional and structural changes of organic matter during commercial hall composting assessed by humic substances fractionation and py-GC-MS.

Nick Quist, Katharina Duran and Rob Comans

Organic matter (OM) plays a key role in multiple organic-geochemical processes. A key role of OM is that of being a reactive surface to which nutrients and contaminants can bind. This binding, and its associated effect on nutrient and contaminant mobility is affected by compositional and structural (trans)formation of OM during humification. To identify OM (trans)formation during humification we studied the solid organic matter (SOM) / dissolved organic matter (DOM) partitioning and related compositional, structural changes of OM, during household green waste maturation after 1, 2, 3, 5 and 9 weeks of commercial hall composting. We determined the carbon and nitrogen content of SOM and DOM humic substances via rapid-batch fractionation. We characterized the lignin content and molecular structure of SOM and DOM humic acids (HA) and fulvic acids (FA) via pyrolysis gas chromatography/mass spectrometry (Py-GC/MS). The SOM/DOM partitioning of HA showed a distinctive increase. This increase in SOM/DOM partitioning was not found for other humic fractions (FA, hydrophilics and hydrophobic neutrals). HA has the lowest C/N ratio (10) of the determined humic fractions and is affected little by maturation. The N enrichment of HA compared to FA, Hy and HON was also validated by specific N containing pyrolysis products. Distinct differences were found in lignin content and structural components between the SOM and DOM HA and FA. Overall, our data shows compositional and structural transformation of humic substances during household green waste compost maturation, which could affect their contaminant binding affinities.

Defining emission and scaling factors for predicting methane emissions and inventories from Italian rice paddies using country-specific datasets

Lucia Crosetto, Luisella Roberta Celi and Daniel Said Pullicino

Rice cultivation is one of the main anthropogenic sources of methane (CH4) that accounts for 10% of the total emissions from agriculture. Estimating greenhouse gas emissions from rice paddies is becoming increasingly important both to evaluate the effectiveness of water, crop residue and fertilizer management strategies to mitigate climate change, as well as to report on emission inventories at regional or national scale. These estimates are generally based on relatively accurate site-specific measurements (e.g. using non-steady state close chamber approaches) and predictive model outputs, or on more approximate national inventories calculated by adopting Tier 1 IPCC guidelines. However, neither of these approaches are immediately effective at offering decision support to end-users. The aim of the study is to use previously acquired field-scale CH4 emission datasets to define emission and scaling factors from estimating site-specific CH4 emissions from Italian rice paddies, by considering the relationships between pedoclimatic variables, crop characteristics, agronomic management practices (water, crop residue and fertilization management), and emissions. This approach will be further validated at farm-scale and results will be used to evaluate the effectiveness of such an approach to offer ex ante decision support to rice farmers. This research will also contribute to allow a more accurate estimation of national and international inventories (ex post) and to understand potential impact of future changes in management techniques and climate on greenhouse gas emissions from rice

paddies. It will also aid in improving climate change mitigation policies by supporting efforts to reduce methane emissions from rice paddies.

A Comparison of LI-COR 7820 N2O/H2O Analyzer and Manual Static-Chamber for Measuring N2O Emissions from Agricultural Soils

Meng Kong, Søren O. Petersen, Jørgen Eriksen and Christian Dold

Nitrous oxide (N2O) emissions from agricultural soils are a crucial contributor to greenhouse gas emissions. Most published data on N2O emissions from agricultural soils used manual non-steady-state chambers (MC) and gas chromatography to estimate the N2O flux. A new equipment, the LI-COR 7820 N2O/H2O trace gas analyzer (LI-7820) and smart chamber (20 cm diameter) (LI-COR Biosciences, Lincoln, NE, USA), measures N2O at 1 Hz and calculates fluxes within 2 minutes on-site, which could in many studies save time and resources. However, there are limited studies on the feasibility and accuracy of the LI-7820 as compared to MC, leading to uncertainties regarding the comparability of methods. This study aims to evaluate the performance of the LI-7820 compared to MC for measuring N2O fluxes. We hypothesized that the two methods do not differ significantly in measuring N2O fluxes. To test this hypothesis, we are comparing the N2O fluxes of maize and spring barley plots (n=3 in randomized blocks) with different mineral N and cattle slurry inputs from April to July 2023; each plot is equipped with one collar (74x74 cm2) for MC and 3 collars (20-cm diameter) for LI-7820. Preliminary results found no significant difference ($p>0.05$) between a 2-min and 10-min flux with the LI-7820, suggesting that longer measurement time is not required. The 2-min N2O fluxes measured with LI-7820 prior to fertilization were low, but significantly correlated to MC ($r= 0.51$, $p<0.001$); a dataset including the period after fertilization will be presented.

The green areas of the city of Barcelona as carbon sinks: a pilot study

Sílvia Poblador, Lucilla Boito, Arthur Vienne, Francesc Sabater and Sara Vicca

In order to limit global warming below the 2°C, as agreed in the United Nations Paris Agreement, we need both rapid decarbonization and the implementation of negative emissions technologies (NETs), that actively remove CO2 from the atmosphere and ensure stable long-term carbon storage. In agroecosystems, enhanced silicate weathering (ESW) is a promising NET that has been associated with multiple co-benefits for crop production by spreading silicate minerals on arable soils (i.e. increase in crop yields, restoration of soil base cations and micro- and macronutrient stocks). Besides agricultural land, also urban soils can be suitable for EWS; application of ESW in parcs and gardens represents an opportunity to increase the capture of atmospheric CO2, while also favoring the vegetation growth (lawn, shrubs and flowers) and potentially increasing resistance to drought and pests. EMBARCARB is a pilot project that aims to increase soil carbon sequestration and improve the vegetation status in two parcs of the city of Barcelona (SE Iberian Peninsula). Moreover, the project also aims to compare the carbon sequestration capacity of soils with weathering of silicate rocks and concrete demolition fines, thus reusing construction debris and strengthening the circular economy of the area. Here, we explore the design and preliminary results of the project.

Can soil quality monitoring networks be used for assessing changes of bulk density? A case study in France.

Jose-Luis Munera-Echeverri, Manuel Martin, Line Boulonne, Nicolas Saby and Dominique Arrouays

Bulk density (BD) and coarse fragments (CF) are often missing in soil monitoring networks. In the French Soil Quality Monitoring Network, BD and CF have been measured in two campaigns down to 50 cm in sites

distributed over the mainland territory. Thus, the objective of this work is to evaluate i) the change of BD and CF, ii) the effect of volumetric methods and land use on the observed changes, and iii) to simulate the impact of the changes of BD and CF on the change of soil organic carbon (SOC) stocks. The results showed that there was no significant change of (Δ) CF between campaigns in either the topsoil (0-30cm) or subsoil (30-50cm), while there was a significant decrease of BD only in the topsoil which corresponded to -3.1±0.9 %. When methods were constant in both campaigns, BD decreased in the topsoil in croplands and grasslands and it did not change in forests. We could explain a rather low part of the ΔBD variance (R2=0.21), which was mostly linked to the site-specific changes of CF. We simulated the changes of SOC stocks assuming SOC constant over time and i) site-specific BD of each campaign and a site-specific CF average of the two campaigns, and ii) site-specific BD and CF values of each campaign. We ran the simulations in stony vs non-stony soils and assessed in which scenario we found the largest consequences for SOC stock changes. The results will help to improve the assessment of SOC stock changes.

The effect of pH on dissolved organic matter fractions in solid waste

Frank van Raffe and Rob Comans

Organic matter (OM) is of high importance for the availability and mobility of nutrients and contaminants; they provide a binding surface and retain compounds when present as solid organic matter (SOM), or enhance mobility when present as dissolved organic matter (DOM). The partitioning between SOM and DOM is dependent on a variety of environmental parameters, a key parameter being the soil pH. pH dependent tests were conducted on solid waste from three different landfills. These samples contain OM of different origins, to further enhance insights on the role of pH for different types of OM. The samples were extracted at 8 different pH levels between pH 2 and 12, taking a pH range beyond environmental relevance to better elucidate mechanisms of importance, e.g. electrostatic repulsion or co-precipitation with oxides. Samples were analysed for organic matter concentration and concentrations of humic substances, the latter traditionally providing a proxy for "reactive" organic matter to which compounds can bind. All samples showed increasing DOC concentrations with increasing pH, bar between pH 2 – 4, where decreasing pH resulted in increased DOC concentration. This effect at low pH was particularly pronounced for the soil remediation waste samples relatively poor in organic matter. Humic substances showed that with increasing pH the relative contribution of humic acid increased, the relative contribution of hydrophilic acid decreased, and the relative contribution peaked around pH 7. These changes in humic substance solubility correlated with the solubility of various compounds with high OM affinity, e.g. Chromium and Copper.

Assessing the soil respiration in soils treated with composts with varying C: N ratios

Nuusiku Nakwafila

Organic amendments play a critical role in sustaining soil health and providing a valuable carbon source to the soil. Despite being commonly used in New Zealand, the impact of composts with different C: N ratios on decomposition rates in different soils has yet to be extensively researched. This study aims to address this gap by investigating the decomposition rates of two composts with different C: N ratios, added at different rates to soils with varying carbon concentrations in New Zealand. The study involved adding Composts 1 and 2 at two carbon rates (10% and 20%) to four soils with different carbon concentrations and monitoring CO2 emissions over a period of three months. The soils were incubated at a constant temperature of 15 °C and 70% total water holding capacity. The results showed no significant difference in the decomposition rates between the two composts, although both composts exhibited high CO2 release at the 20% rate. Additionally, soils with high carbon concentrations displayed high respiration rates. These findings indicate that compost has limited influence on respiration rates unless applied at high rates. The loading of soil carbon was found to have a greater influence on decomposition rates than the type of compost. These findings have

practical implications for determining the optimal compost composition for different soil types in New Zealand.

Can selective use of forage species improve soil quality in subtropical smallholder farming

Niklas Wickander, Peter Dörsch and Marit Jørgensen

Livestock is vital for food security and economy for a large part of the population in Ethiopia. The country has the highest livestock numbers in Africa, but cultivation of forage crops is still not common. Most of the feed for the animals is derived from crop residues after harvest, and during the dry season, the livestock roams freely and grazes on communal land. The intensive grazing causes a low nutrient return to the soil, which leads to severe degradation of the soil quality. We are investigating how introduction of selected perennial forage species impacts microbial activity in the soil and if it potentially improves soil quality. We use four different forage species, the grasses Brachiaria hybrid Cayman and Panicum maximum, and the legumes Desmodium intortum and Stylosanthes guianensis, in a greenhouse experiment. The plants are grown in quartz sand inoculated with four Ethiopian farm soils, two from the southern Sidama region and two from the northern Amhara region. The plants are grown in single stands and in two-species mixtures of Cayman and P. maximum, and Cayman and D. intortum, for 12 weeks. To assess potential plant effects on the soils, we will sample the soil at the end of the experiment and determine microbial biomass carbon, nitrogen and phosphorus, and the enzymatic activity of four enzymes involved in C, N and P acquisition. This will be compared to a time zero analysis of the soil to discern the impact the plants have on the soil microbial nutrient stoichiometry.

Towards a model of forest soil carbon dynamics under tree species composition shift

Olga Vindušková, Gaby Deckmyn, Kateřina Jandová and Veronika Jílková

Temperate forests will be undergoing a shift from coniferous to deciduous species as forest management responds to climate change. However, predicting the impact of such shift on soil carbon (C) dynamics will require soil C models that include all relevant mechanisms. Furthermore, advancing from the use of theoretical, kinetically defined soil organic matter (SOM) pools to empirically defined SOM fractions such as particulate organic matter (POM) and mineral-associated organic matter (MAOM) has been suggested as a way to improve C models. Both POM and MAOM decomposition may be increased by DOC (dissolved organic carbon) inputs via the priming effect (PE) which is stronger in less-protected fractions (i.e., POM) and is also influenced by the DOC input quality. In our previous study, we showed that spruce litter leachates induced a higher PE than root exudates. Even though PE effects could reduce soil organic C gains from enhanced ecosystem productivity under global change, the PE has been introduced to few models only recently; none of them, however, considers how C input quality affects the PE. The recently introduced KEYLINK model allows to model the interaction between C dynamics, soil biota and soil structure, but requires further validation with experimental data. Here we review which of the currently available models of C turnover include empirically defined SOM pools (POM and MAOM), PE and effects of soil biota and propose how to combine these into a model that is capable of modelling the impact of shift in tree species composition on forest C stocks.

The Interplay of Biotic and Abiotic Processes that Stabilizes Soil Organic Carbon During Water Erosion

Nan Zhang and Elly Morriën

Soil erosion is a major threat for soil biodiversity. Especially, loess soils in hilly landscapes under intensive agriculture practices face the risk to lose top-soil and valuable soil biodiversity during water erosion. Currently,

we lack fundamental understanding how/if we can protect soil biodiversity from water erosion by stimulating a healthy soil community which will lead increases in soil carbon stocks. Aim: Our research aims to unravel the interplay between biological components and inorganic phases in stabilizing soil organic carbon(SOC) during water erosion in loess soil. We study: i) under which circumstances erosion processes and SOC loss is minimized; ii) which biotic components(plants, microbes and their exudates) stabilize OC; iii) in which form SOC is stabilized. Method: We set up plant-soil systems with Trifolium pratense and Lolium perenne in loess soil of a low and high SOC content. We grew the plants with mycorrhizal inoculum versus no-inoculum added in low-SOC soil to test if arbuscular mycorrhiza fungi (AMF) is able to prevent soil erosion. The plants grew 8 weeks on a slope followed by simulated rainfall. Runoff, root and soil samples were collected; biological parameters: soil microbial biomass, extracellular polymeric substances, fungal biomass, root AMF colonization, and abiotic parameters: aggregate stability, SOC fractions were measured. Results: Our preliminary results showed that a commercial AMF inoculant caused a significant increase of root AMF colonization of Lolium perenne in low-SOC soil, while Trifolium pratense was more successful than Lolium perenne in reducing runoff and soil loss. More results are expected to come out.

Soil structure changes over time, and it matters!

Anne-Catherine Renard, Clémence Pirlot and Aurore Degré

The emergence of alternative agricultural practices aims to create sustainable production systems to meet future dietary needs. These practices and climate changes (Linnerooth-Bayer et al., 2015) will affect soil structure and hydraulic properties (Chandrasekhar et al., 2018). However, most models do not consider changes in hydraulic properties over time, leading to incorrect decisions. Therefore, understanding these changes is crucial. This study aimed to monitor the temporal evolution of hydraulic properties in three innovative production systems up to 90 cm depth. The project focuses on the value and resilience of innovative rotation systems (vegan, agro-ecological, off-soil). For this purpose, different theoretical water retention curves (WRCs) such as pedotransfer functions (PTFs) (HYPRES and ROSETTA 1,2,3 and EU-HYDI) were evaluated and compared. The EU-HYDI WRC were then compared with i) experimental WRC determined by an evaporation method (Schindler et al., 2006); ii) continuous measurements taken in situ. Results showed that theoretical EU-HYDI WRCs were overestimated, and there were technical limitations in visualizing soil dynamics below the sensor threshold. Continuous measurements were analysed for each plot's three horizons (30, 60 and 90 cm) at different time scales, highlighting the impact of annual rainfall on the soil retention profile and the influence of agronomic itineraries. A comparative analysis of WRC and yield was performed. The communication will present the first results.

The effect of carbon produced by methane plasmalysis (CMP) on bioavailable nutrient fractions in soils

Nadine Abu Zahra, Celia Fernández Balado, Veronika Kanzler, Robert Obenaus-Emler, Stefan Wagner, Markus Puschenreiter and Thomas Prohaska

Soil degradation affects its physical, chemical, and biological properties. Carbon in form of biochar has been applied to improve soil quality, resulting in greater crop growth. An emerging side stream material from hydrogen production may serve as a soil amendment that potentially increases bioavailable nutrient fractions in soils: CMP – a solid carbon produced by methane plasmalysis. This study aims to investigate the potential increase of bioavailable nutrients in soils by CMP application. As the effect of CMP on nutrient availability and uptake remain unexplored, growth experiments were conducted. After the chemical characterization of CMP, maize (Zea mays L.) response to CMP application was assessed in (a) a greenhouse experiment using three different soils with pH of 7.6, 5.4 and 4.6, respectively, and (b) a field trial in Austria. The effect of CMP was assessed by analyzing plant-available nutrient fractions in soil along with nutrient uptake in

above-ground tissues of maize. Depending on the soil type, the results of the greenhouse experiment showed that maize biomass increased significantly ($p < 0.01$) from 1.2 g pot-1 in controls to 2.2 g pot-1 in soils amended with CMP at 25 g kg-1. In the field trial, elevated extractable P levels in CMP-treated plots (90.4 mg kg-1) as compared to controls (73.2 mg kg-1) were observed ($p < 0.08$), likely indicating mobilization of plant-available P due to CMP addition to soil. These results demonstrate the potential of CMP for agricultural applications, improving soil properties, especially in soils with low nutrient availability and acidic pH.

Microplastic Transport in soil columns as Affected by Irrigation Intensity

Rozita Soltani Tehrani, Jos van Dam and Xiaomei Yang

Plastics are synthetic polymer materials that have emerged as contaminants in soil, posing a significant risk to ecological systems and human health due to their wide distribution and potential negative impacts. This study aims to investigate the transport of three types of microplastics (LDPE, PBAT, and starch-based plastic), each with a size of smaller than 250 μm, through soil columns and to examine the impact of irrigation intensity on their movement. To achieve this goal, we set up soil columns filled with loam soil, into which we mixed 7 g of one type of microplastic into the top 10 cm (1200 g of soil). Subsequently, we applied irrigation on the top of the soil column and collected the water samples that drained from the bottom of each soil column to examine the transport of microplastics. Additionally, at the end of the experiment, soil samples were taken from each column to determine the distribution of microplastics in the soil. The soil columns were kept in an unsaturated condition throughout the experiment. Our results demonstrate that irrigation intensity plays a significant role in the transport of all three types of microplastic in soil columns. Specifically, higher irrigation intensity led to greater transport of all three types of microplastics through the soil columns. We also found that LDPE showed the highest degree of transport, while PBAT and starch-based microplastic showed a lower degree of transport. Overall, the study highlights the importance of considering both types of microplastic and irrigation practices in the management of microplastic pollution in the environment. By understanding the transport and distribution of different types of microplastic, we can develop effective strategies for mitigating their impact on the environment.

Winter cover crops in Santiago del Estero: I. Biomass, evapotranspiration and water use efficiency

Salvador Prieto Angueira, Maria Clara Berton and Javier Ventura

Cover Crops (CC) in agricultural systems probed to be a natural contribution to sustainable food production, reducing soil and water degradation. However, in Santiago del Estero, because rainfall concentrates in the warm summer, it is unknown whether winter CC (wCC) would be successful, due water limitations and therefore low biomass production (B), or real evapotranspiration (ETr) higher than fallow and therefore decrease in the available water (AW) for subsequent crops. To quantify the production of aerial biomass (B), ETr and water use efficiency (WUE, relation between B and ETr) of different Wcc, an experiment was carried out in 2016 and 2017 seasons (S) in Quimilí, with 6 wCC: short (W-sh) and long (W-lg) cycle wheat, short cycle rye (Ry-sh), long cycle triticale (Tt), hairy vetch (Vv), white sweet clover (Clv). wWC were dried at flowering and B, ETr and WUE were determined. Response of wCCs varied between seasons (significant S*wCC interaction -$p<0.0001$- in all variables). Changes in B were associated with: i) drying time, ii) AW at sowing and iii) sensitivity to frost. ETr were significantly ($p<0.05$) higher in the wCC with longer cycle (Vv and Clv). Although there was interaction, WUE was significantly ($p<0.05$) higher in cereal wCC. Results show that it is feasible to include wCC in the semi-arid Chaco region of Argentina but with high interaction in their behavior. Regardless of wCC, the highest ETr and therefore biomass production is associated with late drying, but with interaction between wCC and environment.

Thursday

Plenary

Keynote lecture: Challenges to provide cross scale soil function maps for soil policy

Madlene Nussbaum

European policy makers show a previously unknown interest in soil and quantifying, monitoring, protecting or improving its functions and services to society. Increasing efforts have therefore been made to map soil properties and asses functions in space and/or time. Several challenges hamper the provisioning of the required soil data to implement new legal frameworks to take policy decisions and effectively protect soil functions as intended. Relevant soil measurements are often not available to evaluate soil function indicators. Even if basic soil properties were observed more complex attributes are missing and need to be approximated (e. g. soil density, structural and biological attributes). These approximations and lack of high resolution survey results in prediction uncertainty in many cases larger than the level of decision or the temporal changes evaluated. Even if changes for example due to different management practices are significant, functional effect remains unclear for many indicators. A change in soil function indicator for primary production might remain irrelevant as biomass production is not substantially altered.

3D+T mapping reveals soil organic matter changes between 1953 and 2022 at 25m resolution in the Netherlands

Anatol Helfenstein, Vera L. Mulder, Gerard B.M. Heuvelink and Mirjam J.D. Hack-ten Broeke

The Soil Deal for Europe is expected to yield valuable outcomes, including a better understanding of how soil health supports soil functions. Soil organic matter (SOM) is crucial for multiple soil functions, including carbon and climate regulation and nutrient cycling. Consequently, a better understanding of soil health and soil functions largely hinges on the role of SOM, which varies across space, depth, and time. As a result, high-resolution, spatio-temporally explicit assessment of SOM is required to enable management and land use decisions that are tailored to local soil conditions. We developed a modelling platform in 3D space and time (3D+T) as a new paradigm for monitoring and mapping SOM. It provides annual predictions of SOM and its uncertainty in the Netherlands at 25m resolution between 0-2m depth from 1953-2022. This innovative tool enables the identification of areas with high risk of greenhouse gas emissions and areas with potential for carbon sequestration. Furthermore, it represents a crucial first step towards establishing scientifically-backed threshold values that link SOM to soil health and carbon credits. From 1953 to 2022 we found SOM decreases of >25% in bogs and brook valleys, average decreases of 0.1-0.3% on croplands on mineral soils, and changes between 10-25% on reclaimed land due to land subsidence. Hence, SOM was highly variable over depth and time. The novel use of 3D+T spatially explicit environmental covariates has the advantage that we let machine learning detect complex relationships between SOM and peat occurrence in 3D space and time. Therefore, the implications of this research extend beyond the examined spatio-temporal domain. We can identify the key drivers of SOM changes and predict future dynamics. In addition, our findings are relevant for areas worldwide undergoing peatland conversion, land reclamation, and agricultural intensification.

Field history matters: the effect of spatiotemporal dynamics and management practices on the soil bacterial and fungal communities in two agricultural fields

Lisa Joos, Sarah Ommeslag, Steve Baeyen, Wouter Asselberg, Koen Van Loo, Lieven Clement, Jane Debode, Bart Vandecasteele and Caroline De Tender

The spatiotemporal dynamics of soil microbial communities, even within more homogeneously managed agricultural fields, are complex and variable. However, most studies only sample one field or use limited samples over time, leading to a lack of comprehensive understanding of the microbial community dynamics. In this study, we aimed to identify the spatial and temporal variability of bacterial and fungal communities in relation to the impact of organic amendments (biochar and compost) in two agricultural fields. Over the course of a year, thirteen sampling events were conducted every five weeks in two fields: Field A amended with biochar and sampled at a depth of 0-25 cm, and Field B amended with compost and sampled from 0-10 cm and 10-30 cm. The microbial community was studied by metabarcoding, metatranscriptomics, HWC, and PLFA. The sampling period encompassed diverse weather conditions, including a cold winter and a dry and warm summer with a heatwave. Strong spatiotemporal effects were observed, depending on the field, sampling depth, and microbial community studied. Bacterial communities in the top layer showed strong temporal trends, while fungal communities exhibited stronger spatial differences related to the history of the field. Functional categories were mainly influenced by temporal trends and were not affected by compost amendment. These findings highlight the complexity of the soil environment and microbial communities, emphasizing the importance of well-designed experiments and sampling scheme.

Detection of soil compaction effects on crop growth using drone images

Adriaan Vanderhasselt, Pamela Fernanda Mejia Leyva and Wim Cornelis

Soil compaction has become one of the main threats to the well-functioning of arable soils in Western-Europe. The use of ever-heavier farming machinery and the increased share of crops with a late-season harvest, like maize and potatoes, in the rotation have systematically increased the risk of soil compaction during the recent decades and have pushed the impact down into the deeper subsoil. Detecting soil compaction at these depths with the standard measuring techniques can be very difficult and labor intensive. Therefore, it remains interesting to find innovative techniques that would allow for a quick and reliable detection of this problem. In this regard, we evaluated the potential to use drone image derived parameters, like excess green vegetation index (ExG) and canopy height models (CHM), to assess the level of (sub)soil compaction and to get a better view of in-field variation. Regular drone images were taken of three experimental fields in Flanders, Belgium, for which the penetration resistance was measured extensively. Linear regressions between CHM, ExG and PR were established. These regressions showed that the above ground traits of the crops were explained to a certain degree by the presence of a compacted layer. This supports the idea that remote sensing can be used in the detection of compaction and its spatial variation. ExG showed a slightly higher level of correlation with the compacted layer in one of the fields, but no other significant correlation was found. CHM had a good correlation with the penetration resistance on two fields.

Development and testing of site-specific fertiliser formulations for crops in sub-Saharan Africa

Johan Leenaars, Lieven Claessens, Gerard Ros, Wim de Vries, Pepijn van Oort, Kazuki Saito, Sara Dahhani and Ramatoulaye Ndiaye

Soil fertility is recognised as a prime factor limiting agricultural productivity in sub-Saharan Africa and needs targeted management. OCP Africa initiated a long term R&D collaboration with ISRIC World Soil Information

to develop and test site-specific fertiliser formulations for important farming systems in Africa. The approach is based on spatio-temporal nutrient gap analysis wherein crop nutrient demand is compared with soil nutrient supply and fertiliser efficiency codetermined by water-nutrient interactions. Proof of concept is provided for irrigated rice in selected areas in Senegal and Mali. First, we modelled supply and potential uptake of soil- and fertiliser nutrients as driven by transpiration with INITIATOR, crop nutrient demand, uptake and yield with QUEFTS (in which we integrated Cu, Zn, B, S) and attainable yield with ORYZA, using data from local trials and Africa SoilGrids. Then we sampled soil rootable depth in the areas of interest and used the soil analytical results to produce area-specific updates of Africa SoilGrids. We calculated site-specific fertiliser formulations at 250m resolution which we generalised to three spatial recommendation domains per country. The recommended fertilisers were blended by OCP and validated onfarm relative to default recommendations. Grain yield response to the new formulations is on average 160 to 221 % of the response to the default in Mali and 111 to 215 % in Senegal (significant at α=0.05 in five of the six domains). The outperformance is firstly explained by the site-specificness of the new fertilisers and secondly by the inclusion of micronutrients.

Parallel Session

S1: Soil monitoring and mapping

Interpreting and evaluating digital soil mapping prediction uncertainty: a case study using texture from SoilGrids

Gerard Heuvelink, Linda Lilburne and Anatol Helfenstein

Digital soil maps have become increasingly popular, but their quality is influenced by several factors, such as the mapping algorithm, calibration data size and quality, and the relevance of co-variates used. To address this issue, spatially explicit prediction uncertainty information has been introduced in digital soil mapping, commonly in the form of a 90% prediction interval. In this study, we assessed the validity of spatially explicit prediction uncertainty information for SoilGrids sand, silt, and clay layers in the Netherlands and New Zealand. We used completely independent data sets from both countries and evaluated the uncertainty information using quantitative metrics and graphical tools. Our findings showed that prediction intervals were wide in both countries, despite SoilGrids having more calibration points in the Netherlands than in New Zealand. There was no correlation between the prediction interval width and the sampling density of the training data. Spatially, the prediction interval width varied significantly in the Netherlands compared to New Zealand. Moreover, independent validation revealed that the clay prediction intervals were too wide in both countries, while sand prediction intervals were too narrow. Further comparison of prediction errors with prediction interval widths at validation locations showed that the prediction errors tended to be larger at locations with wider prediction intervals. Our analyses highlight the importance of producers evaluating the validity of the uncertainty information before releasing digital soil maps. Likewise, users must also consider the soil uncertainty information before using the soil maps. Understanding the limitations of digital soil maps is crucial, as it allows for better decision-making in soil management and use.

Effects of modern and historic landscape context on soil fungal diversity of arable fields

Tanel Vahter, Inga Hiiesalu, Oscar Zarate-Martinez and Maarja Öpik

Historic land-use context has been found to be an important predictor for current species diversity and distribution patterns for different organism groups. While there is some evidence to support the linkage

between modern landscape configuration and soil biodiversity, the scale at which historic landscape legacy applies to soil microbial communities is largely unknown. To assess this, we carried out a spatially intensive sampling of three agricultural fields in Estonia with the aim to describe the effects of current and historic land-use context on soil fungal diversity. The fields and their surrounding landscapes' land use has been recorded on maps since the turn of the 18th to 19th century, depicting the management succession from forested and seminatural areas to arable field. We sampled these fields in a 100 meter grid, comprising 100 soil samples in total. Soil total, and AM fungal diversity were determined by DNA metabarcoding, supplemented by measurements of soil genetic, physical and chemical properties. Historic land use was extracted by digitizing available historical maps. Our results indicate that while soil properties account for the majority of soil fungal variation, historic late 18th century landscape configuration is more strongly related to modern day fungal distribution than the current landscape. While management and modern anthropogenic pressures can be useful in assessing both regional and macroecological species distributions, historical legacies could be persistent and affect these assessments at local scales.

Mapping soil carbon and organic soil condition in Scotland

Matt Aitkenhead, Fraser Macfarlane, Ciaran Robb, Malcolm Coull and Margaret McKeen

Peat soils (histosols) are important for multiple reasons, including carbon storage, water supply and biodiversity support. They are demonstrably important for all four types of ecosystem service (provisioning, supporting, regulating and cultural). In Scotland, 25-28% of soils are peat by area, with the Scottish definition of peat being relatively conservative (i.e. if the World Reference Base definition were used, a much larger area would be classified as peat/histosol). Previous work on mapping peat depth and condition in Scotland has provided maps with reasonable accuracy at 100 metre resolution, allowing land managers and policymakers to both plan and manage these soils and to work towards identifying priority peat sites for restoration. However, the spatial variability of peat depth and the surface condition is much finer than this scale, limiting our ability to inventory greenhouse gas emissions or develop site-specific restoration and management plans. Here we demonstrate work that has mapped peat drainage channels and erosion features at a national level and a fine spatial scale (25 cm), and mapping of depth and carbon stocks of all Scottish soils at 10 metre resolution, using combined remote sensing and digital soil mapping approaches. The mapping of peat drainage and erosion will allow more precise and quantifiable understanding of the distribution of key peatland condition classes. It will also provide baseline information for planned and ongoing research within the Scottish Government's Strategic Research Programme.

Improving cropland N, P and K nutrient budgets through local and global data

Cameron Ludemann, Renske Hijbeek, Marloes van Loon, T. Scott Murrell, Achim Dobermann and Martin van Ittersum

Cropland nutrient budgets show the difference between the inputs and outputs of nutrients to an area of land over a specified period of time. They are useful to aid decision-making for nutrient management, both from an agricultural and environmental point of view, and can indicate 'hot-spot' locations with a surplus or deficiency in nutrients. Estimates of cropland nutrient budgets at national to global scales typically rely on average nutrient concentrations of crop components removed from the soil. Given the wide-spread use of nutrient budgets it is important that more locally relevant coefficients or models are developed. Using maize as an example, we assessed how much a country's estimated nutrient removal is affected when using global (Tier 1), regional (Tier 2) or national/sub-national (Tier 3) estimates of harvest index and nutrient concentrations of crop products and crop residues. Estimates of cropland removal of nitrogen, phosphorus and potassium varied substantially (up to 54%), depending on which Tier approach was used. This had considerable impact on national nutrient budgets. Therefore, if Tier 2 data are not available, Tier 3 offers a

methodology to overcome such data limitations through the application of models, trained on localized but widely available data for countries. The methodology used for maize will also be applied to other crops to improve cropland nutrient budgets and estimates of crop nutrient use efficiencies.

S2: Soil in space and time

Resampling soil physical libraries at three decades of interval for studying soil changes across Swiss habitats

Sarah Semeraro, Roxane Tuchschmid, Jean-Michel Gobat, Sergio Rasmann and Renée-Claire Le Bayon

Soils contribute a vital role in supporting human well-being and environmental sustainability. For example, the largest fraction of carbon on Earth is stored in soils. Soils, also evolve through time, depending on the local biotic and abiotic factors of the ecosystem. Therefore, monitoring soil evolution across ecosystems will help to better mitigate the anthropogenic impact on soils degradation. However, soil evolve and change over the timespan of multiple human lives, therefore, monitoring soil changes across time is often limited to the study of chronosequences. Yet, a novel approach using soil physical libraries, which are repositories of old soil profile samples, has emerged recently, but rarely for comparing entire soil profiles across a variety of ecosystems. We here took advantage of a physical soil library that, since the 1990s has stored >4000 samples of soil samples from around Switzerland. By re-visiting 28 fully described (>250 soil horizons) and geographically traceable soil profiles found in different habitats and across >2000 meters in elevation span, we asked whether it was possible to detect broad-level changes in soil physicochemical properties over 20-30 years, and second, whether climate would drive variation in these changes. We found that across all soil profiles, CN ratio increased by 10% and that low elevation soils with higher solar radiation were more prone to change. We also however observed site specific changes, indicating high context-dependency in which soil parameters are more likely to change. Together, this work highlights the usefulness of physical soil libraries for estimating the effect of climate on soil evolution over time.

Estimating soil organic carbon stock change at regional scales: Challenges and possible solutions

Gábor Szatmári, Gerard Heuvelink, Annamária Laborczi, Béla Pirkó, Sándor Koós, Zsófia Bakacsi and László Pásztor

Many national and international initiatives rely on spatially explicit information on soil organic carbon (SOC) stock change to support policies aiming at climate change mitigation, water security, food security and land degradation neutrality. In the past few years we have made efforts to predict SOC stock and its change and quantify the uncertainty associated with these predictions for Hungary using advanced digital soil mapping (DSM) techniques. In doing so we faced a number of challenges. For example, uncertainty quantification approaches that assume normality and homoscedasticity of the error distribution may yield inaccurate uncertainty quantifications as data on SOC stock are frequently found to be positively skewed and have a positive relation between prediction uncertainty and predicted value. We also experienced that prediction uncertainty of spatial averages is strongly dependent on the spatial correlation of prediction errors. Even if we find a DSM technique that is accurate in both the spatial prediction and uncertainty quantification, uncertainty of predictions at small supports may be too large to detect statistically significant SOC stock changes. Furthermore, prediction errors for different years may be correlated, which should be taken into account in order to reliably characterize the uncertainty of SOC stock change. Using the example of Hungary, our aim is to illustrate these challenges and present some possible solutions and discuss them in a broader context. This may help not just to yield accurate and reliable predictions of SOC stock change but also to better understand its spatiotemporal variability.

The potential of integrating process-oriented model into machine learning framework for soil carbon modelling in space and time: a case study in a cropland area in China

Lei Zhang, GerardB.M. Heuvelink and Vera Leatitia Mulder

Monitoring and modelling soil organic carbon (SOC) in space and time can help us better understand soil carbon dynamics and essential for predicting and mitigating future climate change. However, since carbon stocks in soils have complex variations influenced by natural and anthropogenic factors, space-time modelling of soil carbon is usually challenging in the research field of digital soil mapping (DSM), especially in areas represented by agricultural lands that are strong affected by human activities. Although machine learning (ML) have attracted many attentions in the DSM community for their powerful learning ability to generate soil-environment relationships, its drawback of the 'black box' problem still hampers the effective representation of existing pedological knowledge in soil predictions. By contrast, some existing process-oriented (PO) models (e.g. RothC model) explicitly describe the accumulation and decomposition of SOC. These models have the mechanistic knowledge built in for expressing physical, chemical and biological processes that influence soil carbon dynamics and turnover rates of different carbon pools. Therefore, considering the benefits and drawbacks of PO and ML models, it naturally aroused our research interest to integrate these two kinds of model for pursuing more robust soil carbon predictions in space and time. In this study, the scientific issue addressed is how to form a general framework that integrates PO and ML models to achieve a hybrid model dual-driven by the soil process mechanism and observed sample data. The proposed methodology is tested in an application scenario predicting SOC stocks in space and time over a cropland area located in eastern China. The proposed integration strategy and its comparisons with the single models were evaluated by analyzing their modelling results in spatial patterns, temporal trends and prediction accuracies.

Synthesizing recent advances in understanding spatial and temporal dynamics of phosphorus cycling in soil

Julian Helfenstein

Improved phosphorus (P) management is essential for achieving sustainable development goals related to food production, clean water supply, climate mitigation, and conserving biodiversity. However, despite the importance of P and clear signs that our alterations of the global P cycle are threatening planetary health, until very recently little was known about the global distribution and availability of P in soils. In this contribution I will synthesize recent published and not-yet-published research on spatial and temporal dynamics of P cycling in soil. First, I will summarize how improvements in data availability and harmonization have improved global maps of P pools. This is promoting a better understanding of the relative importance of anthropogenic versus natural drivers of P distribution at large spatial scales. Although these advances improve our understanding of P stocks, linking stocks to ecosystem services requires knowledge of the turnover and fluxes between these pools. Therefore, in a second step, I will summarize how isotopic tracers have enabled quantification of turnover of different P pools and how natural fluxes to, from, and within the soil compare to anthropogenic fluxes. Finally, I will discuss the implications of these findings for modeling and policy making, as well as research gaps. This contribution will provide critical insights into recent advances in quantifying the P cycle and mapping P in soils, as well as its impact on global sustainability goals.

Visualizing heterogeneous microenvironments: in-situ application of planar optodes in agricultural soils

Martin Reinhard Rasmussen, Klaus Koren and Klaus Butterbach-Bahl

Greenhouse gas emissions and nutrient leaching, and their impact on our environment, are subjects of intense discussion due to the high quantities of fertilizers used on agricultural soils. However, the transition to sustainable agricultural practices that balance productivity and reducing environmental harm can only be achieved by a better understanding of biogeochemical cycles in soil. Soil emissions are affected by the complex, heterogeneous soil matrix with microscale variations of soil parameters like pH, O2, and NH3. In recent studies, we showed that planar optodes can be used to elucidate the significance of soil microenvironments by visualizing, in 2D, the spatiotemporal dynamics of these soil parameters after the application of artificial fertilizer or manure. We further aim to bring this proven measurement approach to the field by developing a novel in-situ platform for parameter visualization of pH, O2, and NH3. Our current proof-of-concept prototype is based on relatively cheap and compact components housed in a ø250 mm plexiglass cylinder, allowing for 360° image acquisition and capabilities for measuring vertical or horizontal landscape gradients over several meters. We will target the in-situ application of planar optodes in agricultural soils to examine fluctuations in soil microenvironments over changing seasons, gradients, and landscape management. Thereby, providing data on soil biogeochemical heterogeneity that can be coupled to the formation of "hot spots" and "hot moments" of soil surface N2O emissions. Integration of new in-situ data into existing landscape emission models could further improve climate adaptation strategies of agricultural food systems.

S3: Remote and proximal sensing

Sentinel-2 Imagery for Monitoring Exogenous Organic Matter Fertilizers on Winter Wheat Crop: Proximal and Satellite Approaches

Maxence Dodin, Florent Levavasseur, Antoine Savoie, Lucie Martin, Jean Foulon and Emmanuelle Vaudour

The use of exogenous organic matter (EOM) fertilizers, such as digestate and cattle slurry, has gained increasing attention due to their potential to reduce reliance on synthetic fertilizers in agriculture. This study evaluated the utility of Sentinel-2 imagery for monitoring different liquid EOM fertilizers applied on winter wheat crop, using both proximal and satellite scales. At the proximal scale, spectral field measurements were taken of experimental fields consisting of three treatments (cattle slurry, liquid and raw digestates) and a control over 46 days. Field reflectance spectra were simulated into the MSI spectral bands of Sentinel-2. At the satellite scale, Sentinel-2 images were analyzed before and after EOM application for each experimental field. EOM and vegetation indices were used to monitor EOM application at both scales. The main findings of this study refer to digestates. Firstly, the spread of digestates on emerging wheat can be easily detected in late winter, up to 15 days after application. Secondly, the visible to near infrared bands are the most impacted the first days after spreading and the visible to red-edge bands are persistently impacted 15 days after spreading. Finally, the detection of spring spreading events is constrained or even hindered by developed vegetation. These findings did not apply to cattle slurry, which was hardly visible in the field and in Sentinel-2 images. This Sentinel-2-based approach can serve as a primer for further implementation over larger fields.

Integrated crop and soil organic matter model for arable cropping systems

Ines Astrid Tougma, Marijn Van de Broek, Heidi Webber and Johan Six

Soil organic matter (SOM) dynamics play a fundamental role in many environmental processes. In agricultural systems, there is uncertainty around the effect of climate extremes on SOM transformations, plant growth

and nitrate leaching in the current climate and future climate conditions. Process-based simulation modelling can aid in understanding these complex processes and their interactions with crops and climate conditions and support improved nitrogen management in cropping systems. Against this background, the overall objective of this study is to develop a process-based soil organic carbon and nitrogen model and link it with a crop model to get an integrated soil-crop model. The soil model developed is novel in that it represents organic matter in measurable pools (particulate organic matter versus mineral-associated organic matter), unlike most soil models in agriculture, which use conceptual pools. This makes it possible to calibrate the model with each pools sizes, making it more accurate than calibration against total carbon or nitrogen. The soil model also includes the simulation of Δ14C to better constrain the turnover time of slowly cycling soil organic carbon pools. It will be calibrated with weather, plant biomass and soil data that have been collected in the patchCROP experimental site, Tempelberg, Brandenburg, Germany. The soil-crop model will be an open-source code in the SIMPLACE modelling framework that the scientific community can use for different purposes, for example, to improve the simulation of crops yield, carbon sequestration, nitrate leaching and nitrous oxides emissions for different soil characteristics under uncertain weather drivers.

A New Approach to Predict Nutrient Content in Costa Rican Soils Using V-NIR Spectroscopy and Machine-Learning

Johan Perret, José Eduardo Villalobos, Heilyn Calvo Vargas, Diego León Dardón and Jhohan Elguera

Visible and near-infrared reflectance spectroscopy (VNIRS) combined with machine learning can be used to predict soil properties. This research was undertaken to test and improve chemometric methods to produce the most accurate soil infrared spectral models to predict the nutrient content. A FieldSpec 4 Standard-Res ASD (Analytical Spectral Devices Inc., Boulder, CO, USA) spectroradiometer with a spectral range of 350 nm to 2500 nm with a spectral resolution of 3 nm and 10 nm in the ranges of 350 nm to 1000 nm and 1000 nm and 2500 nm respectively was used to generate the Vis-NIR spectral signatures. A total of 4073 tropical soil samples from Costa Rica have been collected, processed (oven-dried and grind) where macronutrients (P, K, S, Ca, Mg) and micronutrients (Zn, Cu, Fe, Mn, B), Si, and Na were analyzed in the laboratory using an Inductively Coupled Plasma (ICP) along with an optical emission spectrophotometer. Carbon, Nitrogen, soil pH, soil extractable acidity (EA), soil texture, bulk density, soil effective exchange capacity, and soil organic content were also assessed. For every soil sample, 4 spectral signatures were collected at different orientations (0o, 90o, 180o and 180o) (generating 16292 spectras in total) in order to minimize noise caused by sample position. The hyperspectral library was divided into two data subsets, one for calibration and the other for validation using a Kennard Stone algorithm. More specifically, 80% of the samples were used to calibrate the models and the remaining 20% were assigned to assess the predictability performance of the machine learning algorithms. Two categories of vis-NIR signal pre-processing techniques (scatter correction methods and spectral derivatives) were used to remove instrumental noise in the spectras. A new three-dimensional filter applying a mahalanobis distance algorithm in the first three principle component (PCA) space was also developed to identify and remove outliers. This technique improved the predictions metrics for the four machine learning techniques that were used to predict soil properties from hyperspectral signature namely Memory Based Learning (MBL, also known as k-Nearest Neighbors KNN learning), Support Vector Machine (SVM), Random Forest (RF), and Partial Least Square Regression (PLSR). The predictability of these algorithm was analyzed by grouping soil samples in different clusters based on 1) their origin (location clusters), 2) their color (RGB clusters subdivided in three groups: dark, yellowish and reddish soils) and 3) their acidity (pH clusters). Results indicated that the MBL model outperformed the RF, SVM, and PLSR and that clustering significantly improved the R2, residual deviation of prediction (RPD) and root mean square error of predictions (RMSEP). A maximum R2 of 0.98 was obtained for manganese (Mn) in the RF and SVM models, both with the yellowish cluster. Likewise, the SVM algorithm generated a minimum RMSEP value of 0,03 for Nitrogen (N) using the second derivative preprocessing and the yellowish cluster. In the case of Magnesium (Mg), R2 of the order of 0.93 were obtained for predictions for the dark cluster

with the MBL model, followed by 0.88 in the same cluster for the RF model. The predictions of soil carbon and soil organic matter also yielded high R2 with values of 0.94 for the MBL model and the RF model, while the PLSR models generated R2 of 0.91. These results demonstrate that the use of soil spectras with 1) proper preprocessing, 2) outlier removal with PCA using 3D mahalanobis distances, 3) clustering (location/color/pH) and the use of several machine learning algorithms permits reliable predictions (R2>0.8, RPD>3) for most soil nutrient concentrations. Instead of relying on only the best machine learning algorithm, a weight average prediction from the four best models were used to predict the macro- and micronutrient concentrations in soil. This approach is now routinely used to quickly estimate several physicochemical soil properties necessary for decision making in precision agriculture for tropical soils of Costa Rica.

Root electrical capacitance indicates wheat nutritional status and predicts grain yield non-destructively

Imre Cseresnyés, Eszter Tóth, Péter Mikó, Judit Bányai and Klára Pokovai

The efficiency of measuring root electrical capacitance (CR*) at flowering for whole-plant phenotyping was assessed in five wheat cultivars in three replicate plots over two years. Linear regression analysis was used to correlate CR* with plant-size parameters and flag-leaf traits (extension and SPAD chlorophyll content) at flowering, and with yield components at maturity. The plot-mean CR* was correlated with the plot leaf area index (LAI), the chlorophyll quantity (LAI×SPAD) and the grain yield across years. At plant scale, CR* was found to show the strongest positive regression with total chlorophyll in the flag leaf (flag leaf area × SPAD; R2: 0.65–0.74) and with grain mass (R2: 0.55–0.70) for each cultivar and year. Likewise, at plot scale, the regression was the strongest between CR* and the LAI×SPAD value (R2: 0.86–0.99) for the cultivars. Consequently, CR* indicated the total plant nutrient and photosynthate supply at flowering, which depended on root uptake capacity, and strongly influenced the final yield. Our results suggested that the polarization of the active root membrane surfaces was the main contributor to CR*, and that the measurement could be suitable for evaluating root size and functional intensity. In conclusion, the capacitance method can be applied for non-destructive whole-plant phenotyping, with potential to estimate root and shoot traits linked to the nutrient supply, and to predict grain yield. CR* can be incorporated into allometric models of cereal development.The project was funded by the National Research, Development and Innovation Office of Hungary (NKFIH; FK-137617).

Advanced screening methods for potential soil pollution introduced via biobased fertilizers

Boris Jansen, Yan Dong and Supta Das

The linear use of synthetic fertilizers has proven indispensable to provide sufficient food for a growing world population, but suffers from serious issues including soil acidification and soil degradation. As a result, the last decade has seen an increasing attention for the use of nutrient rich waste streams, such as crop and animal remains, to produce biobased fertilizers (BBFs) as an alternative fertilizer source. In the EU funded LEX4BIO project we are studying the potentials and risks of large scale BBF application. A primary concern is the potential introduction of organic pollutants, specifically pharmaceuticals and pesticides, to the soil via BBFs. Both pollutant classes contain a wide range of compounds given the wide range of BBF source materials, which in turn provide a complex range of organic matrices with which those compounds can interact. As a result, screening for pharmaceuticals and pesticides poses a challenge. In an attempt to overcome this, we developed an advanced screening method to simultaneously screen for a broad suite of pharmaceuticals and pesticides in BBFs and in soils [1,2]. It consists of a combination of a QeEChERS-based extraction followed by UHPLC-QTOF-MS/MS analysis. We successfully applied the newly developed method using target analysis and suspect screening to scan for > 500 pharmaceuticals and pesticides in total, in 15 BBFs and 2 soils from field-trials within the LEX4BIO project. The results indicate a very limited presence

of pollutants in the BBFs and soils [1,2]. [1] Das et al., Organic contaminants in bio-based fertilizer treated soil: target and suspect screening approaches, Chemosphere (under review). [2] Dong et al., Simultaneous detection of pesticides and pharmaceuticals in three types of bio-based fertilizers by an improved QuEChERS method coupled with UHPLC-QTOF-MS/MS. Journal of Hazardous Materials (under review).

S4: Modeling over scales

A novel soil pore three-dimensional index integrating angle factor and anisotropy

Lei Liu, Qiaoling Han, Yandong Zhao, Runze Song and Yue Zhao

Accurate calculation of soil pore anisotropy is essential for studying the pore topological structure and analyzing the direction of water and gas migration in soil. However, the existing calculation of pore anisotropy is a numerical value of the pore-specific angle, which cannot fully and accurately characterize the extension of pores in different directions in space. Therefore, this study proposed a new pore three-dimensional index integrating the angle factor and anisotropy. Based on sequential soil computed tomography images, a simplified convolution network was used to segment the pore structure from the soil solid phase, and the neighborhood tracking method was used to develop the digital soil pore model. Then, the multi-angle anisotropy of the pores was defined and proved by mathematical analysis. Multi-angle anisotropy is a vector that represents the pore extension at different angles. The results show that the multi-angle anisotropy of the pore structure in the soil samples mainly focused on [90°, 120°); more than 85% of the pore structure multi-angle anisotropy values were greater than one. Compared with the general anisotropy, the general anisotropy is just the value in the projection direction of the multi-angle anisotropy. In general, multi-angle anisotropy can more comprehensively and accurately represent the extension of different pore structures and provide a theoretical reference for the study of soil management and soil water transport analysis.

Investigating the issue of imbalanced datasets in larger-scale mapping of soil properties from earth observation data

Nikolaos Tziolas, Achilleas Zalidis, Eleni Kalopesa and George Zalidis

This study investigates the issue of data imbalance in machine learning models used for predicting soil properties from multi-spectral space-borne data at larger (national or continental) scales. For example, in the ESA WORLDSOILS project the soil organic carbon (SOC) distribution of croplands in Europe, per the LUCAS 2018 topsoil database, has a skewness of 3.96. To predict the European-level SOC content, first Sentinel-2 multi-spectral data are aggregated, forming the bare soil reflectance composites from 2017 to 2019 at the LUCAS 2018 soil samples' location. After randomly splitting the dataset to calibration (70%) and independent test sets (30%), typically applied ML algorithms (Support Vector Regression and Random Forest) exhibit low prediction accuracy with a mean RMSE 14.10 g C / kg, R2 0.19, and RPIQ 0.71, under-predicting higher SOC concertation samples. The accuracy is moderately enhanced when imbalanced learning algorithms (e.g., weighted RF) are applied, with a mean RMSE 13.41 g C / kg, R2 0.24, and RPIQ 0.75. Only by augmenting the entire dataset with more data points (either synthetic via SMOTER or the higher SOC content samples' spatial neighbours) the prediction accuracy becomes acceptable with a mean RMSE 19.89 g C / kg, R2 0.59, and RPIQ 2.23.

Linking soil aggregate stability with soil erosion at catchment scale: the ESTABLE-project

Deborah Feldmann, Michael Kuhwald, Philipp Saggau and Rainer Duttmann

The ESTABLE project focuses on investigating the spatial distribution of soil aggregate stability (AS). AS is considered as an indirect measure of soil erosion susceptibility, and its spatial distribution is influenced by various topographic and physical factors such as surface curvature, soil management practices, and soil characteristics. The project aims to investigate the impact of reoccurring soil erosion events on the spatial distribution of AS. A total of 500 topsoil samples were collected from two study sites in northern Germany and are currently analyzed for their AS using the wet sieving method. Machine learning models, such as tree models and random forest, are employed to develop predictive models for AS distribution. Their performances, parameterizations and interpretabilities are compared with conventional interpolation techniques, such as multiple linear regression and regression kriging. Finally, the results of the best-performing model will be compared with the amounts and patterns of soil erosion over the last 30 years, which will be calculated using the model Erosion 3D (E3D). The additional use of UAVs and field mapping will enable a more detailed and accurate assessment of the spatial distribution of soil erosion. Overall, the ESTABLE project aims to provide a comprehensive understanding of the spatial distribution of AS and its relationship with soil erosion, as well as to develop a model for the spatial distribution of aggregate stability that could be used for future studies and on other sites.

Geospatial modelling of soil phosphorus fractions and sorption indicators using geochemical survey data from wide-scale heterogeneous landscapes

Rebecca L. Hall, Felipe Bachion de Santanaa, Margaret Browne, Vincent Gallagher, Eric C. Grunsky, Victoria Lowe and Karen Daly

Digital soil mapping of phosphorus (P) pools at regional scale can be used to inform policy and land management strategies in agri-environmental systems. Mapping P over heterogeneous landscapes depends on linking soil P behaviours such as bioavailability and sorption dynamics to geological controls, however, linking an element that is predominantly managed by fertiliser and organic inputs to regional scale geochemistry can be problematic. This study uses a geological survey of the northern half of Ireland at $\leq$4 km2 resolution to map; total P, available P and Legacy P pools, alongside interactions with sorption indicators (available aluminium, Al). Bioavailable P shows no spatial continuity in Kriged variogram output and is regulated by fertiliser inputs which mask any underlying geological processes. Available Al concentrations are regulated by underlying geology and have a significant negative correlation with agronomic soil P indices. Areas of high Al concentrations ($\geq$ 702.5 mg kg-1) are dominant in the study area and show mainly low P values, however potential legacy P pools are indicated. Whereas, areas of low Al concentrations ($\leq$ 697 mg kg-1) show moderate to high P concentrations which could identify areas where P is likely to remain in solution phase and being a risk to local watercourses. Using Available Al as a sorption indicator can identify areas of high P fixation and low soil P retention in the northern half of Ireland which could benefit from targeted management approaches.

Advancing the spatial characterization of peat layers through probabilistic 3D modelling

Pablo De Weerdt, Jeroen Verhegge, Philippe De Smedt and Ellen Van De Vijver

The reconstruction of peat layers in pedo- and geological models on the landscape scale attracts increasing attention in both policy making processes and land development projects. Considering the importance of accurate volume, depth and thickness predictions, and their associated uncertainty, as well as the propagation of uncertainty in derived models, for instance, on greenhouse gas emissions, there is a clear incentive to further develop probabilistic modelling tools. In this case, a highly heterogeneous 1000 ha study area in

the Flemish Scheldt river estuary at the North Sea in Belgium is chosen, where a redevelopment project to expand the Port of Antwerp is ongoing. Within the area, 80 interpreted boreholes collected over the past decades are used as both discrete and parameterized continuous input data, for which respectively the associated geological member and lithological units have been identified up to a maximum of 12 m below surface. We compare deterministic modelling of lithology as applied in an existing regional 3D subsurface model, with more advanced probabilistic geostatistical methods to characterize a buried peat layer. Both approaches are assessed through independent validation of predictions with parameter optimization, including the reconstruction of spatial variability. The measure of uncertainty provided by probabilistic methods is expected to enhance the quantitative spatial analysis on the occurrence of peat in the subsurface.

Poster

Mapping land suitability for agriculture in Europe's humid continental climate

Andrei Dornik, Marinela Adriana Chețan, Tania Elena Crișan, Raul Heciko, Alexandru Gora, Lucian Drăguț and Panos Panagos

Land suitability assessment (LSA) is a vital tool in increasing agricultural productivity sustainably, mitigating land degradation, and adapting to climate change. This approach uses geographic information systems to provide a high-resolution (250 m) geospatial assessment of land suitability for different crops and land uses in Europe's humid continental climate. We employed 17 eco-pedological indicators (e.g. soil texture, pH, porosity, temperature, precipitation) for LSA to crops and land use according to a rule database that assigns a discrete suitability rating (0, 0.1, . . . , 0.9, 1) for each category of each eco-pedological indicator. The suitability maps were further spatial cross-tabulated with a crop map to determine how well the land was utilized in the study area. The results show that wheat and barley are most suitable in the southern part while potatoes and sugar beet exhibit extensively suitable land in the northern parts. Corn and sunflower had a much lower extent of suitable land. The study identified four ecological parameters (water table depth, precipitation, temperature, and terrain slope) and three soil attributes (soil porosity, SOC, and topsoil texture) as limiting factors for land suitability in the study area. The study concludes that there is no space left for expanding crops on arable suitable land, but potential enhancements were identified for agricultural practices to locate crops in the most suitable lands. The study identified regions where wheat and corn are over-cultivated on unsuitable land, which has the potential for the cultivation of more suitable crops such as barley, sunflower, sugar beet, and potato.

Towards effective sampling for nutrients' predictive mapping in farm-scale crop management

Jan Skála, Daniel Žížala and Robert Minařík

Plant nutrition and balanced fertilisation require highly accurate field information with limited sampling. Therefore, the optimisation of sampling schemes is crucial. The aim of the study is to compare the widely used sampling designs combined with variable sample size for supervised prediction of common soil macronutrients. Conditioned Latin Hypercube Sampling (cLHS), Feature Space Coverage Sampling using k-means (FSCS) and Simple Random Sampling (SRS) were compared. The influence of sampling scheme and sample size on the accuracy of predicted nutrient maps was investigated in a real case study of a field (35 ha) with heterogeneous soil properties. A total of 200 training points were placed in 6 networks: cLHS and FSCS with 10, 30 and 60 samples each, corresponding to 1 sample per 3, 1 and 0.5 ha respectively. For the numerical experiment with the varying sampling rates, all 200 training samples were interpolated into a set of nutrient maps, which were treated as an error-free dataset for both calibration and validation samples included in the predictive modelling. Sampling networks of variable sample size from 2 to 60 were generated using the

SRS, cLHS and FSCS combined with a pragmatic suite of environmental covariates. Each network of each method was automatically generated 100 times using the same algorithm settings. These were used for covariate-driven models. The performance of the models was monitored. The results show the advantage of using the FSCS, which shows both less variation in the accuracy of the prediction compared to SRS and cLHS, and better results under sparse sampling. This research was created with the financial support of Ministry of Agriculture of Czech Republic, National Agricultural Research Agency under the project NAZV QJ21010247

Understanding the Drivers of Nematode Functional Diversity Across Europe

Doina Mani, Carmen Vazquez Martin, Titia Mulder, Jakob Wallinga and Rachel Creamer

The recent trend of land use intensification within Europe poses a threat to the ability of the soil community to sustain soil functions (nutrient cycling, carbon sequestration, water regulation, disease suppression, and primary production). In order to predict soil functions and their resilience to disturbance across the heterogeneous landscapes of Europe an increased understanding of the drivers of the spatial distribution of belowground organisms is needed. Soil food-web dynamics and community traits are much stronger predictors for soil functions than species diversity. Therefore, shifting the focus from biogeography to functional biogeography could facilitate the link to soil functions. Nematodes are present throughout the soil food-web and can thus function as indicators for soil food-web dynamics. Within this study I aim to uncover how soil forming factors (climate, organisms, relief, parent material and time) drive belowground functional diversity across Europe, using nematode-based indices of soil food-web dynamics as an indicator for functional diversity. Data on nematode diversity was obtained from a large database of nematode community studies across Europe. Additionally, soil maps were consulted to gather data on environmental and soil physical properties. The findings in this study show that nematode-based indices vary across different environmental zones in Europe and that this variation can in part be explain by soil forming factors. Geographical location should therefore be considered when assessing soil health and soil multifunctionality.

Evaluation of soil properties maps produced with Convolutional Neural Networks and Random Forest: pointwise and contextual pattern analysis

Giulio Genova, Laura Poggio and David Rossiter

Digital Soil Mapping (DSM) is a valuable tool to produce soil properties maps. Machine Learning (ML) algorithms have proven to be a useful approach for DSM; however, most applications have only considered covariates at each point, and most evaluations have also been pointwise. In this study, we used Convolutional Neural Networks (CNNs), a ML model that can include context information around a point. We also evaluated the results pointwise and considered the spatial patterns of the maps generated, comparing them with a Random Forest (RF) approach. We trained our models on a global dataset consisting of 110,000 topsoil samples using 40 environmental covariates as predictors of soil properties including pH, Soil Organic Carbon, Sand, Silt, and Clay concentrations. To evaluate the spatial patterns, we analyzed the range and strength of spatial autocorrelation and computed various landscape metrics used in landscape ecology. Our results show that the overall pointwise prediction accuracy of the CNN is comparable to that of the RF model. However, the spatial patterns generated by the two models were substantially different. Pointwise statistics alone do not provide a complete picture of a DSM model, since spatial patterns are related to soil geography and land use potential. This research highlights the importance of considering spatial patterns in DSM and provides evidence that CNNs may provide a more useful representation of soil geography than traditional ML models

Updated map of organic soils in Germany

Mareille Wittnebel, Stefan Frank and Bärbel Tiemeyer

Organic soils store large amounts of soil organic carbon (SOC). This is not limited to 'typical' organic soils such as fen or bog peat soils, but also applies to a wide range of other carbon-rich soils with peatland history, such as peat-derived, covered or deep-ploughed organic soils. In Germany, all organic soils are largely drained and thus contribute significantly to national greenhouse gas (GHG) emissions. In order to plan and evaluate mitigation measures and to adequately calculate GHG emissions, it is important to use the most recent spatial data of these soils. The map currently used in emission reporting was created by harmonising the soil maps of the German federal states. However, since the data collection about ten years ago, several states have updated their soil maps or produced specific maps of organic soils. Therefore, the most recent vector data sets were collected and soil units containing peat and other organic soils were selected. Although there is a German soil classification system, the maps of the federal states vary considerably in terms of soil units, definitions, scale, age and general mapping concepts. To overcome these challenges, we developed a nationally consistent nomenclature based on seven soil properties that are crucial for modelling GHG emissions or their drivers. The updated dataset allows evaluation of the peat type, mineral covers, peat thickness, SOC depletion below 15%, deep-ploughing, underlying gyttja and underlying mineral substrate and their different characteristics. The updated map covers approximately 1.9 million hectares of organic soils.

SOIL O-LIVE EU Horizon Programme: The Soil Biodiversity and Functionality of Mediterranean Olive Groves: WP3 Soil Erosion and Land Degradation

Gabriela Moreno Romero, Christine Alewell and Pasquale Borrelli

The Mediterranean region produces around 93% of olive oil worldwide. In the last fifty years the expansion, increased mechanization, and intensive olive orchard cultivation, especially in areas unsuitable for agricultural use have affected negatively the environmental conditions in many olive groves, which not only already impacted the quality and safety of olive oil production, but has a strong detrimental effect on soil health, biodiversity and ecosystem function and stability in general. Soil erosion and the subsequent delivery of sediment loads to rivers are the principal land degradation forms in the Mediterranean area. The WP3 of the Soil O-LIVE project aims to design and develop a framework to assess and monitor soil degradation under the cultivation of olive trees. This framework will span from remote mapping and modelling land use effects on soil health across the Mediterranean belt, including calibration and validation with specific tracers of sediment transport and indicators of soil degradation. The latter will be presented in this poster. More specifically, we will: (1) Assess on-site soil erosion based on the 3D reconstruction of surface levels, and on fallout radionuclide (FRN) inventories (137Cs, 239+240Pu) on selected olive tree sites. For the former, the model MODERN (Modelling Deposition and Erosion rates with RadioNuclides) which allows using different FRN, land uses, and soil redistribution processes will be applied. (2) Assess off-site soil erosion rates of olive tree sites/catchments under different management with compound-specific stable isotopes. (3) Compare measured erosion rates to modelling endeavours and/or undertake some modelling simulations within the project.

Contribution of different error sources on the prediction accuracy of spectral models

Cynthia van Leeuwen, Titia Mulder and Gerard Heuvelink

In this work we studied the effect of four error sources on the prediction accuracy of clay and pH through a mid-infrared (MIR) spectroscopy model: 1) measurement error in wet chemistry reference data, 2) measurement error in MIR spectra, 3) choices made when subsetting spectral libraries, and 4) model selection

(e.g., random forest). We collected 136 soil samples from 70 locations with diverse soil types and land uses throughout the Netherlands, which were analysed by wet chemistry methods and MIR spectroscopy. To allow for proper quantification of measurement error, wet chemistry analyses were performed twice on 40% of the soil samples. Similarly, the spectra of all soil samples were measured twice. Additional spectra from the USDA-NRCS Kellogg MIR spectral library were used to predict clay and pH in Dutch soils, as the Dutch dataset was not large enough to build a robust spectral model. These spectra were selected based on spectral similarities, after applying a calibration transfer model to the Dutch spectra. The effect of the first two error sources on prediction uncertainty was studied through Monte Carlo simulation. For the latter two, systematic changes, such as the number of selected spectra from the spectral library and the model used, were applied. The contribution of each error source was quantified by computing the variance reduction resulting from treating the error source as certain. The effect of measurement errors in wet chemistry reference data and spectra was rather small, whereas changes in model and spectra selection contributed more to prediction uncertainty.

Updating soil organic carbon prediction map of Tcheboa, North Region of Cameroon through including new data

Cédrick Nguemezi, Francis Silatsa Tedou, Denis Tiki, Lydia Krauß, Patrick Mounoumeck and Daniel Rückamp

The importance of including soil information in planning processes to ensure sustainable land use is increasingly recognized. Soil organic carbon (SOC) is a vital indicator of soil health and plays a key role in the global carbon cycle. Increased knowledge of SOC's nature, magnitude, and spatial distribution is crucial for maintaining and increasing soil health under the changing climate and the increasing threat of food supply crises. Recent efforts contributed to the spatial assessment of the SOC distribution in Cameroon using legacy soil data and a digital soil mapping approach. However, there is a need to refine and update the map to support decision-making at a local level. As part of the technical cooperation between Cameroon and Germany, this study seeks to update the SOC in the north of Tcheboa based on available data from past studies and newly generated data. Eighty-three data points were considered, with 47 from the soil database Camsodat_v01, 22 from the former project PRESS NO&SW, and 14 from the new project PRESS II. Integrating newly collected data showed a high potential for improving the existing SOC map. The method will be extended to other soil properties to improve the regional soil database.

Mapping soil organic carbon stock of an alpine valley (Valchiavenna, Northern Italy)

Sara Agaba, Chiara Ferré, Marco Marco Musetti and Roberto Comolli

We mapped the soil organic carbon (SOC) stock of two soil layers (0–10 cm) and (0–30 cm) of an alpine valley (Valchiavenna, Lombardy) using the digital soil mapping (DSM) approach. We used different machine learning models: multivariate adaptive regression splines (MARS), random forest (RF), support vector regression (SVR), K-nearest neighbors (KNN), and Elastic Net Regularizations (Elastic net). Soil data from 110 profiles was used. The SOC stock of all sampling points was calculated using the bulk density (BD; measured or estimated) and the content of rock fragments. For the DSM application, we used the following covariates: geomorphometric parameters (obtained from a digital elevation model with a pixel resolution of 20 m), land cover, and climatic data. we have randomly split the data set into a training and testing set within the split ratios 0.8 and 0.2. The validation results of the MARS, KNN, Elastic Net, RF, and SVR models for the SOC stock 0-10 cm, expressed as R2, were 0.71, 0.57, 0.49, 0.41, and 0.32, respectively. For the SOC 0-30 cm stock, the results were 0.76, 0.70, 0.22, 0.15, and 0.10, respectively. We mapped the SOC stock of the two layers by applying the MARS model, which is the best-performing model with the highest R2 and the lowest mean absolute error (MAE): 0.42 kg.m-2 for the 0-10 cm layer and 0.40 kg.m-2

for the 0-30 cm layer.

Water holding capacity maps in the Rio Dulce irrigated area, Santiago del Estero, Argentina

Cristina Angueira, Gustavo Cruzate, Daniel Prieto, Salvador Prieto Angueira and Patricio Savino

Soil mapping with Water Holding Capacity (WHC) data is essential for soil, water, and crop management. The objective was to generate WHC maps of the irrigated Area of Río Dulce with 883,556 ha (27°30'-28°35' S and 63°45'-64°35' W) in the province of Santiago del Estero, Argentina. Based on the Geopedologic map, the WHC in mm/m was estimated with Pedotransfer Functions (FPT) of 398 horizons of 108 profiles based on texture, bulk density and organic matter, and Geostatistics were used to generate maps. In the discrete map (GP) each mapping unit was assigned the WHC value of the dominant soil of each association and/or soil complex, and in the continuous map (FPT) the WHC was interpolated by Inverse Distance Weighted (IDW) of all profiles. The WHC were grouped into 6 classes by mm/m less than 100 mm/m, 101-120 mm/m, 121-140 mm/m, 141-160, 161-180 mm/m, and 181-200 mm/m. In the GP map the area in percentage of each class is 4.12%, 13.03%, 8.74%, 42.21%, 24.21% and 7.71%, respectively and in the FPT map is 4%, 7.8%, 26.7%, 43.4%, 13.6 % and 2.2%. Given the shortage of WHC measured data, these maps are indicative for the management of a specific site, although it is convenient to validate and/or develop local FPTs to build a measured, shared and open database.

Soil genesis, its classification and large-scale mapping in complex glacial topography

Baiba Dirnēna, Kristine Afanasjeva, Andrejs Anufrijevs, Andris Avotins, Raimonds Kasparinskis, Aldis Karklins, Imants Kukuls, Betija Lace, Guntis Tabors and Ivo Vinogradovs

The research was conducted in the central part of Latvia where the landscape is a mosaic of agricultural land and forests. Soil groups in the study territory included Histosol, Stagnosol, Cambisol, Luvisol, Gleysol, Phaeosem, Planosol and Arenosol, formed on glacigenic (loam, sandy loam and sand), glaciofluvial (sand, coarse sand) and peat deposits. As previous studies do not cover all the possible diversity and spatial patterns of soil parent material and soil pedogenesis, therefore high divergency of soil cover in a small area and all uncertainties and challenges related to the soil classification and mapping, the aim of the research was to clarify possible driving forces and processes in pedogenesis in young moraine area while testing and approving WRB 2022 soil classification system for soil description and mapping in moraine upland conditions. Our results show that the rapid change of terrain and geological sediments creates difficulties for soil mapping, as there is a wide change of soil types in small territorial units. In these conditions, the changes in soil types are so rapid that it is impossible to fully represent them on maps at a scale of 1:10 000m, therefore, extensive discussions on the compilation of representative maps are necessary. The distribution of the mollic horizon indicates an ambiguous influence of the terrain on erosion and the movement/accumulation of organic matter revealing even new challenges for soil mapping.

How to address the lack of soil mapping in Chaco Americano, Santiago del Estero, Argentina

Cristina Angueira, Gustavo Cruzate, Eduardo Zamora, Guillermo Olmedo, Jose Manuel Sayago, Manuel Sanchez de la Orden and Isabel Castillejo Gonzáles

The Chaco Americano is an ecosystem shared by Argentina, Paraguay, Bolivia, and Brazil where land use change from forest to agriculture and social conflicts have been intensive from XXI. These changes and the lack of reliable soil information at suitable scales are threatening the sustainable development of the region. In Santiago del Estero province, Argentina, a soil survey was carried out on 8800 km2, with the

objective of reducing the knowledge gap. Due the large area, geomorphology diversity, limited funding, and high demand of information, a geopedologic survey using RS and GIS was considered an excellent approach to save time. Survey was divided into steps: review of information, displayed in a GIS, overview of the area, an iterative and exhaustive visual interpretation Landsat, CBERS, SACC imagery and analysis of morph graphic and morphometric SRTM attribute maps, using ArcGis, Imagine and SAGA, a preliminary map units were delineated, a draft hierarchic geoforms legend as cartographic frame to define soil landscape relationships, sites for describing soils and checking boundaries. Physical-chemical laboratory data, and soil were classified according SSS. The interpretative map was converted into geopedologic map after confirming boundaries, legend, characterization of soils and their spatial distribution patterns. Three main landscape units, nine molding types, and fourteen landform types were recognized, described including name, symbol, soil composition, and shown in the geopedologic map. The used approach helped speed up the soil collection at appropriate scale for land use planning.

Monitoring soil organic carbon in Flanders (Belgium): network set-up and first results

Fien Amery, Bruno De Vos, Dries Luts, Suzanna Lettens, Tommy D'Hose, Martine Swerts, Joost Salomez and Katrien Oorts

A carbon monitoring network has been set-up in Flanders (Belgium) to measure size and evolution of soil organic carbon stocks. From end 2021, 2594 plots are sampled during a first 10-year cycle. In a second 10-year cycle, the same plots will be resampled in order to calculate evolutions in carbon stocks. Evaluations for five different land uses will be possible: grassland, cropland, forest, nature and residential area (gardens, parcs, recreational areas and verges). The plots were selected using a generalized random tessellation stratified (GRTS) algorithm. The sampling plot dimensions are 10 by 10 meter. The litter or felt layer is collected if present, for analysis of dry mass, total C and total N. Sampling is done with a gouge auger at four depth intervals (0-10, 10-30, 30-60, 60-100 cm) at 16 (upper two layers) or 7 (lower two layers) GRTS selected sampling locations in the plot. Subsamples are pooled per layer (composite sample). Bulk density is measured by taking four undisturbed samples by Kopecky cylinders per layer. After transport to the lab and sample preparation, total C, inorganic C, total N, pH-KCl, texture by laser diffraction and near infrared spectra are measured on the composite samples. Comprehensive sampling schemes and detailed sampling, preparation and analysis protocols were set-up and tested during the start year of the monitoring network. Sampling, sample preparation and analysis error are quantified by resampling of 5% of the plots by a different sampling team. Results of the first sampling year will be presented at the conference.

A systematic approach to predicting and mapping soil particle size distribution from unknown samples using large mid-infrared spectral libraries covering large-scale heterogeneous areas

Felipe de Santana, Rebecca Hall, Victoria Lowe, Margaret Browne, Eric Grunsky, Mairéad Fitzsimons and Karen Daly

For soil spectroscopy to replace wet chemical methods, there is a need to achieve high prediction accuracy of unknown samples to confidently map predicted values across large spatial scales. This study developed a systematic approach using MIR spectroscopy to predict soil particle size (SPS) of 9,009 unknown samples, representing an area of approximately 35,716 km2. A systematic approach for MIR spectroscopy combined with chemometrics was augmented by including spectral control charts to identify unrepresentative spectra in the prediction of unknown samples. Moreover, 2% of the predicted values (external validation) were selected, covering a wide range of clay, sand and silt, and analysing them using the classical reference method. The MIR model was built using a calibration dataset of 1,000 mineral and organo-mineral (MOM) soils, analysed using the pipette method in an analytical laboratory accredited to ISO/IEC 17025:2005. These samples were used to build spectral models based on the support vector regression algorithm, which was used to predict

SPS from MOM soils from 9009 unknown samples. The accuracy calculated for the 2% of samples selected from the MOM unknown samples (n = 5254) was similar to the accuracy in the internal validation set, with R2val values of 0.90, 0.84 and 0.71, RMSEP values of 2.21, 4.31 and 3.91%; RPIQval values of 4.97, 3.71 and 2.30, for clay, sand and silt prediction, respectively. This systematic approach can be used to predict soil attributes using large spectral libraries, providing confidence for building regional and national scale soil maps.

Combining object-based image analysis image with topographic data for landform mapping: a case study in the semi-arid Chaco ecosystem, Argentina

Isabel Castillejo González, Cristina Angueira, Alfonso Garcia Ferrer and Manuel Sanchez de la Orden

This paper presents an object-based approach to mapping a set of landforms located in the fluvio-eolian plain of Rio Dulce and alluvial plain of Rio Salado (Dry Chaco, Argentina), with two Landsat 8 images collected in summer and winter combined with topographic data. The research was conducted in two stages. The first stage focused on basic-spectral landform classifications where both pixel- and object-based image analyses were tested with five classification algorithms: Mahalanobis Distance (MD), Spectral Angle Mapper (SAM), Maximum Likelihood (ML), Support Vector Machine (SVM) and Decision Tree (DT). The results obtained indicate that object-based analyses clearly outperform pixel-based classifications, with an increase in accuracy of up to 35%.The second stage focused on advanced object-based derived variables with topographic ancillary data classifications. The combinations of variables were tested in order to obtain the most accurate map of landforms based on the most successful classifiers identified in the previous stage (ML, SVM and DT). The results indicate that DT is the most accurate classifier, exhibiting the highest overall accuracies with values greater than 72% in both the winter and summer images. Future work could combine both, the most appropriate methodologies and combinations of variables obtained in this study, with physico-chemical variables sampled to improve the classification of landforms and even of types of soil.

Operationalizing soil spectral libraries: a case study for soil carbon in peat soils of Switzerland

Anatol Helfenstein, Philipp Baumann, Raphael Viscarra Rossel, Andreas Gubler, Stefan Oechslin and Johan Six

Infrared spectroscopic modeling can link and massively scale up traditional laboratory methods for many soil characteristics in a cost-effective and timely manner. This has prompted the development of soil spectral libraries (SSLs) from the regional to global scale. The operational value of SSLs lies in their ability to provide estimations of key soil properties on a scalable basis, from field to regional levels. While various approaches have been proposed for utilizing SSLs for estimating local soil characteristics, such as spiking, subsetting, memory- or instance-based learning, or transfer learning, few studies have focused on organic soils. Given that peat soil conservation is a top priority in Europe, we developed and tested three spectroscopic modeling strategies in the mid-infrared range to estimate soil carbon at local target sites in Swiss peatlands with minimal sampling and measurement requirements. We compared the accuracy of local models, models using the Swiss SSL in conjunction with local samples, and subsets of local and Swiss SSL samples using a data-mining algorithm called resampling local (RS-LOCAL). Our findings indicate that local models require 50 samples for accurate results, with a root mean squared error (RMSE) < 3% total carbon. Models utilizing the entire Swiss SSL with local samples yielded biased predictions with lower accuracy than local models. However, subsets of local and Swiss SSL samples using RS-LOCAL only required 5 or 10 local samples to accurately predict soil carbon (RMSE = 3.16% or 2.71% total carbon, respectively). Thus, we recommend using RS-LOCAL together with a SSL as an efficient and accurate strategy to tailor soil characteristic estimations for a specific region. Even though the Swiss SSL was under-representative of organic soils, adequately mining the information

in the SSL was sufficient for predicting soil carbon in independent peatland regions. This will aid in reducing field and laboratory work and scaling up the acquisition of quantitative soil information over space and time.

Remote sensing of cover crop legacies on soil health and main crop N-uptake dynamics

Nikos Vavlas, Thijs Seubring, Ali Elhakeem, Lammert Kooistra and Gerlinde De Deyn

Sustainable management of arable cropping systems requires insight into the temporal dynamics and spatial variation of crop performance to minimize nutrient losses and enable soil health-based precision agriculture. In arable systems, growing cover crops is a tool to promote soil health as they enable nutrient retention in autumn/winter and provide nutrients in spring/summer to the main crop upon cover crop mineralization by the soil biota. However, different cover crop monocultures and mixtures affect the soil biology and nutrient dynamics differentially due to the variation in quantity and quality of the plant material returned to the soil. To understand the legacy effects of cover crops on the main crop we need high resolution data of the crop responses to soil health conditions throughout the growing season. Remote sensing can provide such high-resolution data yet requires solid parameterization before it can be operationalized. Here we studied the temporal dynamics of soil nitrogen (N) availability and N uptake in barley in response to the soil legacy of different cover crops. We used high-resolution multispectral images of the main crop acquired from a Unmanned Aerial Vehicle (UAV), and in situ collected plant and soil parameters in a long-term field experiment with eight different cover crop treatments. The cover crop legacies significantly affected N uptake, biomass, and canopy chlorophyll content (CCC) in barley, with highest values in barley grown after vetch-radish or oat-radish and lowest in barley on fallow or oat legacy plots. The temporal dynamics of N-uptake throughout the barley growing season revealed that cover crop legacy effects became apparent/distinct by the end of stem elongation. This work demonstrates the potential of remote sensing to monitor and understand temporal and spatial variation of crop canopy traits in response to cover crop induced soil health legacies. This approach can contribute to more efficient N use by enabling fine-tuning of the quantity, timing, and location of fertilization.

Hybrid modelling of soil organic carbon in space and time to improve soil health assessments

Yuqing Lai, Vera Leatitia Mulder and Gerard B.M. Heuvelink

Understanding the distribution of soil organic carbon in space and time is critical to, among others, food security and climate change mitigation studies. The use of machine learning models for analysis of soil spatial variation and mechanistic models for analysis of soil dynamics have become popular over the last decades. Both approaches have their strengths but also weaknesses, and it is worthwhile to explore if combining the two approaches can remedy these weaknesses. Here, we present our proposed research plan. We will build a new hybrid model by combining the quantile regression forest and the Rothamsted carbon (RothC) models. Different combinations will be evaluated for modelling the spatial and temporal distribution of soil organic carbon, with quantified uncertainty, at different scales (the Netherlands and Europe). An important part of the research is the assessment of the effect of spatial scales, calibration sample sizes and the complexity levels of the mechanistic model on model performance. Subsequently, the results will be used to establish methods for mapping and forecasting soil functions and soil health. With this research, we will advance methods for modelling soil processes in space and time. The societal benefits are expected to be large, as the work supports decision-making for climate mitigation, soil protection and sustainable development at the national and continental scale.

Yield performance zones to account for variation in soil carbon and soil health across farm

David Clarke, Joseph Martlew and Elizabeth Stockdale

It is important for land managers to measure soil organic carbon (SOC) to monitor soil function, mitigate climate change and for inputs into carbon payment schemes, mechanistic models, and tools for monitoring on farm carbon emissions and sinks. SOC has a high degree of spatial variation and requires sampling strategies that account for this as well as variation through soil depths. Accurate measurements also require supporting measures including bulk density and stone content, making it difficult to monitor accurately across space. In this study a fuzzy c means clustering algorithm with an auto completion strategy is used to identify performance zones using yield map data sets across 7 fields with contrasting soil types in England. These zones were used to infer zones of likely homogeneous soil properties and/or differences in historic SOC returns from crop residues. Within each field 3 zones were selected for representative soil properties measurements including soil carbon content, bulk density and stone content and selected soil physical, chemical, and biological measures to depth. Across all fields, between 30-46 % (r^2 = 0.30-0.46, p=0.01) of the variation in soil carbon could be explained by historic standardised yield performance. Results show that zones based on historic yield performance can provide a mechanism for measuring spatial variation in SOC and other soil properties while minimising sampling complexity. Zone performance has also been linked to other soil properties to guide soil management. This work is funded and supported by Bayer Crop Science.

Comprehensive assessment of mechanical soil augering systems for in-situ soil description and sampling

Simon Tanner, Stefan Oechslin, Madlene Nussbaum and Stéphane Burgos

In Switzerland detailed soil information is missing for many regions – although urgently needed. The authorities are legally obligated to delineate areas for the high-quality arable land inventory. Nationwide high-resolution surveys require sampling of large numbers of new locations within the next decade. Even though measuring soil properties by laboratory methods and proximal or remote sensing is as well important, in-situ visual determination and description of some specific soil properties remains essential for the delineation of high-quality cropland under current legislation such as classification of redoxymorphic features or rootable soil depth. Current surveys are limited by manual augering and in-situ classification needs experienced field staff often scarce. Therefore, we tested mechanical augering systems available on the market. We qualitatively assessed different systems regarding suitability for soil description and sampling for laboratory analysis. In addition, we considered economical aspects and practical implementation to sample predetermined locations given by a statistical design with an average distance of 70 m. Tested augering systems could be ranked according to resulting information compared to their implementation effort. Drill cores of 14 cm diameter allow to partly replace profile pits while still resulting in accurate descriptions even for soil structure and massively reducing costs and land damage. Smaller drill cores (3.5 cm) can overcome seasonal restrictions in field work whilst smallest drill cores showed no advantage compared to manual augering systems. To additionally profit from the machine setup we tested a multispectral camera on one auger system to approximate soil properties and in-situ classification of soil horizons.

Accuracy and sensitivity of NH3 measurements using the Dräger Tube method

Alexander Kelsch, Matthias Claß, Muhammad Humza and Nicolas Brüggemann

Regional estimates of NH3 emissions are often missing data from heterogeneous or small fields. Areas with no experienced staff or in-field power supply also prevent the use of accurate and fully established micrometeorological measurement techniques.The Dräger Tube method (DTM) is a calibrated open-dynamic

chamber method, which requires little training to use and is comparatively inexpensive. It uses NH3 detector tubes, an automatic pump, as well as a chamber system comprised of four stainless steel chambers connected with PTFE tubing. Even though the DTM is used in countries such as Germany and China, the measurement accuracy and sensitivity have not been tested yet.In order to quantify the accuracy and sensitivity of the DTM, we simultaneously measured defined NH3 concentrations with the Dräger Tubes, a multi gas analyzer (MGA-7, MIRO Analytical AG, Switzerland) and a G2103 (Picarro, Inc., USA). Second, we tested the exchange of the tubing material or heating of the tubing under laboratory conditions, as well as surface coating or treatment of the DTM chamber system during outdoor measurements, on performance improvements.Results showed that the Dräger detector tubes considerably underestimated NH3 concentrations compared to the other devices, particularly at low NH3 concentrations. The PTFE tubing material showed the best performance of all tested tubing materials regarding response time, which was further improved by heating of the tubing to 50°C. The modifications performed during the outdoor experiment did not lead to any improvements of NH3 measurements.We conclude that the DTM is unable to reliably quantify NH3 emissions.

Dynamic monitoring of NDVI in agronomic testing of agro crops using an unmanned aerial vehicle

Maira Kussainova, Maxat Toishimanov, Timur Tamenov, Anel Syzdyk and Nursultan Nurgali

This study proposes the use of unmanned aerial vehicles (UAVs) for dynamic monitoring of the normalized difference vegetation index (NDVI) in agronomic testing of agro crops. NDVI is a commonly used indicator of plant health and growth, and its monitoring can provide valuable insights into crop development and yield potential. The proposed method involves flying a UAV equipped with a multispectral camera over crop fields to capture NDVI data at different growth stages. The collected data is then analyzed to identify patterns and trends in plant health and growth. This approach offers a non-destructive and cost-effective way to monitor crops and can aid in making informed decisions related to crop management and optimization.

Optimizing manure recycling rates to balance crop requirements, mitigate soil acidification and minimize nutrient losses at regional level

Donghao Xu, Gerard Ros, Qichao Zhu, Fusuo Zhang and Wim de Vries

Soil acidification, causing a loss of base cations (BC) affects soil fertility and crop yields. Recycling animal manure to replace mineral nitrogen (N) can mitigate soil acidification, but the required amount of manure to counteract acidification may lead to phosphorus (P) overuse causing eutrophication. The soil acidification model VSD+ has been applied at field level to optimize nutrient management strategies based on agronomic and environmental targets for N, P and BC, but regional applications are still lacking. In this study, we first validated the VSD+ model on measured pH changes (n = 69) in a Chinese agricultural county in paddy and upland soils for which input data were assessed by a regional survey. Overall, the observed average soil pH of non-calcareous paddy and upland soils decreased by 0.66 and 0.09 units during the period 2014-2019, and the average deviation between simulated and observed pH values was within 8.0%. Paddy soils acidified faster due to less manure input and higher bicarbonate (HCO3-) leaching, induced by higher CO2 pressure under irrigated circumstances. Net HCO3- leaching and N transformations mainly contributed to the acidification in paddy and upland soils, respectively. Optimal regional management practices are assessed considering the available amount of manure to meet agronomic and environmental targets for N, P and BC. We show that the VSD+ model can be used to optimize the application of fertilizer, manure and lime in agricultural systems, in view of soil acidification and nutrient losses, at regional level.

Accurate and efficient mapping of soil texture: Direct or indirect approach?

Zhuodong Zhang and Yuhe Shen

Detailed soil texture (ST) mapping is important for land management and environmental sustainability. Digital soil mapping (DSM) is an effective method to predict ST, and two approaches (direct and indirect) of ST mapping are available. The direct approach determines ST by the particle size distribution (PSD) at measured locations and then trains the DSM model directly by the ST types. While the indirect approach firstly predicts the PSD separates, based on which the ST types are then determined. Both the approaches were applied in previous studies, however, only either of the two was applied in each research, thus the accuracy and efficiency of the two approaches could not be properly assessed. Here, ST types were mapped by both the approaches in the same region using random forest algorithms with the same training and validation datasets, so as to compare their performances. Results show that the accuracy of the direct approach (73.9% for 0-5 cm layer; 82.6% for 35-40 cm layer) is higher than that of the indirect approach (43.5% for 0-5 cm layer; 73.9% for 35-40 cm layer). ST maps derived from the two approaches show obvious differences especially for the silt loam type, and there are small abrupt ST patches in the indirectly approached maps. The indirect approach is more quantitative, but there are more steps which bring more errors. Tiny errors in PSD prediction might result in another ST type and the abrupt ST patches consequently. Therefore, the direct approach is recommended for ST mapping.

A weakly supervised pore segmentation method based on traditional segmentation algorithm

Yinkai Fu, Zihan Huang, Yandong Zhao, Yue Zhao and Qiaoling Han

Soil pore structure is related to the developmental status and ecosystem service of the soil. In recent years, researchers have started to use deep learning to segment soil pores. However, when training deep learning models, a large number of manually calibrated dataset are required, which greatly increases the labor and time costs. To address this problem, a weakly supervised pore segmentation method (WSPS) based on traditional segmentation algorithms is proposed in this paper. WSPS produces soil pore pseudo-labels by the traditional segmentation algorithm for the training of the upstream task. Based on this, a small amount of real soil pore labels are used for fine-tuning in the downstream task to obtain the final segmentation effect maps. In this paper, a total of four traditional segmentation algorithms are taken for comparison experiments in the upstream task, and also compared with these four traditional methods themselves and four supervised deep learning methods. Results show that WSPS can guarantee a great improvement in the accuracy of the traditional segmentation algorithms with a small gap from the deep learning methods. In addition, WSPS significantly reduces the manual calibration of the dataset compared to the deep learning methods. This study allows deep learning to be more easily used for soil pore segmentation while maintaining its accuracy, providing image processing technology support for the modern development of soil research.

Using multisensory and multitemporal Sentinel satellite imagery together with in-situ measurements for soil erosion mapping

Marina-Ramona Virghileanu, Bogdan-Andrei Mihai and Ionut Săvulescu

Soil erosion by water is one of the global environmental issue causing serious losses of fertile topsoil, affecting the land production capacity. Mapping the affected areas is a key factor for environmental monitoring and decision-support systems. Remote sensing provides opportunities for soil data extraction with high spatial and temporal resolution. However, the use of remotely sensed imagery for soil erosion mapping is a challenging task, generally targeting the delineation of some erosion features or integration in GIS approaches for potential soil losses quantification. The aim of this paper is to assess the suitability of multisensory

and multitemporal satellite imagery, acquired by Sentinel-1 SAR and Sentinel-2 MSI sensors, together with spectral and biophysical indices and in-situ measurements, for soil erosion mapping within selected test-sites from Romanian Carpathians and Subcarpathians. The approach follows three stages. First, all the satellite imagery are pre-processed in order to obtain calibrated datasets. Second, several approaches for feature extraction are tested, based on different combination of input stacked layers (multisensory, multitemporal and/or derived data) in order to design the most effective workflow for soil erosion mapping. The third level implies the results validation with in-situ measurements on soil sample profiles. The results show good overall accuracies for mapping the soil erosion intensity in qualitative classes (low, moderate, high) based on spectral indices (around 70%) like Soil-Adjusted Vegetation Index and Degraded Land Area. Regarding the classification approach, better accuracies are recorded for multisensory and multitemporal stacked dataset, with an 93% overall accuracy, and 66% for soil erosion class.

Semi-supervised segmentation of multi-scale soil pores based on a novel receptive field structure

Yinkai Fu, Yandong Zhao, Yue Zhao and Qiaoling Han

To better investigate the soil internal structure, researchers used computed tomography (CT) to obtain soil CT images. And the use of deep learning for segmenting soil pores has been found to be practical. However, when dealing with multi-scale soil pores, normal neural networks cannot effectively segment large connected pores and small scatter points simultaneously. To address this issue, this paper proposed a semi-supervised multi-scale segmentation method (SMS). SMS is based on the different feature extraction ability of the convolutional neural network's different downsampled feature layer receptive fields and constructs a novel receptive field structure using multi-scale skip connections for multi-scale soil pores. The structure outputs multi-scale pore segmentation effect maps, and finally, it selects the optimal effect maps through a semi-supervised approach to accomplish the targeted segmentation of soil pores. Experiments show that SMS can effectively enhance segmentation performance in the face of multi-scale soil pores, and its accuracy, precision, recall, and F1-score values reach 99.55%, 83.76%, 96.12%, and 89.35%, respectively, which are the highest compared to three common deep learning methods and three traditional image processing software. This result validates the effectiveness of deep learning in the field of soil pore segmentation and further refines its application. This study can also provide image processing support for further investigation of soil structure characteristics, soil conservation and soil ecosystem service.

Soil organic carbon prediction and mapping using airborne hyperspectral and Sentinel-2 multispectral data: effect of soil texture

Vahid Khosravi, Asa Gholizadeh, Radka Kodešová, Daniel Žížala, Mohammadmehdi Saberioon and Luboš Borůvka

Soil organic carbon (SOC) plays a vital role in the health and fertility of forest and agricultural ecosystems as well as climate change mitigation; hence, continuous monitoring of the SOC content is highly demanded. To fill that need, remote sensing (RS) has gained great popularity due to its unique capability for large-scale monitoring of the soil surface. However, light interaction with the soil surface is affected by some soil properties, like texture, which need to be considered when using RS. In this study, SOC content was predicted and mapped using airborne hyperspectral and Sentinel-2 multispectral data with and without considering the effect of texture. For that purpose, 320 soil samples were collected from four agricultural areas in the Czech Republic. SOC and texture (clay, silt, and sand content) of each soil sample were determined in the laboratory. Two hundred samples remained after extracting bare soil pixels using NDVI and NBR2 indices. SOC prediction models were then developed using random forest (RF) for all areas together and

separately with and without considering the soil texture. According to the results, although models obtained by Sentinel-2 were relatively acceptable for some areas, those developed on hyperspectral data provided much better performance. Separate inclusion of soil texture parameters as predictor variables did not cause significant improvement, except for the clay, which caused an average enhancement of 9 and 12 percent for models developed using Sentinel-2 and airborne hyperspectral data, respectively. Using all texture variables together also slightly enhanced the prediction results.

Inter-layer interpolation for soil CT images based on CNN and optical flow

Hao Bai, Xibo Zhou, Qiaoling Han, Yandong Zhao and Yue Zhao

Computed tomography (CT) is an effective tool to describe the soil internal structure. However, the voxels of CT images are anisotropic, i.e., the resolution in the vertical direction is lower than that in the horizontal direction, which can negatively impact the characterization of soil morphological parameters and the quality of three-dimensional reconstructed images. Currently, interpolation methods to realize the voxel isotropy of soil CT images cannot generate high-quality interpolation images at arbitrary positions between two slices, causing errors in the analysis of soil structure. Therefore, this study developed an interpolation method (ASIBF) based on convolutional neural network (CNN) and optical flow, to generate high-quality images with isotropic voxels and assist in digital soil descriptions. The proposed method used an estimated image synthesis module to extract bidirectional optical flow between two input images and estimated optical flows from input images to arbitrary interpolation positions, to obtain the overall continuous change. Subsequently, the residual stream and its weights were extracted using intermediate image synthesis module to obtain the detail change. Finally, interpolation image synthesis module fused the global and detail information to generate a high-precision isotropic voxel interpolation image. Compared with traditional interpolation methods, the ASIBF method showed superior performance with higher peak signal-to-noise ratio (PSNR) of 32.637 dB and structural similarity index (SSIM) of 0.928. This study demonstrated that the ASIBF method not only enhances the resolution of soil CT images in the vertical direction, but also achieves voxel isotropy, providing an intelligent technique for the understanding of soil internal structure.

New extractive technique for stony soil monoliths

Jordi Panisello Martí, Elena Nieto, Agnès Lladós, Lola Boquera and Jorge Adell

Numerous extraction methods have been described over more than 100 years of soil monolith production by museums, research centres and universities. Many of the extraction techniques use a wooden box as a container to extract and transport the samples, which limits the extraction from stony soils. This article explains the methodology used for the extraction of soil monoliths from the Pyrenees and Pre-Pyrenees with the aim of creating a permanent exhibition of soils for the Pyrenean Soil Interpretation Centre, that currently houses 45 monoliths, located in in the town of Tremp (Lleida). Due to the stony nature of the mountain soils in this part of Catalonia, the usual techniques for soil monoliths extraction were barely feasible and a new technique, known as "mummy", had to be developed. This extraction technique has been developed by the company EUREKA SGN, which has adapted it from the different excavation procedures of palaeontological resources. Although it is not simple and involves several laborious phases, it makes the extraction reliable and efficient. Avoiding the breakage of the sample and providing full efficiency demonstrated in the monoliths made.

Soil data rescue operations in support of national and global soil information: lessons from the Coalition of the Willing (CoW) for data sharing in Ethiopia

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Soil and agronomy data has been collected in Ethiopia for over 60 years to understand soil nutrient status. Unfortunately, this data is difficult to access due to its scattered nature, lack of harmonization, and individual ownership, which makes it vulnerable to permanent loss. This has resulted in duplication of efforts and wastage of resources to generate obscured data. Given the emerging computational capacities to make more robust decisions, a large volume of data is required, which is costly and time-consuming to generate. Cognizant of these, the Coalition of the Willing (CoW) for data sharing and access was created in 2018 with joint support and coordination of the Alliance Bioversity International and CIAT, and GIZ. The CoW mobilized its members to map soil and agronomy legacy data, and embarked on data rescue operations. Accordingly, about 20,000 legacy soil profiles which were with various levels of completeness in terms of soil morphological, physical, and chemical properties were rescued. After cleaning and harmonization, the data were put into a central data repository, which is now accessible to the members and the wider data user community, according to the guidelines adopted by the CoW. We present the approaches and achievements including the way forward to achieve Ethiopia's harmonized soil profile database and the National Soil Information System that meets modern soil data demands and supports the development of national and global 3D soil property and nutrient maps.

Prediction of soil properties in a deep Colluvisol profile using VNIR hyperspectral imaging

Daniel Žížala, Jessica Reyes Rojas and Tereza Zádorová

Colluvisols represent an important part of the soil cover, occupying concave slope elements in landscapes with undulating relief. Their sedimentary character predisposes them to a wide use for the reconstruction of phenomena associated with erosion-accumulation processes. They show significant differences in depth, stratigraphy and properties, resulting from specific local settings. Colluvisols profile consists of layers of different thicknesses and properties; the level of profile heterogeneity is affected by the character of sedimentation. They also act as important sinks of soil organic carbon (SOC) in landscape. Classical point measurements are quite demanding, especially in extremely deep profiles, and provide only discrete information about soil properties, neglecting their micro-variability. Continuous pattern of soil properties and their changes can be obtained by prediction based on hyperspectral imaging. The study aimed to investigate the potential for accurate mapping of soil properties (SOC content, soil texture, calcium carbonate content) within a 5m-deep Colluvisol formed in a Chernozem region in SE Czechia using VNIR image spectroscopy and point laboratory analysis. After pre-processing of spectral data (noise reduction and data transformation), prediction algorithms including Partial least square, Random Forest, Cubist and Support Vector Machine regressions were applied to train the model using analysed point sampling. The results showed good ability to map the micro-variability within the soil profile even in the absence of SWIR spectra, especially for SOC and calcium carbonate contents. SWIR spectrum can be considered for more accurate prediction of soil texture. The study was funded by the grant nr. 21-11879S of the Czech Science Foundation.

Quality and safety assessment of fertilising products derived from fishery waste and by-products

Jingsi Zhang, Çağrı Akyol and Erik Meers

The circular and bio-economy offers great potential for fish and aquaculture industries as valuable fertilising products can be recovered from these industries' waste streams to replace synthetic mineral fertilisers.

In this study, 20 fertilising products were collected from 7 pilot installations which recovered nutrients from fishery waste and by-products using 9 different technologies within H2020 Project Sea2Land. The Nitrogen (N) mineralization pattern of these fertilising products were further investigated as the N use efficiency and ability of fertilisers to substitute mineral fertilisers is fully dependent on the N speciation of applied N in the soil. Following the quality and safety assessment of these fertilising products based on the Fertilising Products Regulation (EU 2019/1009), 8 products were potentially qualified as organic fertiliser and the others could be alternatively used as soil improver, biostimulant or liming agent depending on their characteristics. Total N (TN) content of the organic fertilisers ranged from 1.89% to 9.77% (fresh weight), in which ammonium (NH4+, 0.11 – 10.95 g/kg) comprised the majority of bioavailable N, while nitrate (NO3-) and nitrite (NO2-) content were below 0.002 g/kg. The N release of the organic fertilisers is being determined in ongoing soil incubation experiments under controlled conditions in comparison to synthetic fertiliser. We expect to find NH4+ as the main form of soluble N in the early days, while NO3- and NO2- content increase in time and so does bioavailable N. The expected results will indicate if fishery waste-derived organic fertilisers could exhibit slower release rate than that of synthetic fertilisers.

Permacultural raised bed composition impacts yields and soil properties: results of a 3-years trial

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The use of permanent raised beds composed of various types of organic matter is a practice often promoted in permacultural systems. To our knowledge no study has ever compared the effectiveness and progression of soil properties in the different types of emblematic raised beds of permaculture. Four types of permacultural raised beds of various compositions were implemented in the horticultural TERRA-Terre gardens of the WASABI platform in Gembloux Agro-Bio Tech (Belgium). These beds contained either an alternation of layers of organic matter rich in nitrogen and carbon, with or without the addition of wood at the bottom (lasagna and hugel "Holzer" beds respectively), carbon only (sandwich "Morez" beds) or soil only (soil "Hazelip" beds). They were compared with non-raised beds. All modalities were repeated 9 times. Each year from 2020, a mix of five vegetable species (onions, spinach, fennel, lettuce and peas) was planted on each modality. Measurements were made regarding the growth and yields of vegetables, the soil composition, temperature and water content, microbial activities and quantification of mycorrhizae. This paper will present the results of the first three years of experimentation. Total organic carbon and total nitrogen appeared to be higher in the hugel, lasagna and sandwich mounds. Microbial activity was higher in sandwich, soil and lasagna mounds. Plant biomass production was significantly lower on the sandwich beds, probably due to nitrogen hunger. It was also observed that the mounds rounded 'shape tends to favor soil warming, especially in beds containing slowly decomposing organic matter (like sandwich beds).

Biochar enhances tomato (Solanum lycopersicum) plant yields in alkaline sandy soils

Nayara Vivian Huve Musskopf, Kennedy Odokonyero, Lisa Oki Exposito, Batool Albar, Adair Gallo Junior and Himanshu Mishra

Arid regions such as the Middle East struggle to realize sufficiency in food production due to low-fertility soils and harsh climate. Alkalinity impacts bioavailability of key nutrients, including phosphorus, calcium, and nitrogen. In this study, we pyrolyzed date palm waste to produce biochar and tested its effects on the ion-exchange capacity of soils in Western Saudi Arabia. A field trial was conducted with tomato (Solanum lycopersicum) plants, comparing the effects (individual and synergistic) of biochar, superhydrophobic sand (SHS) mulch, and super-water-absorbent polymer (SAP) in highly alkaline (pH 9.2) sandy soils. The specific

treatments were: (i) NPK fertilizer only (control); (ii) NPK fertilizer with 1 cm-thick layer of SHS on the top; (iii) NPK fertilizer with SAP; (iv) 300 g of nutrients-loaded biochar (with N, P, and micronutrients such as copper, manganese, sulfur, and zinc); and (v) the combination of SHS, SAP, and nutrients-loaded biochar. Surprisingly, compared to the control (i), the soil treatments resulted in enhanced tomato fruit yields as follows: (ii) 81%, (iii) 38%, and (iv-v) 700%. To understand the superior performance of biochar, we analyzed the soil elemental composition. This revealed a higher bio-availability of ammonium, phosphorus, and manganese, which correlate with the fruit yield. In this study, we will explain how biochar boosts plant growth under highly alkaline soil. These results underscore the potential of date palm biochar for food production in hot and dry regions with alkaline soils.

Relationships between soil properties in multifunctional cropping system

Aušra Rudinskienė and Aušra Marcinkevičienė

Multifunctional crops, also known as mixed (multipurpose) crops, are the cultivation of two or more agricultural crops on the same field that differ in their vegetative season, biological and agrotechnical characteristics. Principal component analysis (PCA, based on correlations) was used to determine the correlation between different indicators in multifunctional crops. Two groups of correlating indicators have been identified. The first group of correlates was total nitrogen, organic carbon, CO2 emissions from the soil, plant root biomass and the activity of the soil enzyme urease. The second group of correlating parameters was available phosphorus and available potassium and the activity of the soil enzyme saccharase. During the crop year, soil enzyme urease activity correlated most strongly with organic carbon and available phosphorus levels and plant root biomass. The activity of the soil enzyme saccharase was most dependent on the available potassium in the soil. CO2 emission from the soil was correlated with the total nitrogen content of the soil. In the second year of caraway cultivation, the activity of the soil enzymes saccharase and urease correlated most strongly with the CO2 emission from the soil and the plant root biomass. The activity of the enzyme urease was more dependent on soil total nitrogen than that of the enzyme saccharase. In the third year of caraway cultivation, the activity of the soil enzymes saccharase and urease correlated most strongly with organic carbon and total nitrogen. CO2 emission from the soil was related to plant root biomass.

Evaluation of wool-based mulches as an alternative to plastic geotextile

Marie Dincher, Zoé Ott, Thomas De Lame, Hassaim M. Jijakli and Caroline De Clerck

Mulches allow farmers to play on the temperature of the soil, they reduce evapotranspiration and control the development of weeds. Currently most of the mulches used in agriculture are made of low-density polyethylene. Its degradation during the growing season causes an enrichment of the soil in small plastic particles. Thus, it is now necessary to develop efficient mulches whose degradation will not pollute agricultural lands. This study presents the results obtained tree years in a row with two wool-based mulches: needle-punched wool bands and raw sheep fleeces used for a zucchini crop. Their efficiency was evaluated looking at the local environmental conditions they create, linked with the development of the plants and crop yield. Special attention was also dedicated to the long term influence they could have on soil properties. All this, in comparison with bare soil and a more commonly used mulch: geotextile. Results obtained with raw sheep fleeces were promising both in terms of growth and yield, on the contrary to geotextile. Effect on weed development was similar between wool based mulches and geotextile. Soil studies also show a benefit in terms of temperature and moisture. The presence of fleece was also found to have a positive effect on the concentration of potassium in the soil. Moreover, being unwashed and untreated, raw sheep fleeces are a cheaper material, in addition to the fact that it allows the revalorization of a material classically considered as waste by the textile industry.

Biofertilisers and organic soil amendments might sustain nutrient cycling and microbial diversity.

K M Shamsul Haque, Leslie Weston and Saliya Gurusinghe

"Biofertiliser" contains living microorganisms that help increase the soil's fertility and encourage plant growth. The incorporation of biochar into the soil has the potential to improve its structure, its ability to retain water, and its capability to provide a habitat for bacteria that are advantageous to the ecosystem. Inoculating soil with beneficial bacteria will result in the mineralisation of minerals as well as an increase in the bioavailability of those elements. In this study, an inorganic fertiliser served as the control, and a comparison was made between the effects of specific microbial inoculants and biochar on the vegetative growth of wheat and the dynamics of the soil microbial community. In a glasshouse with a controlled climate, wheat was grown in either Chromosol or Vertosol with six replications. In addition to two different microbial inoculants, biochar and synthetic fertiliser were used as treatments. Plant growth and nutritional composition were analysed. The microbial communities in the rhizosphere were characterised by next-generation sequencing. Plants that had been inoculated with Bacillus exhibited a better harvest index after being treated with biochar. In Vertosol soils that were treated with Bacillus and biochar, there was a considerable increase in the amount of Colwell P. Actinobacteria, a bacterium that encourages the development of plants, rose when treated with Bacillus as opposed to when they were left untreated. The investigation resulted in the gaining of new knowledge about the use of biochar and microorganisms in the context of the role of biofertiliser.

Engineering cation exchange capacity of date palm biochar for soil amendment

Batool Albar, Nayara Huve Musskopf, Adair Gallo Junior and Himanshu Mishra

Biochar is derived from the pyrolysis of organic biomass, such as crop residue and food waste. A number of studies world-over have demonstrated that biochar can improve soils' organic matter content, cation exchange capacity (CEC), and water holding capacity. It also exhibits high chemical stability in the soil, thereby affording an avenue for diverting organic landfills towards long-term carbon sequestration. Here, we investigate the CEC of biochar formulations produced from date palm leaves, one of the most common organic waste streams in Saudi Arabia. We compared the effects of several post-pyrolysis oxidative modifications of date palm biochar. Some of the modifications could enhance the CEC by up to 215%, which was quantified via the following two independent methods, namely: (i) the saturation of the ion-exchange sites with hydronium ions; and (ii) by summing up the base cations extracted from biochar using the Mehlich-3 protocol. We will also present the results of our pot study comparing the effects of the modified and as-produced biochar formulations on tomato plants in terms of plant growth, fruit yield, and nutrient-use efficiency in an alkaline sandy soil.

LivinGro: preserving and improving microbial biodiversity with a sustainable agriculture

Sandra Tienda, Jose Antonio Guiterrez-Barranquero, Victor Carrion, F. Javier Peris-Felipo, Michael Schade, Ana Lia Gayan, Gina Swart and Francisco M. Cazorla

This research is focused within the framework of the international LivinGro® project, promoted by Syngenta. LivinGro® is a long-term study that focuses on the effect of sustainable management practices on agricultural ecosystems to preserve or increase soil microbial biodiversity. To carry out this study, soil samples from different selected experimental plots of stone fruit and olive trees in different geographical areas of Spain were collected and analyzed during two-years experiment. Microbial biodiversity was estimated by the relative abundance of prokaryotic and eukaryotic genera, and the alpha- and beta-diversity was also obtained. More specifically, microbial groups that are increased in relative abundance with ecological soil management and that could have a possible beneficial role for soil or plant health were proposed. Finally, microbial markers

that could be potential fungal pathogens of crops which were decreased in their abundance with ecological management practices were selected.

Effect of biochar and superhydrophobic sand mulches on evaporation and water holding capacity in sandy soils

Lisa Oki Exposito, Nayara Huve Musskopf, Batool Albar, Adair Gallo Junior and Himanshu Mishra

Realizing high irrigation efficiency in hot and arid lands is a daunting challenge due to the significant percolation and evaporation losses. Sandy soils exacerbate the situation due to their low water holding capacity, leading to nutrients leaching. In response, we have developed two soil amendment technologies, namely SandX and biochar, for boosting soil's water-holding capacity and curtailing evaporative losses, respectively. Specifically, SandX is a superhydrophobic material comprised of silica sand grains coated with 20 nm-thick paraffin wax. Biochar was derived from the pyrolysis of date palm (DP) leaves at 500 °C. We investigate the effects of these materials on the hydraulic properties of sandy soil (A3 - fine sand ASTM D3282) via pot studies. Experiments revealed that when SandX is applied as a 5-10 mm-tick mulch over the sandy soil (transient state; initial soil moisture 22wt%; final soil moisture 10wt%), the evaporation loss was reduced by 54% and 70%, respectively, relative to the sandy soil (8.35 mmH2O/day) under an average of 40°C/RH60%. Pot-holding capacities (PHC) for water were determined gravimetrically for sandy soil (23.63% gH2O/g of dry soil) and BC at (a) 2 and (b) 5wt% in sandy soil. PHC increased by (a) 11% and (b) 51%, respectively, for the biochar treatments. The synergistic effects of both technologies as a function of biochar particle size and mass fraction in the soil will be presented. Our presentation will demonstrate the potential of SandX and DP biochar in curtailing high evaporation rates and percolation, respectively, in sandy soils in arid lands.

Investigating the susceptibility of soils to microbial nitrogen-mining across a subarctic ecotone

Agnieszka Rzepczynska and Lettice Hicks

The release of labile carbon (C) through enhanced root exudation associated with climate warming in northern ecosystems may stimulate microbial activity, contributing to soil C loss ("priming effect"). Earlier studies found the addition of labile C to accelerate the turnover of soil organic matter in tundra soils, but gross N mineralization was stimulated more than C mineralization, thus suggesting microbial targeting of N-rich organic matter ("selective microbial N-mining"). However, the susceptibility of soils to selective microbial N-mining induced by labile C input in soils beneath other vegetation types is uncertain. Here we used soils from four different vegetation types along a subarctic ecotone (namely, tundra heath, shrub tundra, treeline, and birch forest), where N and phosphorus fertilisation had been applied annually for two years prior to sampling. We established a laboratory microcosm experiment, where we supplemented the soil samples with 13C-labelled glucose. We investigated bacterial and fungal responses to a pulse 13C addition (1000 µg glucose g-1 soil) over the course of 7 days. C and gross N mineralisation were measured using gas chromatography and 15N pool dilution methods, respectively, and microbial growth rates using stable-isotope incorporation. The "space-for-time" approach employed by the ecotone field design will enable better predictions of the responses of soil C and N cycling under future climate change.

Drivers of bioturbation patterns and the role of bioturbators in modulating soil nutrient availability across climate gradients

Diana Kraus, Jörg Bendix, Roland Brandl, Nina Farwig and Annegret Larsen

Bioturbators shape their environment with consequences for crucial ecosystem functions. Thereby, the abundance and composition of bioturbators depend on climate with ants and mammals dominating in arid and semiarid areas and earthworms dominating in humid areas. Additionally, the activity of burrowing animals is often positively associated with vegetation cover. Bioturbation has also been shown to increase soil vertical mixing, with implications for nutrient availability to vegetation. To understand bioturbation mechanisms, the investigation of the drivers of bioturbation patterns and bioturbators' effects on soil nutrient availability is essential. To do this, we measured the density of holes and excavated soil volume by bioturbators on eighty 100 m^2-size plots ranging from arid to humid in Chile. We differentiated between vertebrates and invertebrates using a threshold of 2.5 cm. Additionally, we analyzed the carbon, nitrogen, and phosphorus contents of bioturbated and control soil. We found that animal hole density decreased from arid (invertebrates: 14 ± 7.8, vertebrates: 2.8 ± 2.9) to humid (invertebrates: 2.8 ± 3.1, vertebrates: 2.2 ± 2.1) environments, while excavated soil volume was 300-fold larger for vertebrates than for invertebrates in all climate zones. The difference in carbon and nitrogen contents between affected and control soil increased with vegetation cover in the arid site. Our results show that climate, vegetation, and vertebrate abundance are significant drivers of bioturbation patterns along a climate gradient. In other words, the magnitude of bioturbation varies along the climate gradient, with the strongest effect in arid regions, where macronutrient enrichment improves soil fertility.

Island formation by the earthworm Aporrectodea caliginosa

Ron de Goede and Floor van den Berg

Extreme soil moisture conditions are expected to occur more often due to climate change. Therefore, it is vital to understand the response of earthworms and their coping mechanism to these conditions. One of the mechanisms used by the endogeic species to avoid anaerobic conditions during flooding is the formation of islands. Such islands created by earthworms have been found in specific landscapes in the Surales in South America. Recently, at a very small scale, island patterns were observed under solar panels in The Netherlands, which seemed to be constructed by the species Aporrectodea caliginosa. A lab experiment was performed with mesocosms with A. caliginosa in mesocosms to determine if they are responsible for the islands. The mesocosms had two different initial conditions (flat or rugged surface) and two different flooding treatments. Earthworm island formation was demonstrated and depended on the initial ruggedness of the soil surface and the rate of flooding. The highest islands were found in treatments with an initial rugged soil surface and the slowest rates of flooding. The earthworm density was higher in the islands than in the surrounding submerged soil.

Complementarity of DNA- and fatty-acid based methods in a nation-wide soil biodiversity monitoring study

Inga Hiiesalu, Tanel Vahter, Siim-Kaarel Sepp, Ayesh Piyara Wipulasena and Maarja Öpik

With no comprehensive overview of the biological status of agricultural soils in Estonia, there are clear obstacles to decision-making at both policy and farm management levels – also a roadblock to the fullfilment of long-term strategical goals.Here, parallel analyses of soil fungal diversity and biomass were used to assess the explanatory power of diversity and biomass assessment methods in different farming contexts. Samples from 300 sites underwent soil DNA-based fungal biodiversity and soil fatty-acid biomarker-based biomass

assessments. Farmer surveys provided relevant management metadata. We assessed the information from both methods in the context of the ability to differentiate between forms of land-use and specific management regimes. Additionally, we assessed the year-to-year temporal variability in repeated measurements from 24 sites.Soil fungal DNA metabarcoding proved to be a suitable method for monitoring both short- and long-term changes in soil fungal biota but future efforts should concentrate on assessing the sources of temporal variability in metabarcoding-based monitoring schemes. Soil fatty-acid biomarker-based fungal, AM fungal and bacterial biomass was able to discriminate between different land-use types but not farming systems (organic, conventional). The two methods used in this study come to similar conclusions overall in terms of management impact to soil biota, but differ in their specific outputs and provide complementary information. As species richness, species identity, lifestyle and biomass all have both functional and ecological implications, the assessment of biomass and species identities in conjunction will yield more complete data for inference with ongoing processes in the soil.

Predation as regulator in eroding permafrost soil revealed through totalRNA sequencing

Maria Scheel, Athanasios Zervas, Ruud Rijkers, Alexander T. Tveit, Flemming Ekelund, Francisco Campuzano Jiménez, Carsten S. Jacobsen and Torben R. Christensen

Arctic tundra soils are at risk of irreversible degradation, but contain over half of all global soil carbon, equal to twice the global atmospheric carbon. As global warming causes these soils to thaw, these carbon pools become bioavailable for microbial degradation into greenhouse gases, such as carbon dioxide and methane. The magnitude of this carbon release though is not only shaped by abiotic soil conditions but also by biological processes, such as predation on soil bacteria by microbial predators. These bacterivores in temperate regions were shown to influence the microbial community composition and activity. In our most recent study we sequenced RNA of up to 26'500-year-old permafrost during abrupt erosion. Both thaw and soil moisture impacted the total active community composition, yet also the increased abundance of predators with thaw impacted both prokaryotes and microeukaryotes. With Myxobacteria at shallower depths, Protozoa, such as Cercozoa and Ciliophora, doubled in relative abundance in deeper, ancient, but freshly thawed layers. However, their importance in carbon cycling in these vulnerable tundra carbon-rich tundra soils remains unknown, which is why I propose a new study to focus on predation impacts on carbon cycling in the tundra.

Perennial intermediate wheatgrass improve soil microbial biomass, community composition, and soil fertility

Shoujiao Li

Soil microbes play significant roles in the ecosystem for nutrient cycling and plant productivity regulation. However, the conventional monoculture of annual crops, with highly intensive agronomy practices strongly disturbs the soil microbial community development thus influencing soil microbial biomass, nutrient cycling, and soil health. The perennial cereal grain crop e.g. Intermediate Wheatgrass (Thinopyrum intermedium) can survive several years without replanting. Due to the reduced soil physical disturbance and year-round plant root presence, Intermediate Wheatgrass is expected to improve the soil microbial biomass and soil health. This study quantified the soil microbial biomass, community composition, and soil fertility in organic Intermediate Wheatgrass sole cropping, intercropping, ley, rye, and conventional annual wheat cropping systems. The phospholipid fatty acid method is used for soil microbial biomass and community analyses. Results show that Intermediate Wheatgrass cropping systems have more abundant soil microbes including a higher amount of bacteria, fungi, arbuscular mycorrhizal fungi, and saprotrophic fungi than annual cropping systems, especially in the 0-5cm soil layer. The soil microbial community composition of conventional cropping is significantly different from that of organic cropping. Total soil microbial biomass, fungal biomass, bacterial biomass, and bacterial activity are positively correlated with soil total carbon and nitrogen concentration.

Overall, management, perenniality of cropping systems, and soil depths play important roles in shaping the soil microbial community. Our study confirmed that the perennial cereal grain cropping systems improve the soil microbial biomass, soil total carbon, nitrogen, and organic matter concentration under organic management, especially for the upper soil layer, indicating the implementation of perennial cereal grain crops under organic management has the potential to improve soil health and sustainability of crop production.

Factors influencing the microbial communities associated with wild plants in alkaline-saline soils

Dania Randi, Eva Oburger, Walter Schenkeveld, Stefanie Wienkoop and Dagmar Woebken

Droughts, aggravated by climate change, are intensifying the need for crop irrigation, which leads to the expansion of agricultural areas affected by soil salinization. This salinization is commonly accompanied by soil alkalization, and both affect metabolic processes of microorganisms and plants. Numerous soil microorganisms have evolved to withstand high salinity and alkalinity, and some of them have been shown to alleviate stress in plants. In turn, several plant species were shown to recruit beneficial root microbiomes; however, our understanding of the microbiome associated with wild plants in natural alkaline-saline soils and their beneficial effects is still limited. Our aim was to focus on a naturally high salt/pH-challenged ecosystem and investigate the relationship between the soil properties, root-associated microbial communities and physiological state of salt-tolerant plants. We conducted a 2-year field study of the salt-tolerant plants Lepidium cartilagineum (Brassicacea) and Lotus tenuis (Fabacea) in the soda lake region Seewinkel-Neusiedlersee, Austria. The abiotic factors affecting the root-associated microbial communities and plant physiological state were characterized by measuring soil geochemical properties. The responses of plants to varying salinity/alkalinity were determined by measuring a set of metabolic stress markers. Root-associated microbial communities were investigated by 16S rRNA and ITS2 amplicon sequencing and shown to be shaped by the abiotic stressors and plant species. Both investigated plant species belong to plant families containing numerous crop members. Therefore, insights into the interaction of wild plants and their associated microbial communities in a natural high salt/pH-challenged ecosystem will be of interest for sustainable agricultural practices.

Soil management influences the network among soil communities and their associated functions

Chenguang Gao, Martijn Bezemer, Franciska de Vries and Peter van Bodegom

Recent studies indicate that soil management practices can influence the structure and composition of soil communities. Most studies focus on specific groups of soil communities, or consider soil biota as a black box, whereas management effects on the entire soil community, its interconnectivity, and their associated ecosystem functions remain incompletely understood. Such information is necessary to facilitate reliable predictions of impacts of soil management practices. We will examine the soil food webs and their associated functions using soil samples collected from 93 croplands and dairy farms in the Netherlands. Soil earthworm abundance was recorded and soil microbial communities of bacteria, fungi, and nematodes were characterized by amplicon sequencing analysis. Soil microbial biomass of bacteria, fungi were tested by PLFA and soil biotic activities were quantified by soil respiration measurements and enzyme assays. Collected soil community data will be analyzed to investigated the possible effects of different soil management practices on the complexity of soil networks and the abundance of keystone taxa. Also further analysis will be conducted to explore the effects of soil management practices on the relationships between soil networks and nutrient cycling in soils. The results of this study will provide a better understanding of the management effects on the entire soil communities and their associated functions, enabling stakeholders to make decisions for optimizing ecosystem functioning and promoting the sustainable use of land.

Root traits explain multitrophic interactions of belowground microfauna on soil nitrogen mineralization and plant productivity

Junwei Hu, Ummehani Hassi, Mesfin T. Gebremikael, Kenneth Dumack, Tom De Swaef, Wim Wesemael, Steven Sleutel and Stefaan De Neve

Both herbivorous and bacterivorous microfauna have been shown to influence root development, soil nitrogen (N) mineralization, and plant productivity. However, our knowledge of these effects is limited as multitrophic interactions remain largely unexplored. We investigated whether and how herbivorous nematodes (Pratylenchus zeae) and bacterivorous nematodes (Poikilolaimus oxycercus), alone and in combination, affect plant biomass (Lolium multiflorum) through root traits and/or soil N mineralization. Bacterivorous nematodes increased, whereas herbivorous nematodes decreased, plant productivity. We found that root trait coordination in response to soil microfauna was consistent with the concept of root economics space. The negative interaction between herbivorous and bacterivorous nematodes on plant productivity at high herbivorous nematode infestation could be explained by reduced N mineralization and variation in the root nitrogen concentration-root tissue density (RNC-RTD) axis aligned with increased herbivore severity. This study revealed that herbivorous and bacterivorous nematodes moderated each other's effect on plant productivity via root trait coordination and N mineralization, and suggests, for the first time, the value of the root economics space concept for interpreting phenotypic root plasticity and functioning in response to local biotic factors.

Influence of rhizodeposition on the assembly of maize microbiota

Daniela Niedeggen

The rhizosphere has been defined more than a century ago as the area around roots influenced by rhizodeposition. Even today, the delimitation of the rhizosphere remains still vague, as rhizodeposits are quickly metabolized by microorganisms while its concentration decreases with distance to the root surface. A more precise understanding of the microbial mineralization dynamics with decreasing concentration of root exudates could greatly improve modelling approaches of micro-scale microbial activity in the rhizosphere. We investigated microbial mineralization of maize mucilage and selected typical exudate components in response to decreasing substrate concentrations to simulate reduced microbial access to C with increasing distance from the root. We found complex temporal growth dynamics in dependence of substrate composition. Generally, microbial mineralization started after about 6 h and peaked after approximately 20 h. Importantly, microbial assimilation of rhizodeposits did not ultimately stimulate growth, but had to exceed a certain C threshold. C-supply below microbial maintenance requirements only enhanced respiration, but was not sufficient for microbial production. Our measurements allow, for the first time, an exact calibration of models on rhizosphere microbial mineralization dynamics with increasing distance from the root surface.

Plant-microbe interactions for growth enhancement increased under long-term silicate fertilization in paddies

Chang-Hoon Lee, Sang Yoon Kim, Pil Joo Kim and Suvendu Das

Since rice is a high silicon (Si) accumulating plant, intensive rice cultivation reduces soil Si content, which impedes the growth and yield of rice as well as soil quality, so the use of Si fertilizer is required to make the rice production sustainable. The application of silicate fertilizer made from industrial slag to increase rice yield is a step forward in the use of slag as a value-added product in agriculture. Intensive studies to date have documented increased growth and yield of rice under silicate fertilization. While plant growth promotion is mainly regulated by microbe-mediated nutrient cycling, phytohormone production, antioxidant production, and

pathogen suppression, the effects of silicate fertilization on these microbe-mediated growth parameters are largely unknown. In this study, using coupled high throughput functional gene microarray and next generation sequencing, we investigated the effects of long-term (20 years) application of silicate fertilizer (made from blast furnace slag) on functional structure of microorganisms involved in nutrient cycling (C, N, and P), phytohormone production (ethylene, auxin, gibberellins, and polyamines), antioxidant production (catalase and peroxidase), and pathogen suppression (hydrogen cyanide synthase, putative pyridine nucleotide-disulphide oxidoreductase, and siderophore production) in paddy soils. It was found that long-term silicate fertilizer application significantly increased the relative abundance of genes involved in labile C degradation, while those involved in recalcitrant C degradation were not affected. Additionally, it markedly enhanced the relative abundance of genes involved in N fixation, inorganic-P solubilization, organic-P mineralization, and hydrogen cyanide synthase, while having no significant effect on the genes responsible for phytohormone and antioxidant production. Conclusively, long-term silicate fertilization benefits rice plant growth mainly by increasing microbe-mediated nutrient cycling and suppressing pathogens.

The effect of microbial inoculation on soil physical properties and plant growth under drought and well-watered conditions

Violeta Angulo, Mariet Hefting and George Kowalchuk

Climate change is affecting precipitation patterns across the globe, increasing the duration and intensity of drought events. Droughts represent a threat to agriculture and soil degradation. Soil microbes, particularly fungi and bacteria, are known to be important determinants of plant health and soil stability during drought events. In this study, we assessed the interactions between the inoculation of fungal and bacterial species and soil moisture on soil physical properties and plant growth. Tomato plants were grown for 38 days in nonnaturalized soils inoculated with individual microbial isolates, 10 fungal and three bacterial species, under two contrasting watering levels. We assessed plant growth properties, soil aggregation (mean weight diameter, MWD), water content, and microbial density at the harvest time. We found that inoculation improved soil aggregation (MWD) under both levels of moisture. Multiple inoculated strains improved plant performance under well-watered conditions, but only a single strain showed a growth effect under conditions of drought. Plant chlorophyll content was also affected by drought conditions. We observed an interactive effect of watering level and strain identity. MWD did not correlate with any plant growth parameter and stable soil fractions 2-1 mm were positively correlated to dry and fresh shoot biomass under well-watered conditions. Improvements in both plant growth and soil structure could be related to the production of EPS, and effective microbial soil colonization. Our study suggests that microbial stimulation of improved soil status may be a useful component of strategies for sustainable agronomic strategies that preserve soil structure while stimulating plant growth

Mapping the spatial multifunctionality of soil-based ecosystem services relationships and bundles at European scale.

Jessica Reyes Rojas, João Coblinski, Nicolas Saby P.A., Isabelle Cousin, Eduardo Medina, Luboš Boruvka and Sophie Cornu

According to the EU Soil Strategy 2030 all soil ecosystems should be kept in good health and become more resilient. Moreover, the soil protection, sustainable use and soil restoration should become a routine by 2050. To accomplish this and improve understanding of soil health and the provision of soil-based ecosystem services (SES), a spatiotemporal assessment of SES provision and spatial associations is required. The objective of this work is to show how an approach that incorporates evaluation of bundles, i.e., mix of positively correlated SES provided together in the same place and at the same time, can improve our understanding of SES spatial

dynamics. We therefore assessed the spatial association among four individual SES spatial assessment using European data (e.g., primary biomass production, greenhouse gas and climate regulation, erosion control and hydrological control). We analysed the paired trade-offs/synergies using Spearman's coefficient and identified the SES bundles by applying clustering analysis (eg., gaussian mixture models clustering algorithm). The SES bundles were juxtaposed with biophysical and socioeconomic data to investigate the influence of drivers structuring SES bundles.

Spatial distribution of the soil moisture along a terminal moraine using two experimental plots in a near-natural forest

Alina Azekenova

Increased intensity of climate extremes affects the behaviour of water fluxes in the forest ecosystem. One of them is the recent dry years that caused disturbances in soil water replenishment and forest growth. The near-natural beech forest prescribes our study area on an old moraine with distinguished soil moisture gradient and tree conditions. Moreover, the management practices of this forest allow the natural process of dead wood decay. In order to analyse the spatial distribution of the soil moisture two experimental plots were designed: along the tree root system and under dead wood. These plots assist in understanding the dynamics of soil water and therefore the sustainability of European beech forests to climate extremes. An integrated approach was undertaken based on the soil-plant-atmosphere continuum, including analysis of terminal moraine soil water properties and correlation with different stand structures along moraine. In addition, the influence of decayed deadwood on vertical soil moisture distribution was considered. This aspect clarifies how the potential increase in soil organic matter from dead wood is linked to forest water storage, particularly soil water dynamics. Ongoing monitoring initiated in 2022 is to be used to determine the influence of spatio-temporal patterns in soil moisture on above- and below-ground C storage. Consequently, feedback effects of deadwood degradation on the water balance and all processes depending on it, should be recorded. Based on this, a complete picture of the alternating scenarios of soil water balance - deadwood - C-storage of the soils emerges.

Taking advantage of digital soil mapping for sustainable territorial planning in Catalonia: a pioneering approach to preserve agricultural capacity

Marc Vicens Ferrer, Antoni Baltierrez, Andrea Vidal and Patricia Lopez

The land capability classification indicates the suitability of soils for most kinds of field crops in an area. Soils are classified based on their limitations for field crops, the risk of losing their agricultural capability, and their response to management. Due to increasing demand for land surfaces to install large photovoltaic plants in Catalonia, there is an urgent need for land capability information, as Catalan law specifies where these plants can be installed according to the land capability class of the area. The ICGC is implementing Digital Soil Mapping (DSM) procedures to complement traditional soil survey methods, with the goal of providing a land capability map of the entire surface of Catalonia by 2026. To date, only 18% of Catalonia (and 33% of its agricultural surface) has been mapped. A pilot area in Penedès is being used to develop seven digital models based on artificial intelligence algorithms for predicting soil properties, including rootable depth, grain size, content of coarse elements, drainage, salinity and sodicity, and available water holding capacity. These models will result in a new Land Capability Digital Model. The digital modeling process will enable exploration of a wide range of covariates, potentially leading to predictions (with associated uncertainty) of a much wider range of soil attributes and functions over larger areas. The application of DSM and its assessment in Catalonia will improve the efficiency of land planning and help guarantee the protection of the best soils for food production, which is essential in addressing food security.

Soil properties as reflected by long-term complex measures

Vaida Steponavičienė and Vaclovas Bogužas

Improved management practices must integrate unique differences in climate and site-specific soil properties, including the use of crop residue management to improve carbon sequestration as a soil stability measure. Therefore, a study was initiated to evaluate the effects of long-term reduced tillage and no-tillage in combination with the use of plant residues and cover crops for green manure on soil organic carbon (SOC). The long-term stationary field experiment was established at Vytautas Magnus University Experimental Station at 54°52'50" N latitude and 23°49'41" E longitude on Plansoils in 1999. Factor A consisted of: R - straw removed (control) and S – straw chopped and spread. Factor B included: CP – discing and conventional deep ploughing (control), SP – discing and shallow ploughing, PLT – ploughless tillage, SD – single seedbed discing before sowing, NTCC – cover crops followed seedbed no-tillage, NT - no-tillage. The following crop rotation sequence was employed: winter oilseed rape (Brassica napus L.), winter wheat (Triticum aestivum L.), and spring barley (Hordeum vulgare L.). Soil tillage systems and other complex measures in permanent crop rotation influenced the accumulation of SOC. In plots without straw reduced tillage systems SD, NTCC and NT increased SOC poll in the 0-25 cm soil layer by 23.1-29.1 % compared with that in conventional tillage. Straw retention in these treatments increased SOC poll by 19.5-31.0 %. Reduced tillage systems SD, NTCC and NT intensified the accumulation of SOC and humification was observed. These practices are efficient measures of soil organic carbon resilience and recovery in a long-term period.

Indigenous Trichoderma (TRB)- a promising turfgrass growth stimulator and soil amendment

Mehrdad Zarafshar, Olivier Bresnard, Auriane Thomas, Jean Loup Petit, Stephane Bazot and Gaelle Vincent

Green keepers use a variety of chemical fertilizers to stimulate grass growth and improve their resistance to adverse conditions. Meanwhile, the chemical inputs bring some toxic impacts for soil and water sources so many chemical companies are looking towards biological products to decline the need for chemical inputs. An alternative is to use native soil microbiome like Trichoderma that simulate more nature close conditions, therefore creating a more resilient system that needs fewer chemical fertilizers. A greenhouse pot experiment, quantifying the growth of turfgrass and soil respiration, with Trichoderma, was conducted in a completely randomized design. Treatments consisted in five replications of control (no agent added), native Trichoderma (TrB) with and without organic amino acid and (iii) commercial biofertilizer of Trichoderma (Trianum, produced by Kopper company) with and without organic amino acid, and those received just organic amino acid. We estimated the grass coverage by pictures taken each week, and analysis of colors on Python. We recorded the soil respiration (CO2 emission) along the time and recorded the root and shoot elongation after one month inoculation. Moreover, we measured the plant production above-ground after cutting. Overall, our experiment obviously indicated that TrB expose promising influence as biostimulator and biofertilizer particularly when they received organic amino acid sources. Our study demonstrates that using of native Trichoderma (TrB) is a promising solution for sustainable management of golf courses but more investigation is needed.

Can earthworms increase inorganic carbon sequestration in an artificial system?

Tullia Calogiuri, Mathilde Hagens, Jan Willem Van Groenigen and Alix Vidal

Enhanced Silicate Weathering (ESW) is a promising Carbon Dioxide Removal (CDR) technology, but the factors that maximize its effectiveness remain unclear. Recent studies have shown that earthworms can amplify mineral weathering rates and increase inorganic carbon (IC) sequestration. Here, we test the capacity of earthworms to accelerate ESW rates by 1) identifying optimal conditions for earthworms in an environment composed of ground silicate rocks and organic substrate, and 2) determining to what extent earthworms

can enhance IC sequestration. We conducted five rounds of two-month experiments in a climate chamber at 25°C, using two endogeic earthworm species, four rock flours in two grain sizes, two organic substrates, and two water irrigation rates at three frequencies in different combinations. Rock flours were used as single types or sizes, as well as mixtures. At the end of each round, we measured earthworm survival and activity, dissolved and solid IC, total alkalinity, pH, electrical conductivity, and major ions. Amongst all the factors considered, we found that mineral type and mineral grain size dominantly drove earthworm survival and activity. Following mineral type and grain size, earthworm species and density determined earthworm survival, while earthworm density and mixtures of mineral types and/or grain sizes impacted earthworm activity. Preliminary results suggest that earthworms increase mineral weathering rates and IC sequestration. We demonstrate that earthworms can thrive in a fully artificial system designed for accelerating ESW rates and can contribute to amplifying this process, with important implications for application of ESW in soils.

Fertilising soils with silicate rocks and biochar can co-benefit soil CO2 sequestration and crop productivity

Emily E.E.M. te Pas, Rob N.J. Comans and Mathilde Hagens

Carbon dioxide (CO2) sequestration in agricultural soils is promoted as a promising option for climate change mitigation. Two nature-based CO2 removal technologies are Enhanced Weathering (EW) and biochar amendment. EW involves the crushing and spreading of silicate rocks, such as olivine-rich dunite, to enhance CO2 consumption. The resulting increase in soil pH and release of nutrients may co-benefit crop productivity, while released heavy metals may have the opposite effect. Amending soils with biochar (pyrolyzed organic material) can increase soil carbon content, crop productivity, and heavy metal immobilisation. Previous experimental studies focused on single applications of either EW or biochar, yet data on potential co-benefits following their combined amendment is missing. We conducted a two-month greenhouse pot experiment growing maize (Zea mays L.) on soils mixed with different doses of dunite (20-220 t ha-1) with and without biochar (20 t ha-1). On a weekly basis, soil CO2 emissions were measured, and soil pore water was extracted for measurements of pH and total alkalinity. Upon termination of the experiment, nutrient and heavy metal concentrations were quantified in biomass using microwave digestion (HNO3-HCl-H2O2) and in different soil pools applying appropriate extraction methods, followed by ICP-OES and ICP-MS measurements. Soil and plant carbon contents were determined with a LECO CN analyser. These data were combined to quantify carbon budgets and heavy metal immobilisation. Our results show that CO2 sequestration increases with dunite dose, while biochar amendment mainly stimulates crop productivity. Important implications for combined EW and biochar applications will be presented at the conference.

Decrease in soil N2O emissions from agricultural acid soils through enhanced silicate weathering practices: a study case of beans crop

Sílvia Poblador, Coline Le Noir de Carlan, Arthur Vienne, Laura Steinwidder, Lucilla Boito, Erik Verbruggen and Sara Vicca

Changes in agricultural management practices to enhance soil carbon sequestration while maintaining crop productivity can contribute to mitigate climate change. Enhanced weathering of silicate minerals (ESW) is a promising CO2 removal technology based on the acceleration of a natural process. Spreading silicate powder on arable soils has been associated with multiple co-benefits for crop production (i.e. increase in crop yields, soil base cations and nutrient stocks) but little experimental attention has been given to the potential effect on soil N2O emissions. We set up an experiment with 21 mesocosms with acid soil (pH 5) receiving different basalt application rates (0, 2.5, 5, 10, 25, 50, 100 T ha-1) and planted with beans (90 days growing season). Soil CO2 and N2O emissions were measured over the growing season (5 times), together with the study of

the soil bacterial community and nitrogen processes. Soil pH increased from 5.5 to 6.83 (0-100 T basalt ha-1). Basalt application did not lead to an increase in beans production, while their Mg and Ni content increased with increasing basalt application rate. Although the increase in soil nutrient availability (Ca, Mg and Cd) suggested larger weathering rates with increasing basalt addition, no soil carbonate precipitation was detected. Soil N2O emissions decreased for higher treatments. Results suggested that N2O emission originated from denitrification processes, and lower emissions at higher basalt application rates were related to greater nosZ gene abundance. Overall, this study confirms the potential of ESW practices to reduce the N2O-source behaviour of agricultural acid soils.

Monitoring basalt enhanced weathering and C sequestration

Arthur Vienne, Jet Rijnders, Sara Vicca and Patrick Frings

Enhanced weathering using basalt is a promising negative emission technology (NET) that can have co-benefits for plant production. Nevertheless, quantification of mineral weathering rates (Wr) and carbon dioxide removal (CDR) is challenging, yet crucial for accreditation of C certificates. In a mesocosm experiment, we cultivated maize on a basalt amended soil and quantified C in three phases (liquid, solid and gas phase). In the liquid phase, C was measured in topsoil pore water and in leaching water at 60cm depth. A comparison of ions in topsoil porewater and leachates allows to detect adsorption of these elements within the column. In the solid phase, we compared sensitivity of methodologies to detect changes in soil inorganic carbon (SIC). Moreover, weathering rates were determined in soils using an established approach (yet novel in EW context): sequential extraction. In the gas phase, soil CO2 efflux (SCE) was measured and partitioned into soil organic matter (SOM) and root respiration based on d13C analyses. Preliminary results indicate sequential extraction as the most sensitive method and further suggest increased decomposition upon basalt application as well as increased SOM stabilization due to cation bonds.

Are C stocks linked to microbial necromass residues? Evidence from a 1km gradient in the tropical Andes

Angela Katherine Martin Vivanco, Outi-Maaria Sietiö, Nele Meyer, Oona Uhlgren, Sylwia Adamczyk, Kevin Mganga, Subin Kalu and Kristiina Karhu

In the Peruvian western Andes, we set a gradient ranging from 3500 to 4500 m a.s.l. in Polylepis forest of the Huascarán National Park. This ecosystem harbours a rich endemic biodiversity that may be threatened because of higher-than-average warming during the last century (Vuille et al, 2008). Soil microorganisms, including fungi and bacteria, are regarded to be the principal decomposers, causing organic matter breakdown and build-up. Microbial residue accumulation contributes to carbon stabilisation in soils (Liang et al, 2017). We aim to test whether microbial necromass residues (amino sugars) are related to C stocks along the gradient, and if the microbial residue accumulation is explained by the microbial community structure profiled by phospholipid fatty acid (PLFA).

Assessing the potential of belowground carbon sequestration after converting a temperate permanent grassland into a bamboo (Phyllostachys) plantation

Nicolas Kovacs, Gilles Colinet, Karen Vancampenhout, Bernard Longdoz and Jeroen Meersmans

The plantation of bamboo forests seems to have great potential to help fight climate change. However, bamboo's exact soil carbon sequestration potential needs to be better quantified. Therefore, in the present

research, the soil organic carbon (SOC) dynamics of three bamboo species (i.e. Phyllostachys nigra, Phyllostachys aurea and Phyllostachys aureosulcata) planted 12 years ago in the Belgian Kempen have been studied in detail. Besides the SOC stock changes, the C-inputs in and C-outputs from the soil have been assessed by measuring the litter fall and root systems versus CO2 respiration rates, respectively. We took soil samples in 10 cm depth increments up to 40 cm. P. aurea and P. aureosulcata showed a significantly higher SOC stock between 30 and 40 cm in depth, with more roots also found. Considering the stocks of SOC, roots and litter, the three bamboo species showed significant additional C-storage compared to grassland. In addition, the relative CO2 effluxes (mgCO2-C gSOC h-1) suggested that SOC from bamboo was more stable. In a nutshell, this study shows that converting permanent grassland into Phyllostachys bamboo plantation results in a net sequestration of C in the soil by increasing both C-inputs and stability. However, to assess its full climate change mitigation potential, future research should consider C-storage in the above-ground biomass and conduct an associated LCA when considering its usage in various products.

Effect of nutrient-enriched biochar on soil properties and onion productivity

Poonam Bhatt, Alina Poudel, Prashanta Raut, Santosh Shrestha and Keshab Raj Pande

A field experiment was conducted at Bhaktapur, Nepal to examine the effect of nutrient-enriched biochar on soil chemical properties and yield of onion and its residual effect in the second year. The experiment was laid out in Randomized Complete Block Design with four replications and six treatments involving application of biochar in combination with chemical and organic fertilizer. Treatments were: Control (T1), RDF (T2), ½ RDF+ Biochar (T3), RDF+ Biochar (T4), Vermicompost+Biochar (T5) and cattle urine+ Biochar(T6). The trial was conducted from 19th December 2021 to 30th April 2022 in a span of two cropping cycles with the aforementioned treatments for the first year, RDF and 30t/ha FYM applied to the whole experimental unit as a basic nutrient in the second year. The highest yield of onion 18.62 tha -1 in the first year was increased to 31.2 tha -1 in the preceding year using T5. T5 showed a significant effect on soil pH which increased from initial pH of 4.0 to 5.83 in the first year and 5.94 in the second year. Soil N, P, K, and organic matter increased by 72%, 125%, 73.24%, and 5.84% respectively. It was concluded that nutrient-enriched lantana-based biochar application significantly increased the yield of onion bulbs and the residual soil chemical properties even in the second year. The study suggests that biochar can be best used as an amendment in combination with vermicompost to get the best results with onion yield and soil NPK in the longer run. Thus, biochar can be a viable option to improve soil fertility and onion productivity.

Future-proof composts and soil amendments to cope with intensified droughts

Lotte Baert, Harika Bommisetty, Sai Nagarjuna Reddy Meka, Steven Sleutel and Wim Cornelis

This study aims to increase the resilience of the soil against prolonged droughts that are predicted under future climate. Increasing the soil water holding capacity might be a solution to this threat, but the impact of compost addition on this property varies among different sources. Furthermore, there might be other soil amendments that can improve soil water retention. This study investigates seven compost types and six ecological soil amendments including biochar, biosolids, chitin, seaweed-, alfalfa- and flax fibre powder. This study entails a pot experiment in an experimental greenhouse in which different doses of composts and soil amendments were tested, according to their nutrient content and potential to influence soil physical properties. Tests were carried out on drought-sensitive sandy loam- and loamy sand soils for two water regimes. In total, 120 treatments were tested. Lettuce was grown in every pot. Undisturbed soil samples were analysed to obtain the plant available water capacity (PAWC). The PAWC was 11%, 18% and 26% enhanced compared to the reference for respectively fruit, vegetable and yard compost, green compost and vermicompost in sandy loam, and 11% when treated with bark compost in loamy sand. Contradictory, a lower compost dose often resulted in a higher PAWC then the larger doses. Increasing the soil amendment

dose resulted in a higher PAWC. The largest increases in PAWC under the addition of soil amendments were noted for biosolids (19%), seaweed- (13%) and flax fibre powder (17%) in loamy sand soil under dry water regime.

Soil-water land-use systems of the sandy soil landscapes: a quantitative study

Laxmi Chaulagain, Jakob Wallinga, Annegret Larsen and Jasper Candel

The sandy soils are nutrient-constrained and frequently experience excess water during winters and scarcity during summers, creating a compromised water situation in the Netherlands. The summer droughts of 2018, 2019 and 2020 were a wake-up call that our landscapes are not sustainable and resilient to climate change, especially sandy soil landscapes. Scientists have also shown that such erratic rainfall patterns make these areas prone to flooding (during winter) and drought (in summer). The low water-holding capacity of sandy soils makes water management practices more cumbersome and complex. To extend the human use of these landscapes, a focus on nature-based solutions that utilize the natural potential of the landscapes is necessary. Therefore, a study will be conducted in the sandy soil regions of the Netherlands to unravel how landscapes function based on soil suitability and water availability, along with the impact of land use. To better understand natural systems, past soil-water-land use systems will be reconstructed and compared with the current system in living labs. The reduced-complexity hydrological and groundwater models will be used to study and quantify the relationship between soil and water on different land uses. This knowledge will be used to evaluate existing or proposed landscape regeneration approaches under various climate scenarios. Thus, the result will be used to recommend sustainable land use practices based on soil type and water systems for making the sandy soil landscapes of the Netherlands future climate-proof.

Dissemination of multi-scale and multi-thematic soil data in Brittany region (France)

Blandine Lemercier, Hervé Squividant, Pascal Pichelin, Christine Lindenberger and Agathe Adam

Delivering relevant information on soils is crucial to preserve natural resources, adapt agricultural practices, develop the territory, and protect sensitive areas. To this end, a mapping portal has been developed via a dedicated Mviewer instance (https://geosas.fr/solsdebretagne) in the Brittany region (North West of France) allowing the visualization, consultation and downloading of available soil maps: - The regional soil map at 1:250,000, which follows the specifications of the national soil mapping programme: thematic vector maps, but also rasters of soil properties at several depths (50m resolution);- Local maps at scales ranging from 1:10,000 to 1:50,000 in image or vector format, covering about $\frac{1}{4}$ of the regional territory; - Functional indicators: for the moment, information on the organic carbon stock is available and will be completed soon by a map of the soil available water capacity.- A tool to help soil identification from a selected position and successive answers to questions. Each of these information has a specific and ergonomic context to facilitate the access to soil information to specialists or simply the curious, for agronomy, environment, and land use planning issues. Links to metadata, soil type descriptions, and data downloads are provided. The tools developed for our portal are designed in a modular, interoperable, generic and open approach in accordance with the FAIR data principles. In order to share these developments, they are available and are currently reused and adapted to another French region: New-Aquitaine (South West of France).

Weighted Overlay analysis based agricultural land suitability assessment for soybean crop cultivation in Tehsil Jaranwala, Pakistan

Noman Ahmad, Hamaad Raza Ahmad, Muhammad Aamer Maqsood and Fahd Rasul

The main objective of this study is to investigate the potentially suitable area in terms of climate, irrigation water, land, and crop requirements for non-conventional soybean crops in the semi-arid terrestrial ecosystem in the Tehsil Jaranwala, District Faisalabad, which covers an area of approximately 1726.69 km2. Multiple Criteria Weighted Overlay (MCWO) analysis, integrated with Analytical Hierarchy Process (AHP) and GIS-based geostatistical interpolation techniques, were selected as the basis for the present study. A total of 19 soil, irrigation water, topographic, and climatic parameters were used to identify potential sites for soybean crops in Tehsil Jaranwala. For land slope and elevation features, this study used SRTM-DEM data, Sentinel-2 images for LCLU, NASA power meteorological data for ten-year temperature and precipitation, and 40 soil and water samples (each collected 7 km apart). In AHP, weights were defined using a pairwise comparison matrix based on expertise ratings. Using United Nations Food and Agriculture Organization (FAO) guidelines, the cropland suitability map was categorized into five classes: highly suitable, moderately suitable, marginally suitable, not suitable, and permanently not suitable. After removing the spaces of permanent features such as built-up areas, barren land, and forests, it was estimated that 47.46% of the land is highly suitable for soybean crop cultivation, with 11.9–21.36% potentially available with site-specific management. Using United Nations Food and Agriculture Organization (FAO) guidelines, the cropland suitability map was categorized into five classes: highly suitable, moderately suitable, marginally suitable, not suitable, and permanently not suitable. After removing the spaces of permanent features such as built-up areas, barren land, and forests, it was estimated that 47.46% of the land is highly suitable for soybean crop cultivation, with 11.9–21.36% potentially available with site-specific management. Also, most of the study area has access to good-quality irrigation water, ranging from "highly suitable" (46%) to "marginally suitable" (1.25%).Based on the findings, it was concluded that soybean is a potential crop for the Tehsil Jaranwala with improved agronomic practices, INUE, and IPM strategies, and that using GIS and AHP in cropland suitability assessment is effective and will assist legislators in enhancing their sustainable natural resource monitoring.

Friday

Plenary

Keynote lecture: Perspectives from Nature Based Solutions to monitor and restore soil and ecosystems

Carlo Calfapietra

The concept of nature-based solutions (NBS) promotes working with natural 'tools' to address societal challenges, to protect and sustainably manage natural and modified ecosystems. Soil provides important ecosystem services, which are essential contributions to NBS. Carbon sequestration in soils contributes to climate mitigation. Soil hydraulic conductivity and cation exchange capacity are important properties that influence the filtering and purification of surface- and groundwater and mitigate flooding. Soils can be biogeochemical barriers to immobilize potentially toxic elements. Diversity and functionality of soil biota are highly relevant for sustainable land management projects, including revitalization of degraded lands, nature conservation or biodiversity-positive food systems. Agricultural soils are the core for food provisioning, whereas urban soils support blue-green infrastructures and contribute to the quality of life in cities.

Soil Health is Human Health: Implications for Restoration and Rewilding Initiatives

Katherine Lawless

This paper explores connections between soil health and human health and their implications for rewilding and ecological restoration. I argue that ecological restoration initiatives of all kinds, including rewilding, will benefit from a conceptual understanding of the relationship between soil health and human health. I verify this claim using methods in conceptual research, including historical research, literature review and theory development. The idea that soil health is human health is not new; it appears in the scientific literature as early as 1910. Pioneers in the organic agriculture movement solidified this connection in the 1930s and 40s, and it is now encapsulated in current conceptions of 'one health.' However, the full extent of this relationship has not yet been explored from a conceptual perspective; nor have the implications for observed or desired ecosystem trajectory changes in response to restoration initiatives. In this paper, I maintain that the conceptual thrust of the claim that soil health is human health must be more fully elaborated to better understand the implications of such a claim for the revitalization and maintenance of wild spaces. Accordingly, I provide a brief overview of the soil health concept in soil science; examine how this concept gained strength through and borrowed from discoveries made by The Human Microbiome Project; and draw connections to recent research on the impacts of soil microbiome rewilding on human health. I conclude with a short reflection on the implications of soil health as human health for further conceptualizing global restoration and rewilding initiatives.

Climate change mitigation? Effects of enhanced silicate weathering on soil organic carbon dynamics

Laura Steinwidder, Lucilla Boito, Jet Rijnders, Patrick Frings, Arthur Vienne and Sara Vicca

There are two main processes acting as carbon sinks for CO2 on land: Silicate weathering and photosynthesis. The former creates bicarbonates which can be stored in soils or leached out and stored in the oceans,

the latter leads to the formation of plant tissue which can be stored as soil organic matter. Soils are thus at the foundation of both of these land sinks. Here, we test a soil-based solution for climate change mitigation involving both sinks: Enhanced silicate weathering. The application of finely ground silicates to soils accelerates the naturally slow weathering process leading to a meaningful carbon sequestration. Often overlooked however, is the effect of enhanced weathering on organic matter. How do enhanced weathering induced changes in soil properties (e.g. pH, nutrient availability, etc) affect organic carbon dynamics? Considering the importance of organic matter as a land carbon sink, addressing this question is crucial. While increased organic matter decomposition could drastically reduce the climate change mitigation potential, increased organic carbon sequestration could have the opposite effect. Not to mention the importance of organic matter for soil fertility and health. To improve our understanding of organic carbon dynamics under enhanced weathering we have conducted a mesocosm experiment with basalt and steel slags added to soils. We determined weathering rates, inorganic and organic carbon sequestration and greenhouse gas emissions. While some treatments consist of pots with bare soil, others included maize plants or earthworms; giving unique insights in interaction effects between the weathering process, organic matter dynamics and soil biota.

Why we need reduced-complexity SOC models

Kristine Karstens, Benjamin Leon Bodirsky and Alexander Popp

Soil organic carbon (SOC) is degraded by human interventions such as land cover change and agricultural management. While SOC models often simulate detailed biochemical processes that lead to SOC accumulation and degradation, the management decisions that drive these biophysical processes are poorly understood at the global scale. We develop a spatially explicit dataset for cropland management that accounts for crop production levels, residue levels, manure application, and the use of irrigation and tillage practices. We combine this dataset with a reduced complexity model based on the Intergovernmental Panel on Climate Change (IPCC) Tier 2 method to produce a dataset with half-degree resolution for SOC stocks and SOC stock changes in the first 30 cm of mineral soils. We estimate that soils have lost about 34.6 GtC due to cropping compared to a hypothetical natural state in 1975. We also find that management decisions have most strongly influenced historical SOC trajectories through residue return, suggesting that increasing SOC through biomass retention may be a promising technique for negative emissions. Assessing SOC management dynamically into the future could be promising, considering interdependencies with environmental, social, and economic sustainability targets (e.g. biomass use for BECCS). The assessment has yet been difficult, as more detailed process-based models are typically too computationally demanding to be integrated into optimization-based integrated assessment models (IAMs). Our reduced-complexity model could be suitable for simulating management-induced SOC enhancement in an IAM, allowing for detailed representation of agricultural soil management.

Destisol: a decision support tool to evaluate ecosystem services provided by urban soils in order to improve urban planning

Geoffroy Séré, Maïwenn Lothodé, Clémentine Chirol and Christophe Schwartz

Urban soils exhibit a large diversity of properties but are dominantly perceived as degraded by stakeholders. As a consequence, their potentials are not taken into account in urban planning even though they can deliver a range of ecosystem services. Destisol, a decision support tool, has been developed to evaluate the soil ecosystem services in order to integrate urban soils' potentials into urban land planning. Destisol was applied to 37 urban soils under various situations and pedoclimates to test the common assumption that highly anthropized soils are systematically less functional than natural soils. Finally, the architecture and performance of our model were discussed to highlight the ongoing issue of defining metrics for the evaluation of ecosystem services. Our results demonstrate a wide distribution of scores depending on the studied urban

soil, but also on the soil function, soil cover or ecosystem service considered. Technosols present the most diverse spread of soil function scores, and no correlation was found between the anthropization gradient and the mean soil function score. Urban soils present an untapped potential in soil management for providing ecosystem services. Used by urban planners, Destisol could promote the re-use of in situ urban soils instead of dumping and replacing them by natural top soil. In addition, it could enhance the consideration of soil in urban planning and promote a balanced approach of project development between ecosystem services and urban services delivery.

Parallel Session

S1: NBS for C sequestration

Climate smart agriculture: microbiological impacts of plant diversity to soil carbon sequestration

Rashmi Shrestha, Luiz Domeignoz-Horta, Karoliina Huusko, Outi-Maaria Sietiö, Anna-Liisa Laine and Jussi Heinonsalo

Biodiversity loss caused by conventional farming relying on monoculture has been identified as a major threat to soil organic carbon (SOC) sequestration, which is crucial for both soil health and climate change mitigation. Soil microorganisms are important as they regulate the turnover and distribution of nutrients, and soil organic matter decomposition rate. Carbon use efficiency (CUE) is the amount of carbon taken up by microbial cells and retained in biomass in relation to amount lost via respiration. CUE is an important microbial property controlling SOC sequestration and nutrient cycling. Polyculture farming using cover crops and avoiding winter bare fields may be better farming practices, however their impacts on soil microbial community composition and CUE in agricultural soil remains unknown. My PhD project aims to study plant diversity impacts on microbial community structure and SOC sequestration. We used an experimental field established in 2019 in Finland where barley is undersown with 1, 2, 4 and 8 cover crop species. The rooting depth and nitrogen(N)-fixing ability of cover crops were combined to form four functional groups: shallow root Nfix and noNfix and deep root Nfix and noNfix. During 2019-2020 period, we collected soils to determine microbial biomass, respiration, microbial community composition and CUE. Soil microbial biomass and CUE increased with increasing cover crop richness. Results suggest that plant diversity may result in higher soil carbon stocks. Additional results on soil microbial community will be presented. Our study will show if diverse cover cropping is suitable climate-smart practice in boreal climate.

Water, Carbon, and Climate: An Integrated Modelling Approach to Nature-Based Solutions

Borjana Bogatinoska, Angelique Lansu, Jean Huge, Stefan C. Dekker and Jetse Stoorvogel

Land and oceans act as critical ‘carbon sinks’, absorbing over half of global greenhouse gas emissions and mitigating further warming. However, land use change and loss of nature have resulted in a significant portion of emissions, hindering efforts to achieve the goals of the Paris Agreement. To limit global warming to below 2 degrees, carbon sequestration is needed, and nature-based solutions such as afforestation, reforestation, and soil and wetland restoration have been proposed as promising strategies. These kind of solutions are connected with local expertise and participatory approaches. This calls for rapid uprisal of hydrological and carbon nature-based solutions to be discussed at a local level. Consequently, the question arises to whether a loose coupling of existing models would help build this needed integrated approach. In this study, we

focus on a lowland basing in the Netherlands, the Aa of Weerijs catchment, and compare two different land use scenarios: i) the existing situation with traditional engineering measures such as dams and levees, and ii) a co-designed nature-based solutions scenario. By employing a loose coupling approach that combines hydrological and soil-carbon models using in-situ and remotely sensed data, we aim to calculate the soil organic carbon (SOC) stocks for 2100. Results will showcase the: i) design of the soil-water integrated modelling approach and ii) from our simulations we will present the insights into the evolution of SOC stocks until 2100 under existing engineering measures versus co-designed nature-based solutions' management. The findings will contribute to our understanding of the potential of nature-based solutions in mitigating climate change effects and inform decision-making for sustainable land management practices at catchment scales. By designing nature-based solutions in a participatory way with stakeholders, we can strive for a higher level of opportunity mapping for carbon sequestration or flood and drought resilience, thus advancing the use of nature-based solutions as an effective strategy for climate change mitigation.

Wetlands in brook catchments: Modelling land-use change and its impact on soil organic carbon (2010 – 2020 – 2050).

Luuk Timmer, Jikke van Wijnen, Angelique Lansu and Jetse Stoorvogel

Nature-based solutions (NbS) in brook catchments, for example wetlands, are considered as climate measures to adapt to hydrometeorological weather extremes (storms, floods, droughts) and human-induced water demand. Furthermore, NbS can also contribute to carbon sequestration. However, implementing wetlands in brook catchments is entangled in anthropogenic land-use change (LUC) and it is unknown how this effects soil organic carbon (SOC). To elucidate this, a system analysis based on 2010 and 2020 of a brook catchment (Dutch Aa/Weerijs; 147 km2; S of Breda) determines the spatio-temporal dynamics of LUC towards 2050 and its connection to SOC including the climate mitigation impact of wetlands. Spatio-temporal in-situ soil datasets are used to establish SOC stocks for nine land-use categories while considering the interdependence between soil specific SOC, land-use, and management practices. For the 2050 land-use outlook, LUC between 2010 and 2020 served as input. Land-use developments are determined by machine learning and a neural network (TerrSet 2020 - Land Change Modeler). Land-use has been predicted in a Technical-physical scenario (LUC development considering the trends between 2010 and 2020) and a NbS/Wetlands scenario (LUC development with emphasis on wetlands) Findings indicate: (1) For the Technical-physical scenario a minor increase of SOC. Tree nursery especially emerges in the catchment. (2) For the NbS/Wetlands scenario, which emphasizes wetlands, a major increase of SOC. Wetlands especially emerges in the catchment. This modelling approach, based on existing soil and land-use datasets, could help rapid outlook studies and opportunity mapping to model different types of local measures and other NbS.

Silicates rock! Silicates and biota as a Nature-based solution to mitigate climate change

Lucilla Boito, Laura Steinwidder, Jet Rijnders, Jasper Roussard and Sara Vicca

Besides rapid and deep greenhouse gas emission reductions, atmospheric Carbon Dioxide Removal strategies (CDRs) will be necessary to mitigate anthropogenic climate change. A promising CDR and Nature-based solution is enhanced rock weathering (EW), deployed on croplands. The principle of EW is the reaction of silicates with CO2 and water to form bicarbonates, storing C for centuries and longer. So far, most research focused on lab-based weathering and sequestration rates, but these might differ substantially in field settings, where biota may have a strong effect on EW processes. Here, we set up a mesocosm experiment to quantify the C sequestration of EW and how this is affected by biota. We also evaluated potential risks due to release of heavy metals present in the silicate rock. The experiment consisted of soils applied with basalt and combinations of corn and/or earthworms. The effect of mycorrhizal fungi was also quantified by adding or excluding mycorrhiza to soil that had been pasteurized before planting. We measured i) CO2 fluxes as well as CH4 and

N2O emissions, in order to assess the full climate change mitigation effect of EW; ii) Soil Inorganic C (SIC), which together with leachate water chemistry allow us to determine the fate of sequestered C; iii) porewater and leachate water alkalinity, Dissolved Inorganic Carbon (DIC), pH and other elemental chemistry in order to determine weathering rates. Here, I will show preliminary results of the first growing season of this experiment.

S2: NBS for land development

Microbial diversity, function and soil fertility of corn and wheat agricultural soils in Mexico

Nathalie Cabriol, Marcelo Rojas-Oropeza, Mariana González-Macedo, Mayra Baeza Montemayor, Jose Antonio Gutierrez-Barranquero, Montserrat Benitez and F. Javier Peris-Felipo

The relationship between microbial communities present in soils and soil health is crucial for sustainable agriculture. Microbes play a critical role in nutrient cycling, plant growth, and disease suppression, making them valuable allies in maintaining healthy soils. This work includes a physicochemical and microbiological study conducted at two study sites: Texcoco (Southern Mexico) and Sonora (Northern Mexico), where corn and wheat are grown, respectively. Sequences for the 16S Bacteria (V6-V8) and ITS Fungi (ITS2) regions using DADA2 after a high-throughput Illumina sequencing process were generated, corresponding to Before and After Cultivation times. Taxonomic characteristics were determined using SILVA and UCHIME databases. Additionally, alpha diversity indexes were calculated with the Phyloseq package, including Microbiome Analyst. Beta diversity for taxonomic compositions was assessed using the PERMANOVA package with UniFrac distances. All microbiological information was related to physicochemical analysis to better comprehend the ecological dynamics in the soil. The results indicate significant changes in physicochemical characteristics, such as acidity, humidity, organic matter (OM), organic carbon (Org C), and nitrogenous forms, from 2021 to 2022 in Texcoco. Microbiological reports determined major potential functional groups of microorganisms, including nitrifiers, phosphate-solubilizing bacteria, plant-growth-promoting, and degraders of different pollutants. Regarding Fungi, there was more abundance, richness, and diversity found after cultivation time. In Sonora, there were significant changes in pH and electrical conductivity, which might lead to better nutrient absorption. However, there were no significant differences regarding the rest of the parameters. This research is focused within the international LivinGro® project, promoted by Syngenta.

Using plant-soil feedback to optimize crop rotations

Zhaoqi Bin, Ciska Veen, Wim van der Putten, Guangzhou Wang and Junling Zhang

Plant-soil feedback (PSF) is a major driver of plant performance and positive PSF effects can enhance plant growth via enhanced nutrient availability, disease suppression, and interactions between plants and microbes. Such positive PSF effects can therefore be used to optimize crop rotations for sustainable agricultural production. However, how to optimize crop rotations based on PSF is still poorly understood. Here we studied PSF for twelve crop species commonly grown in Chinese agriculture systems. We trained soil by growing each of the twelve crops in a 'conditioning phase' and then reciprocally planted the twelve crops in the conditioned soils in a 'feedback phase' under controlled greenhouse conditions. PSF for each crop was calculated by comparing the aboveground biomass of each crop grown in soil conditioned by the other eleven crops against aboveground biomass in self-conditioned soil. Overall, most crops experienced positive PSF in broad bean-conditioned soils, potentially explained by broad bean being a nitrogen fixer. In addition, graminoid species (oat, maize and wheat) generally benefitted from soils conditioned by other plant families, which may be due to their nutrient acquisitive strategy. For all conditioned soils, we use analyses of the microbial community, nutrient cycling and disease suppressiveness and of the plant traits to explain the PSF

effects. With our results, we will build a framework to determine the most productive rotation sequence.

SOILGUARD – Effects of land use and agricultural management along soil degradation gradients on nematodes, acari and collembola in European sites.

Giulia Bongiorno and Ron de Goede

Soil health is defined as the capacity of a soil to function within ecosystem and land-use boundaries. Soil biota can sustain a wide range of functions and as such are intrinsically connected to soil health. Land use, soil management and land degradation can affect soil biodiversity and ultimately soil health. Soil fauna is an integral part of soil biodiversity connected at various levels of the food web with other important soil organisms such as bacteria and fungi. Nematodes are ubiquitous organisms that are sensitive to disturbances and can be divided into functional groups based on feeding preferences and life-history strategies. Mites and collembola are two groups of microarthropods that are sensitive to land use change and soil management. These different groups of organisms can be used as indicators of soil biodiversity and health. The objective of this study is to investigate the status of nematode, acari and collembola abundance and diversity upon various land uses, agricultural management, and land degradation levels. The final aim is to connect their abundance and diversity to soil multifunctionality and soil health. Nematodes, acari and collembola community characteristics have been assessed in seven European NUTS regions with different land use (forest, grassland and arable land), management (clearcutting vs continuous cover, grass monoculture vs grass-clover mix, organic vs conventional agriculture), pedo-climatic (texture, climate) characteristics, and land degradation gradient (organic matter levels). Nematode, acari and collembola abundance and taxonomic diversity are currently being analysed with traditional morphological methods and the results will be presented during the congress.

Dung Beetle Activity Is Soil Type-Dependent and Modulates Pasture Growth and Associated Soil Microbiome

Leslie A Weston, Long Ma, Nirodha Weeraratne, K Shamsul Haque and Saliya Gurusinghe

The introduction of numerous exotic dung beetles across southern Australia in regions where native dung beetles are not generally efficient in processing livestock dung has resulted in significant reductions in the quantity of such dung on the soil surface in recent years. However, the direct impacts of such ecosystem services on pasture quality and soil nutrient mobility have not yet been investigated in the Riverina region of New South Wales (NSW), an area recognised for prime cattle and sheep production in Australia. Utilising 48 soil columns for lysimetry, we quantified the impact of a common introduced dung beetle (Bubas bison) in this region on water quality after permeation through four different soil types sown to winter annual pastures. Dung beetle treatments included dung plus dung beetles, dung alone and no dung beetles, and no dung and no beetles as a control. Dung beetles and soil type impacted on the performance of improved overseeded annual pastures as measured by biomass accumulation over a four-month growing season. The four soil types, namely, Chromosol, Kandosol, Rudosol, and Vertosol, differed considerably with respect to their water-holding capacity and nutrient profiles, as assessed by initial soil testing and soil leachate evaluation following rainfall plus simulated rainfall events. The concentration of Escherichia coli resulting from cattle dung, cattle dung plus beetles, and the control soils without dung or beetles was assessed in collected leachates over a three-month period. E. coli numbers were significantly increased following B. bison activity, when compared to the dung-only and control treatments. Evaluation of the soil microbiome, by assessing genomic DNA in soils sampled 10 cm below the soil surface where dung beetles remained active following tunnelling, revealed significant differences among soil types with respect to bacterial and fungal communities. Within each soil type, dung beetle activity impacted the fungal community structure, but

not the bacterial community. Pasture performance as assessed by biomass accumulation was significantly improved following dung beetle activity in later stages of pasture growth, while E. coli numbers and total coliforms appeared unaffected by beetle presence.

S3: NBS to support soil ecosystem services

Assessment of Ecosystem Services and Accounts for Sustainable Soil Management: Framework, Methodology and Case Study

Kuanting Lin, Horng-Yuh Guo, Mei-Hua Yuan, Yu-Chieh Huang and Shu-Yuan Pan

Natural capital accounting is an important tool for monitoring changes in the stock and condition of natural assets and integrating them into the national accounts system to enhance environmental management. Croplands associated with soils provide numerous essential provisioning and regulation services. However, agricultural land resources face significant environmental pressures from climate change, food security, and land-use changes. Additionally, there is currently a lack of suitable methodology for estimating agricultural ecosystem services at different scales, and few analyses focus on the contribution of soil attributes. To address this issue, this study aims to establish ecosystem services and accounts for cropland and soil ecosystems and apply the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA) to promote sustainable soil management policies. The study area selected for analysis is Yunlin county in Taiwan, which is a top producer of crops. The study examines the indicators of ecosystem services, including the provision and regulation services of cropland such as crop provision and carbon storage services. Data from soil surveys and other environmental datasets are used to analyze the land use, rainfall, and soil attributes of the study area spatially. The framework of ecosystem accounts, including ecosystem asset, physical, and monetary service accounts, and their beneficiaries is developed based on the evaluation results. The study findings are applied to link the cropland ecosystem with the management of sustainable soil. This research provides insights into assessing ecosystem services to encourage local participation in sustainable agriculture and land resource management.

Soil ecosystem services in Aravalli hills, Haryana, India

Deepika Pandey

The Aravalli mountains of India are one of the oldest fold mountain ranges in the world. It has been an important drainage system between the Indus basin and Ganga basin. Aravalli hills act as a physical barrier to check the spread of the Thar desert and a green barrier for Haryana and nearby states, against pollution. The hills work as a groundwater recharge zone and precipitation regulator, having rich biodiversity and reservoir for minerals & resources, and maintain the climate of Northwest India. Aravalli degradation has caused serious environmental issues, such as an increase in dust storms, a rise in pollution levels, biodiversity loss, and an increase in ecological vulnerability. The present study analyzes the changes in ecosystem services of the soils of the Aravalli region in terms of crop production, groundwater availability, pollution level etc. The study is conducted through a survey method for various indicators of natural resources depletion and soil quality assessment from the degraded area, that is rock quarrying, in contrast to fertile cropland.

Environmental controls and effects of soil-disturbing vertebrates on soil and sediment flux

Paulina Grigusova, Annegret Larsen, Roland Brandl, Nina Farwig, Diana Kraus and Jörg Bendix

Soil-disturbing vertebrates are diverse and widely distributed. They can occur in high densities, and substantial evidence has been collected on their overall positive effects on biodiversity and soil quality. The reintroduction (or rewilding) of these animals may present a unique opportunity for cheaper and more sustainable restoration, with greater benefits than mechanical approaches. However, while it is clear that burrowing animals contribute to soil mixing and overall greater soil fertility and biodiversity, little is known about firstly how this effect varies with burrowing animal species abundance and distribution along a climate gradient, and secondly what the offsite-effects of burrowing animal activity is. For example, animal burrows may increase hillslope sediment flux and hence lead to a loss of top-soil, or increase infiltration, leading to more subsurface water flow and piping erosion. In this study, we investigate the environmental controls and effects of burrowing animal activity on surface sediment flux. To do this, we mapped animal mounds in the field along a climate gradient in Chile, and used remote sensing to model burrow distribution. Then, we quantified animal burrow-related sediment flux using custom-made, high-resolution lidar-based technology, hillslope sediment fences, and soil erosion modelling. This study revealed and quantified for the first time that most animal burrowing activity is related to rainfall, which in combination with burrow density resulted in the highest overall contribution of animal burrowing activity to hillslope sediment flux in Mediterranean climate. In contrast, while many burrows are present in the arid climate zone, animals do not need to frequently maintain them, which leads to a comparably small contribution of the burrowing activity to hillslope sediment transport. The spatially explicit approach allowed to cross spatio-temporal scales (plot-hillslopes), and showed that the effects of animal burrowing activity can lead to both, an increase in erosion and accumulation, and hence to an equalization of relief over the long term.

Soil health: a "golden thread" incentivising investment in Nature-based Solutions

Lisette Phelan, Guy Ziv and Pippa J. Chapman

Nature-based solutions (NbS) constitute integrated, systemic approaches to land management, rehabilitation and restoration that safeguard ecosystem services and deliver economic, social and environmental benefits. This presentation takes the Landscape Enterprise Networks (LENs) approach as a case study to discuss the role of soils in NbS for climate change mitigation and adaptation, water management, food production, nature conservation and infrastructural support. Data for this presentation was collected through key informant interviews and a stakeholder discussion involving farmers, business sector stakeholders and civil society stakeholders. Results suggest that soil health is a “golden thread” that can provide a rationale for a diverse set of stakeholders – from farmers and land managers to agribusiness, food companies, water companies and local government authorities – to adopt a LENs approach to implementing NbS and commodifying ecosystem functions and assets at watershed and/or agricultural landscape level. The LENs approach fosters and/or strengthens relationships between stakeholders who might otherwise not recognise that it is in their interest to safeguard ecosystem services and that there are benefits to being part of a purposely established NbS trading community that engages in integrated, place-based investment in ecosystem functions and assets. This presentation highlights the opportunities associated with recognising the role of soils in NbS and framing NbS in terms of a common and shared understanding of sustainable soil management. Moreover, it underscores the governance challenges associated with planning and implementing NbS in contemporary fragmented business landscapes, agricultural landscapes and watersheds.