Understanding Soil Functions

WAGENINGEN SOIL CONFERENCE

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BOOK OF ABSTRACTS

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Marina Luciana Abreu de Melo, Quirijn de Jong van Lier and Fabio Scarpare

Limiting hydraulic condition to sugarcane: calibration and sensitivity to root distribution

Agro-hydrological models stand out as an effective approach to study water stress. We aimed to estimate the limiting matric potentials of the Feddes transpiration reduction function (h3l, h3h and h4) for different patterns of root distribution. The SWAP/WOFOST model was used to reproduce a two-year sugarcane crop experiment (2014 to 2016) in the county of Jau, Sao Paulo, Brazil. Matric potential was measured at 0.2, 0.4 and 1 m depths. Undisturbed soil samples were collected to determine the soil water retention curve. The Parameter ESTimation (PEST) software was used to calibrate simultaneously h3h, h3l and h4 by minimizing the sum of squared differences between 1626 pairs of soil water content values (simulated and observed). This procedure was performed for three patterns of root distribution (pre-calibrated, PCP, uniform among depths, UP, and linear decrease with depth, LDP). The calibrations were assessed using the coefficient of determination (R2) and the Root-Mean-Square Error (RMSE). The three calibrations reached R2=0.77 and RMSE=0.02 m3 m-3. For PCP, the parameters values were about -9 m (h3h), -20 m (h3l) and -98 m (h4). The other patterns affected significantly only the h3h value, with reductions of nine and sixteen percent for UP and LDP. For all patterns, the residuals tended to increase along the two seasons and the soil depth due to underestimations by the model. The estimation of the limiting hydraulic condition to sugarcane is not very sensitive to root distribution, but further attention is required under high demands for evapotranspiration.

Tebkew Shibabaw Achenef, Martin Rappe George and Annemieke Reurslag Gärdenäs

Impacts of Land Use change and Climate change on Soil Organic Carbon Stocks in the Ethiopian Highlands

Soil organic carbon (SOC)-stocks are indispensable for multiple ecosystem services. SOC-stocks are threatened to be deteriorated by Land Use Change (LUC) and Climate Change (CC). We address the potential impact of a change in land use and/or climate on SOC-stocks in soils in the subtropical Ethiopian highlands. The study site is the Birr watershed in NW Ethiopia. The mean daily temperature and annual precipitation are 16oC and 1730 mm for contemporary climate. In 2000, 44% of the Birr watershed was cultivated land, 34% bushland, 13% natural forests and 9% Eucalyptus plantations. The Q model (Ågren et al., 2007), was employed to estimate SOC-stocks changes for various combinations of LUC- and CC-scenarios until the year 2100. The LUC-scenarios, increase of Eucalyptus or cropland on the costs of natural forest, were based on historical LUC in the area. The CC-scenarios included i) unchanged litterfall (CC), ii 5% decrease in litterfall (CC -5%) and iii) 22% increase in litterfall (CC +22%).
We found that all the tested LUC-scenarios resulted into losses of SOC-stocks under contemporary climate. Losses of SOC stocks were largest for the conversions of natural forest into other land uses (-18 to -24 %). The impact of climate change was additive to that of LUC, circa +10% additional SOC losses. A gain in SOC-stocks under climate change could only be achieved by conversion to Eucalyptus from crop or bush land with a simultaneously increase of litterfall. We recommend LUC and management strategies to ensure an increase in tree and litter production.

Kristine Afanasjeva and Raimonds Kasparinskis

Impact of Norway spruce (Picea abies) on soil properties in former agricultural lands after natural afforestation

Natural afforestation of agricultural lands with Norway spruces (Picea abies) leads to sufficient changes of soil properties, quality and soil forming processes which eventually influence further sustainable soil use and land management. However, to date the impact of the natural afforestation process on the soil properties is still relatively poorly understood due to complex processes and various environmental factors.
The aim of the paper is to ascertain factors influencing soil characteristics and elucidate changes in soil properties caused by Norway spruce (Picea abies) as a result of afforestation of agricultural land in order to predict future changes.
The study has been conducted in the Vidzeme upland, Taurene surroundings, in two fields with different soil properties, where abandoned agricultural lands are naturally afforested by 15 year-old Norway spruces (Picea abies). Three zones – trunk, crown and meadow, have been defined and compared around trees, to estimate soil changes.
The result of the research has shown that natural afforestation of agricultural land with Norway spruce (Picea abies) has an impact

on soil chemical, physical and biological properties. Changes could be seen in vegetation cover, root system, soil acidity, bulk density, as well as in concentration of exchangeable cations, organic carbon, total nitrogen and phosphorus. Significant differences occur between different soil types and depths.

Aleksandr Aksenov, Andrey Izmailov and Aleksey Sibirev

Experimental data for modeling erosion and soil fertility

The preservation and improvement of soil fertility is a priority task for all mankind. Agricultural production is characterized by a wide variety of soil conditions. In each of these soils for each crop, individual methods of their mechanical processing and, respectively, used tillage machines. Not the right choice of methods and machines for tillage leads to soil erosion and, as a consequence, a decrease in its productivity. At the same time, the insufficient quality of the preparation for sowing leads to a decrease in potential yield. Vegetable crops are especially demanding for pre-sowing treatment. Studies have been carried out on the territory of the Russian Federation to determine the effect of soil structurality achieved by various methods and soil tillage machines on the formation of erosion-sensitive particles and the productivity of cultivated vegetable crops on various types of soil. Were considered processing on sandy, sandy, loamy and clay soils vertically and horizontally milling machines, as well as flat-cutting and disk tillage machines. In addition, data on the energy consumption of each of the above method. The obtained data allows to simulate and select the system of soil preparation for vegetable crops, taking into account environmental and economic criteria.

Aysha Akter, Nobaya Ahmad, Md. Monirul Islam and Mohammad Ashraful Islam

THE ROLE OF WOMEN IN LAND MANAGEMENT AND CONSERVATION - A CASE STUDY ON RURAL BANGLADESH

In smallholder farming, women play an important role and their contribution to the farm income is often disproportionately high. The study aimed to understand the role and perceptions of women farmers in land management and conservation, and to identify possible pathways for better representation of women's' needs in on farm land management and conservation.The study is based on semi-quantitative surveys of farming families. There are marked differences in the types of farm work between men and women, but also between different groups of women. Caste was not found to be an important criterion in defining the work of women, but rather education and age. More girls are being sent to schools and this inevitably limits their availability for farm work. This trend has also led to a loss of local knowledge on land management with girls and young women. Women without school education obtain their knowledge principally from older women and by practical experiences. Women with school education are able to understand extension messages more easily and they usually have a more 'scientific' approach to understanding things. These differences lead to different perceptions of farming and to problem solving. There are also noted differences between more remote villages and the villages closer to the road network and with better access to extension. Women in villages that are more easily accessible have generally a better understanding of modern technologies. These women also have better access to markets for better cash income, which -in turn- gives them more influence on farming decisions.

Collins Amoah-Antwi, Jolanta Kwiatkowska-Malina, Owen Fenton, Steven Thornton and Ewa Szara

Re-usable organic materials as long-term sources of soil organic matter

Humic substances (HSs) produced from the transformation of soil organic matter (SOM) have diverse functional groups that are central to their functionality. Though they occupy a very remote space in soil, HSs, especially humic acids (HAs) regulate many biogeochemical processes including nutrient cycling, C sequestration, soil aggregation, biological activity, detoxification and primary production. The quantity and quality of HAs have long been used as proxies for soil quality monitoring, with their high stability making them suitable for characterising long-term soil changes. Analytical techniques including UV-Visible spectrophotometry, solid state IR and NMR, and elemental analysis have not significantly improved clarity on the structural modifications that HSs undergo in soil.
In this study, HAs were extracted from soils from long-term field experiments at: (1) Bad Lauchstadt, Germany (farmyard manure); (2) Boku, Austria (biochar); (3) Skierniewice Experimental Station, Poland (farmyard manure). A pilot-scale field experiment was also set up in spring 2017 at the Skierniewice Experimental Station where different re-suable organic materials – farmyard manure, brown coal waste and woodchip biochar – were applied into soil. Soil samples were collected after 6 and 18 months for HAs extraction. We proposed a combination of differential scanning calorimetry (DSC), electron paramagnetic resonance (EPR), attenuated total reflectance-FTIR (ATR-FTIR), CP/MAS 13C-NMR spectroscopy and HPLC for the comprehensive characterisation of long-term quality changes in HAs. Preliminary results obtained for samples from the pilot-scale experiment after 6 months showed similar HAs contents across all treatments with only minor differences in fingerprint region of HAs spectra obtained with ATR-FTIR.

Martin Anikwe and Ejike Ikengannyia

Short-term Effect of Soil Tillage and NPK Fertilization Rates on Soil Carbon Sequestration and Yield of Colocasia esculenta in Two Micro-environments in SE, Nigeria

Quantification of soil organic carbon (SOC) cycling as influenced by management practices is needed for C sequestration and soil quality improvement studies. This study assessed the short-term effect of conventional tillage (CT) and No-Tillage (NT) practices on SOC sequestration and yield of cocoyam (Colocasia esculenta). The experiment was conducted simultaneously at two locations (06◦52' N, 07◦15' E and 06◦ 26' N; 07◦16' E) in southeast Nigeria. A Randomized Complete Block Design with five replications and four treatments which comprised of CT and NT respectively with 150 and 300 Kg/ha of NPK 15:15:15 was used. Soil quality attributes were measured at two soil depths (0-20 cm and 20-40 cm) in both locations and analysed. The results indicated that the quantity of carbon sequestered in the soil at 0-20 cm soil depth for both sites was 46.7- 90.9 and 65.0-117.9 Mg/ha respectively for the two planting seasons in NT plots treated with 300 Kg/ha of NPK. This was followed by NT plots treated with 150 Kg/ha of NPK which sequestered 55.5-86.2 and 46.7-91.9 Mg/ha SOC. CT plots that received 300 Kg/ha NPK with 11.3-47.6 Mg/ha SOC had 44% and 28% lower stored SOC when compared to NT, NPK 150 Kg/ha plots for the two-planting season respectively. This indicate that CT practices significantly limits SOC sequestration. CT with 300 Kg of NPK 15:15:15 gave the highest corm yield, followed by No-till with 300 Kg/ha. A better edaphic condition provided by CT was compensated for by higher doses of N fertilizer in NT Plots.

Valeria Arenas-Montaño, Breda Moore, Owen Fenton, Karen Daly and Mark Healy

Reuse potential of phosphorus-saturated alum sludge to agriculture as evaluated by a germination test

In line with the “circular economy” concept, waste filter media used for the removal of phosphorus (P) from water/wastewater streams could potentially be used as P fertilisers after saturation. Alum sludge (AS), a waste material from drinking water treatment plants, has a good P adsorption capacity and has been successfully used to remove P. However, its high concentration of aluminium (Al) could have a negative effect on plant growth, were it to be used as a P fertiliser. Therefore, the objectives of this experiment are to identify an application rate of P-saturated AS to soil for optimal plant germination and to quantify the impact of AS on the recalcitrant and more bioavailable P pools in soil. To accomplish these objectives, AS will be saturated with different concentrations of a synthetic P solution (1, 10 and 50 ppm) representative of water sources with a low, medium or high load of P. The saturated AS will be mixed with soil at 0% (only soil), 25%, 50%, 75% and 100% (only AS) and the total P and P pools in the mixtures will be evaluated. The mixtures will be added to Petri dishes in which 10 ryegrass seeds will be sown. After 72 hours, the germinated seeds will be counted and the root length will be recorded to evaluate the germination index (GI). The GI will be correlated with the P and Al concentrations of the mixtures to find the maximum rate of AS that will not inhibit ryegrass germination.

Suphathida Aumtong, Tawee Chaipimonplin and Chakrit Chotamonsak

Deep Soil Carbon Storage from Agricultural Soils of Northern Thailand

This study was done to investigate the distribution of TOC (Total organic carbon), and different types of labile organic carbon forms (LOC) across different soil depth of profile from various agricultural soils. The results of the study showed that the first group was comprised of LOC storage at the surface soil (0-30 cm) which was higher than in soil found at more deeper (>30 cm in depth) with containing 28.9-39.5 % of TOC ,and for this group soils showed that in the more deeper layers, LOC storage was equivalent to 17.0-25.5 %. Meanwhile, the second group of soil; at the subsurface was found to have higher LOC storage than the surface soils with an equivalent of 13.9-40.5 %, and amount of recalcitrant carbon factions was similarly higher (59.5-83.0 %).It could then be seen that LOC at the upper surface was higher than the soil in the subsurface which is quite normal but finding LOC in the lower soil surface must necessarily consider soils used in agriculture, an interesting topic to cause further investigation. From the study of the relationship between the amount of LOC and TOC storage in the soil profile, it was found that the amount of LOC storage in the soil significantly affected the TOC stored in the soil. When comparison was made between soils in the upper surface with the lower layer, it was found that LOC storage in the upper layer showed significantly higher TOC storage than in the lower layer.

Jantiene Baartman, Lieke Melsen, Demie Moore and Martine van der Ploeg

On the complexity of model complexity: viewpoints across the geosciences

It is the core task of geoscientists to gain insight into the complex systems of Nature, in which soils play a crucial role. Yet, complexity may be perceived very differently and a plethora of models with different degrees of complexity is available. How do we decide what model complexity is warranted? Does this differ among disciplines? We developed a short questionnaire to investigate the geoscientific community's views on complexity in models. The response was overwhelming, with 618 completed responses. The results show that the number of processes explicitly included and the number of interactions / feedbacks incorporated were seen as important determinants of complexity. Confidence was not higher in the simulations of a complex model compared to a simple one. Interestingly, neither the discipline within the geosciences, nor career stage or work sector, explained the characterization of model complexity. The results of the questionnaire demonstrate that there is no general consensus on how model complexity is perceived or should be defined, and that formal definitions are not generally accepted. We conclude that aiming for a single definition of model complexity is neither feasible nor desirable. Instead, in order to collaborate and communicate more effectively, geoscientists need to clearly state and discuss how they address model complexity: never assume that a definition is generally accepted, always be explicit about your assumptions, ask about others' perspectives and be clear about the approach you are taking and why. In this way, we can avoid, or at least greatly reduce, complications with complexity.

Sarah De Baets and Csilla Hudek

Using root traits to define the suitability of cover crops for providing multiple soil ecosystem services

The use of cover crops (CCs) is a well-established soil conservation technique and has been effectively used in many arable systems. Whereas the obvious protection mechanism of CCs occurs through canopy protection of the soil, plant roots provide multiple important functions. It is important to consider the soil functions delivered by different root systems in order to increase the impact of CCs on sustainable soil and water management. A classification of CC root systems based on functional traits is needed to study their soil bio-engineering purposes such as erosion control and soil structure improvements for hydrological services and optimised crop growth. To study how plant roots can boost soil functions, a greenhouse experiment has been set up using large containers (1m3) filled with sandy clay loam in which various cover crop species were grown for 90 days. In situ root images and plant cover images were taken weekly using mini-rhizotrons and an RGB camera. Root cores were also taken at the end of the experiment for root trait analysis with WinRhizo. For each species treatment, root identity was determined from a distinctive combination of single root traits using PCA. Multidimensional statistics (linear mixed models) were applied to relate root identity to the different soil functional variables. These results form the basis of a model that is being developed that allows combining species with complementary roots traits so that multiple soil functions are enhanced simultaneously.

Nikki Baggaley, Allan Lilly, Kirsty Blackstock, Karen Dobbie and Fraser Leith

Protecting soil functions - Interpreting soils data for policy makers, agencies and industry

Surface runoff, soil erosion, compaction and the leaching of potential pollutants to groundwaters from land can degrade the soil resource and damage the water environment, reduce crop yields, cause the loss of valuable nutrients and organic matter, and increase flood risk. Increasingly, it is recognised that soils information must be translated into practical tools in order to change practices and protect soil functions and water resources. Working alongside agencies in Scotland we applied a suite of simple, transparent, rule-based models to field-scale (1:25,000) soil data to identify areas most at risk of degrading water quality. Here we present three examples. The Scottish Environment Protection Agency have used the maps to focus conversations with farmers about potential diffuse pollution issues on their farms and suggest areas where Good Management Practices could be implemented. Scottish Water has used the runoff risk map in combination with land-use, water body characteristics and water quality data to better understand algal risk factors and associated issues of taste and odour across drinking water supply catchments. At a broader scale the topsoil compaction risk map was used by Scottish Government along-side information on soil wetness to support a derogation request to the European Commission after unprecedented rainfall in the Spring of 2018. This highlighted the high percentage of agricultural land that would be at further risk of soil degradation if farmers were forced to cultivate their land when soils are at, or close to, saturation in order to comply with European Union Greening requirements.

Thahamina Bagum, Md. Kamal Uddin, Salim Hassan, Nitty Hirawaty Kamarulzaman and Md. Zulfikar Rahman

Farmers' Performance on Fertilizer Application in Bangladesh: The Influence of Socio-economic Determinants

The national average rice yield of Bangladesh is still very low (2.94 t/ha) compare to other top rice growing countries. Farmers in Bangladesh were mostly not able to use recommended doses of fertilizer. Prior studies focused on different aspect of fertilizer applications, however less attention has been paid to study how fertilizer is managed by farmers. Therefore, this study aimed to determine farmers' performance towards fertilizer application. Farmers' socio-economic characteristics and their contribution to performance towards fertilizer application were also explored. Data were collected from 355 farmers by using structured questionnaire. Descriptive, correlation and multiple linear regression analysis was used to analyse the data with SPSS v.23. Study result shows less than half of the farmers (45.9%) adequately used fertilizer and thus fell into high performer category. Farmers' rice cultivation experience, household size, education, farm size, training receive, credit received, and extension media contact had positive and significant relationship while proportion of land under rice cultivation and barrier faced by farmers had negative but significant relationship with their performance towards fertilizer application. Farm size has identified as the most contributing factor that influenced farmers' performance. On the other hand, lack of knowledge about fertilizer application was identified as the top most important barrier. The study concludes with the recommendations that socio-economic determinants should be focused upon to improve the current performance of farmers towards fertilizer application in Bangladesh.

Gerben Bakker, Aurore Degré, Attila Nemes and Martine van der Ploeg

Progress on Standarisation, harmonisation and innovation of soil hydro-physics properties through international exchange: the SOPHIE initiative.

Soil Hydro-Physics (SHP) properties are the properties that determine the Soil-Water interactions: i. water flow and water retention, and ii. with the water flow the transport of dissolved compounds, like nitrogen, phosphates, pesticides, antibiotics, and carbon. SHP-properties play an important role in a variety of issues that affect society: crop water stress vs. food security, soil salinity and sodicity, susceptibility to forest fires, soil compaction, dike stability, greenhouse gas emissions, and soil health, among others. The need for reliable SHP-properties is thus widely emphasized by researchers and consultants.
It is, however, recognized that harmonisation of existing protocols, and the development of new techniques is difficult to accomplish and therefore lagging behind in quality needs. This is due to the absence of attention and direct visibility of SHP-properties in the societal topics while these are inherently linked. As a result, current methods remain time consuming, and data remains fragmented and incompatible. The methods need to be improved towards cost-effective ones, and should be sufficiently harmonised to be used at EU-scale and preferably world-scale research.
The SOPHIE initiative addresses the need for qualified SHP data. Such qualified data should come from EU-wide agreed, preferred, and innovated cost-effective laboratory- and field methods, preferably accomplished through international collaboration.
SOPHIE has so far attracted 14 SHP laboratories in Europe, and more than 150 registered participants, including representatives from companies and policy makers. Together, these participants have provided input for a research agenda, and set-up a protocol for standardising soil samples. We will present ongoing activities.

Arlete Simoes Barneze, Andrew Cole, Ruth Gregg and Tony Devos

Peatland restoration had beneficial impact on climate change mitigation

Peatlands store over half of the total soil carbon (C) in the UK, despite covering only 12% of the total land area. Peatlands are natural C sinks, with a net uptake of 700,000 t C yr-1. However, degraded bogs become significant C sources as organic matter decomposition causes the release of large quantities of carbon dioxide to the atmosphere. The Cumbrian Bogs LIFE+ Project (2014-2019) aims to restore three lowland raised bogs through raising water levels, removing trees and revegetating bare peat. One of the sites, Bolton Fell Moss, is designated as a Site of Special Scientific Interest and Special Area of Conservation. However 70% of the site was industrially milled for peat, which finished in 2013 and has since undergone restoration. Restoration, through raising water levels and spreading plant material on bare peat, has started to introduce desired Sphagnum species. Greenhouse gas (GHG) measurements were made in two restored areas and in two control areas over two years. Closed static chambers were used to measure GHG emissions, and gas samples were analysed in gas chromatography. Results show that restoration increased net GHG budget by approx. 48% comparing with non-restored areas. This suggests that restoration work has started to have a beneficial impact on the peatland plant community and net C budget. The increased uptake of C by a lowland raised bogs may be seen as an indicator of good bog hydrology and plant productivity, improving the climate change mitigation.

Christy van Beek

From scan to scale: the journey of a soil sample using sensor technology

Sensor technology offers great opportunities to help farmers select the fertilizers that are best adjusted to their soil and crop needs. Since the introduction of sensor technologies, soil scientists have been arguing about accuracy and comparability with wet chemistry. However, between sample taking and fertilizer selection, so many more processes affect the effectiveness of soil test-based fertilizer selection. In this paper I discuss the process from sample taking till fertilizer application. During the process at least 10 attributes contribute to the effectiveness of the intervention, of which the accuracy of sensor technology is probably of least concern.

Nicolas Beriot, Esperanza Huerta and Raúl Zornoza

Plastic mulch use in agriculture : accumulation of Low density polyethylene debris and pesticides residues and the effects on soil microbial communities

Plastic mulch is widely used in agriculture to decrease the water evaporation, increase the soil temperature, or prevent weeds. Most plastic mulches are made of highly resistant Low Density Polyethylene (LDPE). The incomplete removal of polyethylene mulch after usage causes plastic pollution. In conventional agriculture, the use of pesticides emits substances which can be sorbed to soil particles and plastic debris. Little is known about the long term effects of the use of plastic mulch and plastic debris accumulations in relation with pesticides residues.
We studied 18 parcels in commercial farms, either organic or conventional, where plastic mulch has been used for 5 to 20 years in Cartagena's country side. We compared the macro and micro plastic debris contents, pesticides residue levels, soil physiochemical properties among all parcels. 0-10cm and 10-30cm soil depths were considered to assess the vertical transport of both plastic debris and pesticides residues. 18 insecticides, 17 fungicides, and 6 herbicides were analysed with LC-MS/MS and GC-MS/MS systems. In the soil surface layer, the ribosomal 16S and ITS DNA regions were sequenced to study shifts in bacterial and fungal communities, respectively. We found accumulation of plastic debris in the 10-30cm soil depth whereas pesticide residues are mostly found in the 0-10cm depth. The interactions between plastic debris content and pesticide contents will be presented, together with the interaction of plastic and pesticides in soil with changes in soil microbial communities, identifying the most sensitive groups which can act as bioindicators for plastic and pesticide pollution in soil.

Anneke Beylich, Ulfert Graefe, Rüdiger M. Schmelz and Deborah Linsler

Vertical distribution of microannelids in relation to tillage and vertical gradients of soil organic matter in some European field soils

Microannelids are substrate-feeders that contribute to soil functions by organic matter breakdown, stimulation of microbial turnover, casting and creation of pores. While they concentrate in the uppermost 10 cm of the soil in comparatively undisturbed forest and grassland soils, their activity extends to deeper layers in regularly tilled field soils. Data on microannelids in agricultural fields are rather limited and often based only on the upper part of the tilled soil layer.
Within the scope of the project SoilMan, funded within the EU-Biodiversa framework, we aim at uncovering relationships between soil management practices, habitat characteristics and the abundance and performance of microannelids. Here, our focus is on the relation between the vertical distribution of microannelids and the vertical gradient of organic matter in field soils with different tillage treatments.
Study sites comprise tillage-trials at long-term observatories of five European countries. The tillage treatments studied were conventional tillage (ploughing), minimum tillage (no ploughing) and direct seeding. Sampling depth for microannelids as well as for soil parameters (Corg, bulk density, soil moisture) was 30 cm to ensure complete coverage of the topsoil horizon influenced by tillage. The results show that microannelid abundance and organic carbon content often decrease with increasing depth at sites with reduced tillage. In comparison, ploughed soils show lower organic matter contents in the uppermost 10 cm accompanied by reduced microannelid abundance in this layer, but higher Corg and microannelid abundance below 20 cm. Implications for organic matter breakdown under different tillage systems are discussed.

Sidra Bibi and Loes Van Schaik

Uncertainty of water flow and storage measurements with fiberglass wicks: Measurement uncertainty/efficiency by analyzing variability in flow and storage in fiberglass wicks

Water flux in unsaturated soils is highly variable temporally and spatially. Different devices have been constructed to measure spatially resolved water flow under soil columns. Earlier studies have shown the emphasis on examining soil water drainage and water flux in the vadose zone with the help of fibreglass wicks but we know of no studies where the accuracy of flow measurements with wicks is determined. This study focuses on assessing the use of fiberglass wicks as reliable drainage monitors.
In order to assess the suitability of fiberglass wicks for the measurement of water flow, we established a cylinder (30cm diameter, 9cm high) with 14 drainage wicks and measured water outflow and storage in wicks. These measurements were divided into two steps: flow only through the wicks and flow through a combination of soil columns and wicks. For each condition a series of experiments was performed. The outflow velocity was measured with a high resolution (ml/s). In wicks combined with soil experiment, analysis of the outflow data showed that the mean outflow of the wicks was 0.02 ml/s and the standard deviation was 0.002 ml/s. When looking at the single experiments and single wicks, the variability in outflow between wicks (0.002) was lower than between experiments (0.007). The experiments conducted with wicks combined with soil columns were observed to have lower mean outflow velocities and lower standard deviation compared to those without soil i.e. 0.06 ml/s and 0.05 respectively between wicks while 0.06 ml/s and 0.02 ml/s between experiments.

Lenka Bobulska and Lenka Demkova

Effect of soil management systems on soil microbial indices and functional microbial diversity

There is a need to assess the impact of various farming methods on quality and health of soil ecosystems in specific ecoregions. The types of soil and crop management have direct influence on the physical, chemical and biological soil conditions. Different management techniques can denote different substrate availability, which may benefit or inhibit the establishment of different microbial groups. Microbial activities comprise all biochemical reactions catalysed by microorganisms in the soil, and the integrity of the metabolic capacity of the soil microflora is a fundamental requirement for any concept of soil protection, soil bioremediation and recultivation. Soil chemical properties (soil pH, soil organic carbon), biological properties (soil respiration, microbial biomass carbon), soil enzyme activity (urease, acid and alkaline phosphatases) and microbial functional diversity (using BIOLOG EcoPlates) were determined at the sites (north-eastern Slovakia) under conventional and ecological farming systems during years 2015 – 2018. Research showed positive effect of organic fertilizers on soil productivity, and thus maintaining soil pH and accumulation of humus in soil. The values of soil microbial activity, as well as soil enzymes, confirmed high sensitivity of changes occurred under different farming systems. The study confirmed higher proportion of soil enzymes (38%) in ecological system compared to conventional system. The BIOLOG incubation showed that the physiological profiles were similar in both farming system, but the abundance of functional groups and diversity index was lower (26%) in conventional system compared to ecological, which show lower ability of microorganisms to utilize the carbon substrates.

Clovis Borges, Oriel Kölln, Beatriz Borges, Juliana Oliveira, Martin Polz and Henrique Franco

Quantitative responses of ammonium-oxidation dominate N2O emissions in bioenergy crop

The N fertilization feeding microbial key transformations to released nitrous oxide (N2O) a potent greenhouse gas and predominantly produced from agriculture soils. A field experiment was conducted to compare the effects of different N-sources on soil microbes their activities and N2O emission from bioenergy crop (Saccharum officinarum L.) grown on region of Southern Brazil. Quantitative PCR (qPCR) analysis of key functional genes involved in N2O formation and reduction (amoA, nxrB, nirK, nirS, and nosZ) was measured. The biomass production diminished from 23.2-to-32.5 Mg ha-1, when urea (UR) is applied compared to other N-sources. The intensity of gases emitter when using the UR were 6.8-fold higher than ammonium nitrate (AN) and ammonium sulphate (AS). Ammonia-oxidizing bacteria (AOB) reveled significant contribution to the N2O emissions, but not archaea (AOA). Urea elevated AOB population, enhanced N2O emissions and load higher emission factor 2.19%. Collectively, our data indicate that UR enriched AOB community consequently enhanced N2O fluxes and support the hypothesis the main N2O source in this system appeared to be via nitrification. Conversely, MAP could affect the microbial nitrogen transformation process and reduce N2O emissions from cane fields.

Alain Daniel Brauman, Phantip Panklang, Frédéric Gay and Alexis Thoumazeau

Lost of soil resilience after 80 years of rubber monocropping

The long-term effect of agriculture on soil biodiversity and related soil functions has become a societal issue. Rubber

chronosequences represent a good model to address this question since rubber trees have been continuously cultivated in monoculture over 80 years in south of Thailand. Our study aims to highlight the long-term impact of rubber cultivation on soil biodiversity and functions. Across an 80-years rubber chronosequence, we compared (i) 3 successive rotations of 25-30 years to assess the long-term impact of rubber mono-cropping, and within each rotation, (ii) young and mature plantations to determine the resistance and resilience effect after logging disturbance. A secondary forest was also studied both as the initial and reference system. Main soil physico-chemical properties were assessed together with soil taxonomic and functional biodiversity (macrofauna, nematodes and bacteria) and soil functions related to carbon transformation, nutrient cycling and structure maintenance using microresp® and Biofunctool® (Thomazeau et al., 2019). After the third rotations, we observed a strong depletion of soil resources together with a steep decrease of soil biodiversity (bacteria, nematodes and macrofauna). Soil biodiversity and soil chemical properties were mostly affected by the number of rotations, whereas most of soil functions were more affected by the tree age (young versus mature plantations). However,after three full rotations the soil system lose its resilience capacity. This study demonstrates that, with the current practices, long-term mono-cropping of rubber trees deeply threatens the sustainability of the soil ecosystem. More conservative logging and replanting practices might limit such effects

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Inna Brianskaia, Hajiaghayeva and Vasenyov

Soil organic carbon stability of urban soils under different hydrothermal conditions

High anthropogenic impact and the rate of urbanization result in a decrease of urban soils' capacity to perform ecosystem services. Carbon sequestration is an important soil-based ecosystem service, which can be assessed through quantity and quality soil carbon stocks.. The stability of soil organic matter (SOM) is characterized by the resistance of its constituent components to biological, chemical and physical destruction. In the study, SOM stability in artificial substrates used for urban soils' construction was analyzed in response to temperature-moisture conditions. The decomposition rate of various substrates was assessed. Decomposition was assessed through studying microbial production of CO2. In the research the CO2 emissions were studied under following temperatures and moisture conditions: temperature – 7°C, 22°C, 30°C and 40°C and moisture – 0.2 WHC, 0.4 WHC, 0.6 WHC, 0.8 WHC, 1 WHC. Moisture affects the amount and activity of microbial biomass, controls the availability of oxygen to microorganisms, causes periods of water microbial stress and also can destabilize organic matter, resulting in increased availability of carbon to soil microorganisms. The obtained results showed significant correlations (R=0.9)between temperature conditions and CO2 emissions. Different patterns of moisture and temperature impacts on the soil organic carbon (SOC) decomposition rates were observed as well. It was concluded that, depending on the qualitative composition of carbon, the impact of hydrothermal conditions on the emission of carbon dioxide changed.

Sidona Buragiene, Egidijus Sarauskis, Kestutis Romaneckas, Aida Adamaviciene, Vilma Naujokiene and Rasa Kimbirauskiene

The effect of bio-preparations on soil respiration

Bio-preparations regenerate soil vitality and biodiversity, making them an excellent alternative to modern agriculture. Biological products reduce the energy consumption, financial costs and ecological footprint in agriculture. In preside days, plenty bio-preparations are used in agriculture, however most of them are not deeply investigated. Therefore, the aim of the research was to determine how the biological preparations and their mixtures affect CO2 emissions from the soil in a North Eastern Europe climatic conditions. Field experiment was carried out in 2015-2017 at the Experimental Station of Vytautas Magnus University Agriculture Akademy, Ag (54° N, 23°E), Lithuania. Seven different bio-preparations and its mixtures were tested. The CO2 emissions from the soil during investigations period ranged from 0.62 to 11.07 μmol m-2 s-1. Bio-preparations with active microorganisms caused increase of soil respiration. In most cases, soil respiration depended on soil aeration porosity and meteorological conditions. In pure soil and wet vegetation conditions, the respiration of soil was significantly higher.

N.N Buthelezi-Dube, J. C Hughes, P. Muchaonyerwa, A. T Modi, K. Canister

Farmer perceptions and laboratory measurements of soil fertility in four villages of eastern South Africa

Understanding local perceptions of soil fertility is necessary for the development of appropriate fertility assessment methods and sustainable soil/cropping systems. A study was conducted to investigate farmer's perceptions of soil fertility in four villages of South Africa. A questionnaire was administered to 50 farmers from each village to obtain a general overview local soil knowledge. Further in ten farmers were chosen for in-depth interviews to gain more insight into farmers' soil fertility perceptions and

assessment. These farmers were asked to identify fertile, moderately fertile and poor plots in their fields from which soil samples were taken for laboratory fertility analysis. Local soil fertility indicators included crop performance and yield, and soil texture, stoniness and consistence. Using these, farmers have developed specific soil use and management practices. Farmers' good understanding of soil-crop associations forms basis for local soil suitability.
There was generally no good agreement between farmer subjective fertility and measured chemical parameters. Laboratory measurements of individual soil physicochemical properties were thus not relevant to the farmers' fertility assessment. However, local soil/cropping systems could benefit from laboratory data providing accurate fertiliser recommendations. Subjective soil fertility assessment revealed local fertility problems shown by interest in other soil property attributes including drainage, flooding.

Meritxell Grau Butinyac, Vincent O'Flaherty, Karl Richards, David Wall and Fiona Brennan

pH and P effects on denitrifying microbial communities in grassland soil

Nitrogen applied to agricultural soils in excess can cause environmental pollution through N losses. Reducing emissions of potent greenhouse gas nitrous oxide (N2O) is of critical importance towards sustainable agriculture and climate change mitigation. Microbial communities in soil drive N transformations. As such, an understanding of the soil, climatic and edaphic factors impacting microbial community structure and activity is essential for predicting and mitigating N2O production. Availability of inorganic N in soil can stimulate microbial communities to carry out denitrification, an anaerobic respiratory pathway where N2O is an intermediate product. Soil pH strongly impacts the microbial community structure and has a direct effect on denitrifying communities as NosZ, the enzyme catalysing N2O reduction, is pH sensitive. We would expect that microbial communities in acidic soils have a decreased capacity to mitigate N2O emissions. Other management factors, such as phosphorus (P), likely interact with pH; causing changes to chemical nutrient availability and direct effects on microbial composition. The link between N2O emissions and microbes dictated by soil pH; and the interacting role P availability plays in this relationship are not fully understood. Therefore, the impact of soil pH on the potential of the community to denitrify, and the functional microbial community, were analysed by potential denitrification assays and qPCR analysis of denitrification genes across a pH gradient and under a range of P application rates in two soil types. Understanding the link between the microbial communities and N2O production can be applied to inform agricultural management to reduce emissions from fields.

Geovani Caetano, Vera Quintino, Carlos Rodrigues, Samara Viana, Tatiana Michlovská, Vitor Veneziano and Polyanna Trindade

Evaluation of the phosphorus availability in soil using slow release fertilizer

This work aim to evaluate the release rate of phosphorus (P), the P remaining (P-R) and the maximum P adsorption capacity (MPAC) after two soybean seasons under monoammonium phosphate (MAP) and slow release monoammonium phosphate (SRMAP) doses in a Red Oxisol. The doses applied were 0, 54, 108, 162, 216 and 270 kg ha-1 of P2O5. After each season, soil samples were collected in 0 to 0.10 m deep and dried in the air. Sequential extractions were performed using Mehlich 1 and estimated desorption curves, P-R and MPAC. In The first season, there was increase in P-R under the MAP highest dose and with 134.25 kg ha-1 of MAPSR. With the highest dose of MAPSR there is a reduction in P-r indicating that the slow release may have increased the efficiency of use by the plants and reducing the losses by adsorption. In the second season, there was a linear increment of P-R for both sources, with the highest increment per unit of P applied when using MAP, which explains greater loss by adsorption with this source. With sequential P extraction, higher extractable P values were get when MAPSR was used, indicating a higher residual effect. At the end of the two seasons there was lower MPAC with the application of MAPSR. With the results may be conclude that MAPSR actually releases the P in a slower way and with this there are lower losses by adsorption in soil.

Julian Cardenas and Eva Kaštovská

Soil stoichiometry effect on microbial processes and its reflection in C and N isotopic composition

Given its association to biogeochemical transformations, d15N and d13C have high potential as indicators of soil C and N transformations. d15N reflects openness of the N cycling in ecosystem and is closely associated with P availability. d13C vary with microbial C use efficiency (CUE). Main drivers of variation in natural isotopic composition of ecosystem components are not specified yet. Henceforth, we investigated how CNP stoichiometry of a grassland soil affects microbial growth and activity and the d15N and d13C of soil pools. We compared a non-amended control with 7 treatments representing all the possible combinations of C (800 g g-1 of sucrose-C), N (46 g g-1 of NH4NO3-N) and P (17 g g-1 of KH2PO4-P) addition: N, P, N+P, C, C+N, C+P and C+N+P. Size and isotopic composition of the soluble and microbial C, N and P pools, CO2 production and O2 consumption, soil potential enzymatic activity, total, fungal and bacterial DNA in soil and net mineralization and denitrification were measured. C

addition was enough to stimulate microbial growth. Microbial C:P was highly variable but not related to the treatment. Under C limitation, microbes kept a high oxidizing enzymatic activity while C addition stimulated hydrolytic enzymes, mainly phosphatase under P limitation. d13C of microbes reflected incorporation of C-source but its enrichment compared to soil solution further depended on mass-specific respiration, which was altered by N and P availability. Microbial d15N was related to microbial growth and following nitrification-denitrification processes and was a good indicator of microbial N limitation.

Coleen Carranza, Harm-Jan Benninga, Rogier van der Velde and Martine van der Ploeg

Monitoring agricultural field trafficability using Sentinel-1

The use of heavy mobile machinery in agriculture is now indispensable but its regular and prolonged use is a leading cause of soil compaction. To minimize this harmful effect, trafficability of agricultural fields needs to be determined. Soil moisture is one of the dominant controls for trafficability therefore satellites such as Sentinel-1, which is one source of soil moisture information, could be useful in assessing trafficability. However, satellites only map soil moisture at the upper surface layer. In this study, we determined the feasibility of Sentinel-1 surface soil moisture to monitor trafficability over 2016-2017. We first determined coupled conditions when surface soil moisture is a good indicator of subsurface values. After which, we applied a probabilistic framework to determine trafficability using extensive in situ measurements of penetration resistance and surface soil moisture for a variety of crops. Furthermore, we looked into the variability encountered in these measurements to gain insights on other temporal controls. Results show that coupled conditions occur values >= 0.19 cm3cm-3 where an almost 1:1 correspondence between surface and subsurface soil moisture values occur. An increase in variability observed in penetration resistance values coincided with maturity of crops for cultivated fields. Aside from soil moisture, plant roots may have a significant impact on the temporal variability of soil's penetration resistance. Trafficability can be regularly monitored through the high temporal resolution of Sentinel-1. However, aggregation to coarser resolutions maybe necessary as its original 10 m resolution may be suboptimal, based on validation against in situ measurements.

Joanna Clark, James Blake, Emily Trill, Samantha Broadmeadow, Chris Short, Tim Clarke, Ian Davenport, Angie Elwin, Russell Frost, Richard Gantlett, Julian Gold, John Hammond, Adrian Hares, Amanda Ingham, Martin Lukac, David Macdonald, Jess Neumann, Tom Nisbet, Gareth Old, Tom Ormesher, Anne Verhoef, Louise Webb, Kevin White, Bel Whitwam and Becky Wilson

Evaluating the natural flood management potential of soil use and management strategies by integrating farmer knowledge and scientific knowledge

How soils are used and managed affects hydrological processes linked to run-off generation and flooding. Soil use and management as a form of Natural Flood Management (NFM) has great potential to increase infiltration and soil water storage above and below ground to ultimately slow the flow of water through catchments to reduce flooding. Here, we report preliminary findings from the LANDWISE project (Landwise-nfm.org) that seeks to examine the potential for land use and management in lowland groundwater fed catchments in the River Thames Basin, England. We focus on five soil classes within two distinct soil types: shallow permeable soils on carbonate geology (Limestone and Chalk) and deep clay soils on mudstone geology. We combine technical knowledge with local experiential knowledge to explore the following aspects: (1) how farmers use and manage different soil types in practice from a questionnaire; (2) evaluation of soil properties and potential for NFM based on best available evidence and opportunity mapping; (3) evaluation of different soil use and management strategies through a survey of 160+ fields to provide further empirical evidence and assessment of the technical opportunity maps. We adopt a participatory approach to the co-production of research to help shape the work so that it can deliver usable impacts for the farmers and land managers who could ultimately deliver NFM by soil use and management. This work will help inform policy and the design and delivery of environment schemes to help co-deliver NFM alongside other ecosystem services.

Joanna Clark, Nerea Ferrando, Vicky Struthers, Daphne Parramon-Dhawan, Macarena Cardenas and Steven Loiselle

Exploring relationships between soil colour, water colour and soil properties for citizen science projects on soil carbon

There is a growing interest in enabling non-professionals to participate in research through ‘citizen science.’ The development of simple and robust methods that non-professionals can easily use is key to address research questions is key to the success of these projects. Here, we explore the relationships between simple and rapid assessments of soil colour and water colour of soil extracts made by citizen scientists with laboratory measurements to determine whether these rapid measurements can be used as proxy for

more standard measurements of carbon quantity and quality made in the laboratory. Laboratory measurements included comparative assessment of soil colour and water colour extracts and quantitative measurement of UV-Vis, dissolved organic carbon and associated indices (e.g. SUVA) on water extracts and loss on ignition and total carbon of soil samples. Work was based on samples collected through the Earthwatch and HSBC Sustainability Training Programme Events, where non-professionals participate in a research project looking at the impact of urban tree management on soils in Kew Gardens (London), Cannon Hill Park (Birmingham) and Campus Serge Kampf Les Fontaine (Paris).

David Corbett, Patrick Tuohy, Bridget Lynch and David P. Wall

The influence of lime on the physical and chemical composition of heavy soils

Soil pH is a major limiting factor as regards output potential on grassland farms. The target soil pH for grassland soils is 6.3. Soil pH plays a key role in soil fertility and is the basic fundamental factor that must be corrected when improving soil fertility. Optimum soil pH increases soil microbiological activity, it promotes the release of nutrients and increases the efficiency of organic and chemical N, P & K fertilisers. Lime is lost in the soil over time depending on the intensity of production and soil physical characteristics. A plot study was established on three commercial dairy farms with contrasting heavy soil types: 1. Humic surface water Gley, 2. Stagnic Luvisol, 3. Brown Podzolic, to assess strategies for increasing soil pH. Seven treatments were imposed; namely 2.5, 5.0 and 7.5 tonne/Ha of ground limestone and 1.5, 2.5 and 7.5 tonne/Ha of granulated limestone, applied at the beginning of the study and an untreated control. The plot study ran for 3 years from March 2015 to March 2018. The change in soil chemistry (pH, P and K) and soil physical properties (bulk density, shear strength and penetration resistance) were assessed over this time period. Results indicate that there was no significant difference between treatment products in increasing soil pH over time but there was a difference between soil types. Granulated lime showed a significant peak in soil test pH post application and lime was found to have a varying effect on soil physical properties.

David Corbett, Patrick Tuohy, Bridget Lynch and David P. Wall

The effect of soil variability and nutrient management within the farm on soil fertility status

Farms dominated by soils of high proportions of fine soil particles are faced with a continuous challenge in improving soil fertility. It is one of the main factors inhibiting the output potential of these heavy soils. For optimal grassland production, the desired soil pH is 6.3 on mineral soils while phosphorus (P) should range from 5.1 – 8 mg/l (Morgan's extractable P) and potassium (K) should range from 100 – 150 mg/l (Morgan's extractable K). Soil tests carried out over four years, across six heavy soil farms shows only 0 – 55% of paddocks are in the optimum range for pH, P and K in any given year. Despite regular application of significant quantities of nutrients, nutrient levels remain low, particularly with phosphorus. The objective of this study was to examine farm and paddock scale historical data to assess soil fertility dynamics across a range of heavy soil types. Farm outputs were related to nutrient status in order to understand the fate of nutrients; taken up by the grass sward, stored in the soil or lost through leaching/ runoff. We evaluated nutrient balances at paddock scale and assessed relationships with soil nutrient levels. Nutrient balances were calculated on a per paddock basis according to nutrient inputs (chemical, slurry, concentrates) and off-takes (milk, meat, silage). Changes in soil test pH, P and K were correlated with the application of lime, P and K. Results indicate that nutrient build-up in these soils requires significant investment of resources and extended time periods.

Fabio Corradini, Esperanza Huerta-Lwanga and Violette Geissen

Sewage sludge disposal: an entry door for microplastics in soils

Microplastics are emerging pollutants that pose an environmental threat. Wastewater treatment plants efficiently remove microplastics from sewage, trapping the particles in the sludge, preventing their entrance in aquatic environments. It has become common practice to use this sludge on agricultural soils as a fertilizer. The question then becomes – what happens to the microplastics after they are applied to these agricultural soils with the sludge?
To help answer this question, the aim of the work was to assess the impact of successive sludge applications on the total count of microplastic in soil samples. Thirty-one agricultural fields in Chile with similar edaphoclimatic conditions but different sludge application records were selected for sampling. Field records of sludge application covered a ten year period
Soils receiving 1, 2, 3, 4, and 5 applications (40 ton ha-1 each) of sludge presented a median of 1.1, 1.6, 1.7, 2.3, and 3.5 particles g-1 dry soil, respectively. There were statistical differences in the microplastic content according to the number of applications that a field had undergone (0 < 1, 2 , 3 < 4, 5). Sludge microplastic content ranged from 18 to 41 particles g-1, with a median of 34 particles g-1.
Our results revealed that microplastic counts increase over time where successive sludge applications are performed, stressing the

relevance of sludge as a driver of soil microplastic contamination. Further research will look at the implications of microplastic accumulation for soil biota and agricultural production, as well as transport processes in which they may be involved.

Raphaell Couto, Luiza Mendes, Carlos Rodrigues, Kassia Barbosa, Polyanna Trindade and Tatiana Michlovská

SOILS PHOSPHORUS FRACTIONS UNDER DIFFERENTS APPLICATION METHODS AND PHOSPHATE SOURCES

The objective of this study was to evaluate the alteration of soil phosphorus fractions after fertilized soybean cultivation, with different mineral phosphate fertilizers applied in broadcast and rows in two kind of soils, Red Oxisol (RO) and Quartzipsamments (Q). The experimental design was randomized blocks in a 4 × 2 + 1 factorial, being four sources of phosphorus [Bayóvar Reactive Phosphate (BRP), Monoammonium Phosphate (MAP), Simple Superphosphate (SS) and Triple Superphosphate (TS)], two application techniques (broadcasting and on rows) and an additional without phosphorus. After the soybean harvesting, in the two seasons, soil sampling was performed at 0 to 0.10 m depth, and then the sequential fractionation analysis of the P fractions according to the method of Hedley. Principal component analysis was performed. Through the Kaiser criteria, six main components were selected and the correlations between the evaluated variables and the main components for both soils were estimated. With the results it was concluded that the P sources and applications changed the P fractions in soil, differently in the RO and Q. In Q, the most labile P fractions correlated with productivity and were buffered by the less labile fractions and by the increase of microbial P and organic fractions. In the RO, the inorganic fractions of medium to low lability correlated with the labile fractions, which buffer the P available for plants, and showed low influence on the P organic fractions.

Stephen Crittenden and Henry Wilson

Spatial and Temporal trends in Soil OC, N, and P based on Landform, Tillage, and Input Management

Agricultural management including soil amendments and cropping systems affect dynamics of soil properties. Soil properties are also dynamic across landforms due to water, wind, and tillage erosion. This study was conducted on 26 watersheds from 2013 to 2018. Upper, middle, lower, and depressional landform positions were soil sampled for phosphate, nitrate, and organic carbon. A subset of data that included fertilization and tillage information was also analyzed for water extractable total dissolved P, dissolved reactive P, total organic nitrogen, nitrate, ammonium, total dissolved nitrogen, and dissolved organic carbon. The research aimed to investigate whether nutrients are accumulating in lower areas, does stratification exist and is it exacerbated by reduced tillage systems, and what are the inter-relations of nutrients and accumulation. Phosphorus and organic carbon accumulated in low landform positions and depressions whereas nitrate only stratified by depth. This may be due to erosion processes not in the time-scale of the present work and due to the dynamic nature of nitrogen in soil, i.e., a greater number of pathways of loss than phosphorus. There were no temporal trends evident.

Stephen Crittenden, Henry Wilson, John Fitzmaurice, Melanie Dubois and Jason Vanrobaeys

Living Laboratories of Agriculture and Agri-Food Canada: A Collaborative Program

The Canadian Living Laboratories Initiative of Agriculture and Agri-Food Canada is both an interdisciplinary approach and a forum for innovation where local stakeholders co-develop new knowledge and technologies within the Canadian agri-environmental context. The Eastern Prairie Living Laboratory (EPLL) will address the need for place-based solutions to ongoing regional agri-environmental issues, for increased involvement of end-users in the innovation process, and will lead to increased adoption of practices that create resilience and sustainability in the agricultural sector. Principles of co-design and partnership with end-users were used in developing our proposed activities and will shape the implementation and adaptation of the research, development, and knowledge transfer. Proposed activities are structured under three main themes that were co-developed with producer input: 1) Identifying the potential for perennial crops, cover crops, and associated management practices in local farming systems to improve environmental health, 2) Management practices for annual crops that increase efficiency of nutrient use and reduce losses to air and water, and 3) Sustainable management of water quantity (drainage and retention). Research and development activities proposed under each theme will focus on the four main environmental health priorities of the EPLL: a) soil health, b) water management, c) habitat capacity, and d) climate change. These activities will address gaps in knowledge required to improve efficacy of associated agri-environmental management practices and to increase rates of adoption. The location of these activities will capture differences in farming systems throughout the region and reflect producer interest identified during local co-development meetings.

Felicity Crotty and Nicola Cannon

Earthworms as an indicator of soil health

Earthworms are ecosystem engineers because they affect the physical soil environment for other species living within it. Through bioturbation, burrowing, casting and mixing of litter and soil; the soil structure, aggregate stability and water infiltration properties are all changed, as well as other soil functions e.g. nutrient cycling, mineralisation and decomposition. Earthworms are considered an indicator of a 'healthy' soil, creating a soil with better physical properties compared to a soil without earthworms. The three functional groups of earthworms – epigeics (surface dwellers), endogeics (horizontal burrowers) and anecic (vertical burrowers), live in synergy, mixing the soil, utilising recently fallen plant litter and moving plant material from the soil surface to deep burrows. Here, we describe a number of studies that show how agricultural management effects earthworm abundance and what this means in relation to soil health.
The main agricultural management trade-offs relate to food source/availability and habitat disturbance for earthworm abundance. Utilising two years of cover crop experiments, food source/availability was monitored in relation to earthworm abundance, the results suggest a lack of food rather than earthworm feeding preferences driving the changes in earthworm populations found. When investigating mechanical habitat disturbance it was found in two long term trials, that ploughing is detrimentally effecting earthworm abundance and diversity, however other establishment methods also have an impact. The results suggest it is a continuum of relative disturbance effecting earthworm populations rather than plough having a negative effect and all other methods having a positive one.

Felicity Crotty and Chris Stoate

How can a soil improving cropping system reduce compaction?

The management of soil functions in agriculture needs to balance the production of a healthy and profitable crop whilst reducing the negative spiral of degradation, increased inputs, increased costs and damage to the environment. Stakeholder meetings were held to discuss what the most pressing concerns were in relation to the future of farming and compaction was identified as a key area for investigation. An experiment was set up to understand how to alleviate or reduce the impact of compaction on crop yields. On a 0.36 ha area within an arable field in the East Midlands, U.K., the level of compaction was increased by multiple tractor movements perpendicular to tramlines to purposefully compact the area in a standardised way. The experiment was set up with four treatments and three replicates. Two mechanical method treatments were used to alleviate soil compaction directly – plough and a low disturbance subsoiler; and one biological, the addition of arbuscular mycorrhizal fungal inoculant at the time of drilling; as well as a no treatment control. This was repeated over two harvest years, first year barley, second year beans. The change in compaction was monitored over time, along with the effect of treatments on greenhouse gas flux, earthworm abundance, soil physics, weed abundance and crop yield. There were significant differences between treatments in relation to the overall soil health and weed and yield abundance, however which treatments would be considered a soil-improving cropping system in relation to soil health and/or stakeholder opinion, needs further consideration.

Imre Cseresnyés, Tünde Takács, Bettina Kelemen, Anna Füzy, Ramóna Kovács, István Parádi and Kálmán Rajkai

Electrical characterization of intact plant root systems: An innovative method for sensing soil environments

Electrical capacitance, impedance phase angle and electrical conductance were concurrently detected in intact root-soil systems to evaluate plant responses to a changing soil environment. Potted wheat and maize plants were exposed to soil alkalinity and inoculation with symbiotic arbuscular mycorrhizal fungi (AMF). Single-frequency (1 kHz) electrical measurements were sequentially performed using a ground electrode inserted into the soil and a plant electrode attached to the plant stem and connected to an LCR instrument. Increasing soil alkalinity progressively reduced the electrical capacitance due to restricted root growth and activity, and decreased the phase angle due to membrane damage and enhanced cell wall lignification. The increased electrical conductance induced by alkaline stress was related to reduced membrane stability and intracellular Na+ accumulation. AMF colonization increased the electrical capacitance, had no influence on root biomass, and reduced the root length and surface area. These results indicated an enhanced absorptive root-soil interface caused by the growth of external AMF hyphae. The functional aspects of the symbiotic association were shown by the increased root electrical conductance of inoculated plants, in association with the increased rate of water and nutrient uptake maintained by the hyphal network. In conclusion, electrical root characterization is a novel, efficient, non-intrusive technique for studying both adverse and favorable soil environmental factors affecting root growth and function. The adaptation of the method to field conditions is now in progress.
The research was financed by NKFIH (K-115714) and a János Bolyai Research Scholarship from the Hungarian Academy of Sciences.

Angelique Daniell and Pieter Willem van Deventer

An overview of pedogenesis in Technosols in South Africa

The name, Technosol are given to soils dominant in technical artifacts that formed from anthropogenic deposits or transported materials. Pedogenic processes are active in these Technosol including transformation and translocation of elements, minerals and particles within these materials. Three different Technosols were assessed as part of this investigation, encompassing gold, platinum and kimberlite Technosols. The primary concern of this study was to discuss the pedogenic processes observed within the three Technosols and how it would influence the soil functions of these materials. The discussion is based on observations of different pedogenic processes within the Technosols as well as analytical data and published data from the literature. Irrespective of the time since deposition or rehabilitation, well-defined pedochemical transformation processes, such as changes in pH and cation exchange capacity and base saturation, have been observed within the selected Technosols. Additional pedogenic processes, including leaching, eluviation–illuviation and oxidation, resulting in the development of different soil functions. Finally, field observations revealed processes such as salinisation, neo-mineralisation, surface crusting and horizon differentiation in terms of structural differences have been observed within the Technosols studied. Structural differences resulted in horizon differentiation due to the addition of compost and the establishment of vegetation in a portion of the Technosols

Angelique Daniell, Dawid S Malo and Pieter Willem van Deventer

Monitoring the pollution effects from a gold tailing storage facility on adjacent land through Landscape Function Analysis

Landscapes adjacent to gold tailing storage facilities (TSFs) typically suffer from loss of ecosystem function as a result of seepage pollution leading to degradation in soil quality. Restoration of these areas has become a primary concern in the fields of environmental science and management within recent decades. To assess the extent of land degradation that took place on the farmland, detailed monitoring of pollution took place over a period of 4 years on farmland. The Landscape Function Analysis (LFA) monitoring procedure was developed by David Tongway for the Australian rangelands, was used in this investigation to assess the impact of seepage pollution on the soil functions within the aforementioned farmland area. This study revealed that the LFA procedure could not accurately present landscape stability and ecosystem functionality at the seepage-polluted sites within the short monitoring period presented in this study. It was established that no adverse effects on the natural vegetation were apparent, other than encroachment by Seriphium plumosum, which affected the grazing quality of the area but contributed significantly to the LFA values.

Marko Debeljak, Aneta Trajanov, Vladimir Kuzmanovski, Jaap Schröder, Taru Sandén, Heide Spiegel, David P. Wall, Marijn Van de Broek, Michiel Rutgers, Francesca Bampa, Rachel E. Creamer and Christian B. Henriksen

The Soil Navigator: a decision support system for the assessment and management of soil functions

Among the soil functions that provide long-term sustainable agricultural production are primary productivity, nutrient cycling, water purification and regulation, climate regulation, soil biodiversity and habitat provision. Estimating their performance and the selection of management options that will maintain and improve these soil functions is a very challenging task. Therefore, our research goal was to develop a field-scale decision support system (DSS) that helps to assess the performance of these soil functions and provides management mitigation measures to enhance their performances. To address this goal, we developed the Soil Navigator DSS by applying qualitative multi-criteria decision modelling using the Decision Expert integrative methodology. Multi-criteria decision models for the five above listed soil functions were developed, calibrated, and validated using knowledge of domain experts, results of data mining and available empirical data. The models for the five soil functions were integrated into a single DSS to assess these soil functions simultaneously, and to provide advice to improve their performance. The communication between the users and the DSS is through a computer-based user interface, which enables the users to provide the required data about an agricultural field into the DSS and to get textual and graphical results about the performance of each of the five soil functions in a qualitative way. The final output from the DSS consist of qualitative measures of the performance of each soil function, and a list of management mitigation measures that can be applied in the field in order to achieve the desired performance of the soil functions.

Hedwig van Delden, Luuk Fleskens, Jantiene Baartman, Gijs Simons and Roel Vanhout

Policy support for sustainable land management and poverty alleviation in tropical regions

Subsistence systems adjoining tropical forests have large environmental impacts due to continued expansion into these forests through slash and burn. Finding solutions for this problem requires understanding how subsistence farmers operate, what possible alternatives are available to them and what the expected impact of planning and policy is in supporting preferential alternatives. Due to the complexity of these interactions a transdisciplinary approach is required to understand farm systems, the impact of socio-economic drivers on these systems and the larger society in which they operate, as well as impact of various agronomic practices at present and under climate change.
The World Bank has initiated the LAUREL program to support integrated decision making for landscape management across sectors and levels of government by promoting improved tools for land use planning. These result in more evidence-based decision making around long-term sustainable land use, which in turn aims to improve resilience and the ability of landscapes to deliver ecosystem services and development benefits.
We present a system for Madagascar which includes a suite of tightly-coupled models representing land use, farmer decisions, hydrology, vegetation and soil processes. To understand the emergent behaviour across sub-systems, these components represent feedbacks between the various socio-economic and bio-physical processes. This allows, for example, the simulation of soil degradation due to poor management practices, impact on yields and hence pressure to clear new forests. Conversely, the system shows how improved practices can lead to improved yield, providing a stepping stone to self-sufficiency and production of cash crops to improve livelihoods.

Antonio Delgado, Lilian O'Sullivan, Marko Debeljak, Aneta Trajanov, Rachel E. Creamer, Christian Bugge Henriksen and David Wall

Farming systems targeted to water regulation and purification in agricultural soils

Water regulation and purification is one of the five major soil functions that agricultural soils deliver, including primary productivity, climate regulation and carbon sequestration, soil biodiversity and habitat provision. Water is intrinsically linked to agricultural development and food security but is often ignored in policies. Under climate change, it is expected that water scarcity and shortages will increase in the future. This research proposes a more holistic approach to soil management whereby farming takes the effects of management on all soil functions into consideration.
Firstly, a literature review to identify gaps/opportunities in existing research finds that most studies emphasise primary productivity and nutrient cycling with few studies focused on the whole set of soil functions that society demands. Prolific research exists that posits the interactions between soil and water from the perspective of diffuse land pollution and as its role as a source of pollutants. These issues have been researched extensively, and represent important considerations for defining management needs. Secondly, a new modelling approach that better explains the water function in soils related to specific soil properties that reflect impact of drivers such as soil management practices is presented. The water function is governed by a complex interaction of soil, environment and management. A Decision Expert integrative methodology (DEX) was used to structure a qualitative multi-attribute decision model of water interactions in soil. Through this process the top-most attributes identified were 1) water storage 2) water run-off and 3) percolation. Finally, key areas that require enhanced stakeholders involvement were identified.

Sofiya Demina, Viacheslav Vasenev, Ksenia Makhinya and Anastasia Melnik

Comparative analysis of the state of green spaces and the physical chemical and microbiological properties of the soil in the recreational areas of the New Moscow with a different land-use history

In conditions of on-going urbanization, urban parks play a key role in the sustainable development of urban space. New Moscow, the territory attached to Moscow in 2012, is currently the largest area in Russia experiencing rapid and intensive urban development. New Moscow territory involved more than 70 parks with a different land use history. Most of them were created or reconstructed during the last 7 years. The aim of our study is to study the physical and chemical changes in the soil and to assess the state of green spaces in the recreational areas of New Moscow, depending on the history of land use, as well as the analysis of anthropogenic factors affecting them. For analysis, 4 parks were chosen. Two parks were established on former cropland, and the two other parks - on former forest. In these areas, soil and vegetation state and quality was analyzed. Soil samples were collected from the depths 50 cm in the parks following randomized stratified design with 9 or 10 samples from each park considering land-use history and current functional zoning. In the collected samples, physical (bulk density and texture), chemical (pH, C / N, and heavy metals' contents) and microbiological properties were analyzed (microbial biomass (Cmic), basal respiration (BR), qCO2) and. The visual tree assessment was made at the research plots with circle shape with 20 m radius from soil sampling points... The interrelationships

between soil quality and vegetation stage were analyzed and discussed in the context of current and former land-use.

Lenka Demkova and Lenka Bobulska

The influence of old mining wastes to the biological and chemical soil properties

According to the list of mining wastes of Slovakia, there is registered more than 300 repositories of old mining material, almost 30 are considered as a highly toxic. Inadequate storage leads to the risk elements releasing and contamination of the surrounding environment. Soil samples were taken from 10 heaps of waste material and 10 grasslands localized in the immediate vicinity of the heaps. Nutrients content (Ca, Na, K, Mg) and a total content of risk elements (As, Cd, Cu, Fe, Pb and Zn) were determined on an Agilent ICP-OES spectrometer 725. The activity of soil enzymes (urease, acid and alkaline phosphatase, FDA and β-glucosidase) and soil pH was carried out in the laboratory conditions. The aim of the study was to determine the content of risk elements in two types of sampling sites (heaps and grasslands) and to evaluate the risk element influence on the soil characteristics (the activity of soil enzyme, nutrient content and soil pH). The values of one-way ANOVA showed that the nutrients and risk elements were significantly higher, and the values of the soil enzymes and soil pH values were significantly lower at the heaps of waste material comparing grasslands. Spearman's correlation coefficient confirmed a significant negative correlation between some risk elements (As, Cd, Pb, Zn) and urease and FDA. Inhibition effect of the risk element to the acid, alkaline phosphatase and β-glucosidase wasn't significant. Soil pH was significantly negatively influenced by high values of As, Cd, Pb and Zn.

Anja Derycke, Ellen Van De Vijver and Marc Van Meirvenne

Optimizing the sampling strategy for monitoring the bioremediation of contaminated soil at a landfarm

Landfarming is a widely applied technology for bioremediation of soil contaminated with petroleum hydrocarbons. The contaminated soil is spread out in layers in which biological degradation is enhanced through tilling for soil aeration, sometimes complemented with nutrient amendments. Repeated measurements of the contaminant load and the soil conditions governing biological activity are crucial for the monitoring and controlling of the natural attenuation processes. Yet, the complexity of these processes and their interaction with dynamic environmental conditions challenges the design of an efficient monitoring strategy.
In this case study, we consider a 3-ha landfarm constructed at an industrial site in Flanders, Belgium, in 1999. The soil contaminated with petroleum hydrocarbons was excavated and reorganized in layers according to the degree of contamination. A drainage and soil vapour extraction/air sparging system was installed to enhance biodegradation. In 2011 and 2013, soil samples were collected adopting a systematic grid sampling pattern. At every sampling location, one sample per 0.5-m soil layer down to 2 m depth was taken and analysed for the petroleum hydrocarbon concentration. In 2013, the landfarm was surveyed with a multi-receiver EMI sensor providing exhaustive measurements of the soil electrical conductivity for different soil volumes.
Considering the electrical conductivity as indicative of variations in soil conditions influencing the bioremediation processes, we propose to optimize the selection of monitoring locations through a Latin hypercube sampling conditioned to this sensor data set. The efficiency of the designed sampling strategy is evaluated with the data from the systematic sampling campaign.

Saman Dharmakeerthi, Darshani Kumaragamage, Doug Goltz and Srimathie Indraratne

Effect of gypsum and biochar amendment on P fractions in soils under simulated spring snowmelt and summer flooding conditions

Application of gypsum and biochar alter phosphorus (P) release from flooded soils to overlying floodwater and their effects are dependent on soil type and flooding conditions. Information on changes in soil P fractions are important to assess the long-term effectiveness of these management practices to reduce P efflux from agricultural soils to surface water bodies. The effect of wallboard gypsum and wood chip biochar on extractable P fractions of flooded prairie soils was investigated under simulated spring snow melt flooding (SMF) and summer flooding (SF) conditions. Two contrasting soils (Fyala and Neuenberg series) were incubated under SMF (previously frozen soils; flooded at +5 °C) and SF (unfrozen; flooded at +20 °C) conditions unamended, or amended with either biochar (1% w/w) or gypsum (0.25% w/w) for 10 weeks. Molybdate reactive and non-reactive P contents (Pi and Po, respectively) were measured in fractions extracted sequentially with H2O, 0.1M NaHCO3, 0.5 M NaOH and 0.1 M HCl, before and after flooding. Weakly adsorbed Pi and easily hydrolysable Po contents (0.1M NaHCO3 extractable P) and P associated with crystalline Al and Fe (oxy)hydroxides and clay minerals (0.5 M NaOH extractable Pi) were significantly higher in Fyala than in Neuenberg soil. Phosphorus associated with fulvic and humic acids (0.5 M NaOH extractable Po) were significantly increased by gypsum application after 10 weeks. Except in Fyala under SF, biochar application significantly increased NaOH extractable Po. The effects of gypsum and biochar amendments on P release from flooded prairie soils appears to be short term.

Jesús Díaz-Sanz, Catherine Keller and Samuel Robert

Can vegetated urban soils help to reduce run-off? Case study in Marseille, France

Urban areas are subject to flooding because flood risk increases with soil sealing and Climate Change. However, precipitation infiltration into urban soils is poorly known and barely considered in urban planning. Our objectives were (1) to study infiltration on vegetated urban soils, and (2) to identify the relevant parameters for their infiltration. The study area is located in the 16th district of Marseille (France). We sampled: 15 plots where clay quarries and tile factories were active in a recent past (ACTI), 20 plots in vegetable gardens without previous known industrial activities (VG), 2 control plots in a cropland and a scrubland. We determined previous industrial activities and land-use age, we described the present vegetation cover and the soil profiles morphology. We measured in situ penetration resistance for the first 15 cm (Qd), infiltration, and physico-chemical properties. We estimated field-saturated soil hydraulic conductivity (Kfs) and run-off. The first results revealed a general low run-off. Qd threshold that limits root growth (> 2 MPa) was overcome in 36 % VG and 100 % ACTI. Qd was not correlated with Kfs. The impact of vegetation cover on Kfs was not significant. Kfs was significantly higher in soils identified as being in place since > 36 years than in soils < 13 years. Our study concludes spatial planning should consider precipitation infiltration of vegetated urban soils to minimize flood risk.

Baiba Dirnena, Raimonds Kasparinskis and Nauris Rolavs

Characterization of podzolization process after afforestation of former agricultural lands in boreo-nemoral zone, Latvia

Podzolization process is one of the dominant soil forming processes in boreo-nemoral region. It is increasing in wider areas due to the abandonment of agricultural lands and results in reduced soil fertility and soil degradation that occurs due to changes in soil chemical, physical and morphological properties.
The aim of this study was to clarify development of podzolization process and its influencing factors after afforestation of former agricultural lands in different soil parent material formed by Quaternary deposits. Based on age of forest land (30-167 years) and geological deposits (glacigenic, glaciolacustrine) and sandy Baltic Ice lake and eolian sediments, soil samples in 19 sampling plots were obtained from genetic horizons and were extracted with citrate-dithionite (d) and acid ammonium oxalate (o) to measure Fed, Ald and Feo, Alo compounds.
Study results of soil morphology shows that intensity of podzolization process between the sampling plots differentiate, e.g. features with clearly distinct boundaries between A, E and B horizons is observed in the plots within the Baltic Ice lake and eolian sandy sediments. Contrarily, weak boundaries between genetic horizons in the plots within the glacigenic and glaciolacustrine deposits were detected.
Results showed, that the amorphous Fe compounds in the younger forest land group were more in the E horizons, indicating the beginning of the podzolization process. In the older forest land group Fe and Al concentration were highest on the horizons B - indicating the podzolization process. The crystalline Fe and Al compounds become mobile only in the oldest forest land group.

Anna Edlinger, Gina Garland, Chantal Herzog, Samiran Banerjee and Marcel van der Heijden

The impact of agricultural diversification and management on soil aggregation across Europe

Soil aggregation is important for soil quality, due to its role in stabilizing the soil matrix and storing carbon. Earlier work has shown that agricultural practices can affect soil aggregation, and that microbes play an important role in stabilizing the soil. However, it is still poorly understood how these factors interlink at a large geographical scale.
To test this, we sampled soils from arable fields with contrasting management histories across Europe. Nearby extensive grasslands served as a positive control. We assessed the mean weight diameter (MWD) of water stable aggregates, an index for the structural integrity of the soil. Additionally, a range of chemical, physical and biological soil parameters including soil microbial biodiversity, pH, texture and soil organic carbon (SOC) was measured.
Preliminary results show that the MWD of grassland soils is higher compared to arable soils throughout the climatic gradient. Furthermore, organic management increased aggregation of arable soils. Regression analysis revealed a strong positive relationship between MWD and SOC in arable soils. In grasslands, this relationship seems to level off at high SOC contents, making climate variables the predominant controlling aggregation. By stepwise model selection, the effects of inherent factors and management was tested. While climate and texture had an overruling importance, agricultural activities such as the period of soil cover or fungicide application affected soil aggregation significantly.
Our findings highlight the importance of using management practices that increase soil organic carbon and promote soil life as a tool

to improve the structural stability of arable soils.

B.A. Emmett, A. Thomas, S. Anthony, C. Bell, I. Dickie, A. Fitch, R. Gooday, E. Kettel, L. Jones, R. Matthews, G. Siriwardena, C. Steadman, D. Thomas, M. Vieno and B.J. Cosby

Soil Ecosystem Services, Public Goods and Economic Value in post-Brexit Wales

The UK national governments face significant challenges preparing for potential impacts of Brexit on the agricultural sector and wider environment. In Wales, the "Quick Start" (QS) program partnered Welsh Government and their stakeholders with a consortium of research organisations to address these challenges. QS combined expert knowledge with decision support and modelling tools to identify possible changes in agricultural land use resulting from three potential Brexit trade scenarios. The land use changes were mapped at field and farm scale across Wales and combined with other national data sources to drive agricultural, woodland and ecological models which provided estimates of impacts on provision of soil-mediated ecosystem services (e.g. water quality, carbon sequestration and greenhouse gas emissions). Exploratory ‘what if’ exercises were used to evaluate a range of land management and policy options intended to deliver sustainable ecosystem services into the future in post-Brexit Wales. These exercises included woodland expansion and reduction of agricultural activity on peatland and in low quality farmland for three contrasting landscape types. Economic values were derived for public goods provided by the soil-mediated ecosystem services under each land management option and on each landscape type. Key QS outputs include maps of potential land use change across Wales and national maps of potential changes in ecosystem service delivery for each Brexit scenario, and estimates of the highly variable economic value (per hectare) of public goods under a range of post-Brexit land management policies.

Amandine Erktan, Matthias Rillig, Andrea Carminati, Alexandre Jousset and Stefan Scheu

How do predators modulate the influence of microbes on soil aggregation?

Soil aggregates are micro- to millimetre sized organo-mineral associations considered as the basic units of soil structure. Soil bacteria and fungi influence their formation and stabilisation, but to date most experimental evidence account for these effects in isolation. Here, we investigate how trophic interactions modulate soil aggregate formation and stabilisation.
We focused on: (i) a bacterial-based system comprising Amoebae (Acanthamoeba castellanii) grazing on free-living bacteria (Pseudomonas fluorescens), and (ii) a fungal-based system comprising Collembola (Heteromurus nitidus) grazing on saprophytic fungi (Chaetomium globosum). Soil organisms were incubated in microcosms for 7 weeks containing unstructured sterilized soil. Soil aggregate formation was assessed by dry sieving and soil aggregate stabilization was assessed by capillarity re-wetting of macroaggregates, followed by dry sieving. Changes in microbial biomass and community composition were assessed by phospholipids fatty acids (PLFA).
Soil aggregate formation and stabilisation were significantly enhanced by the inoculation with fungi with the addition of Collembola negatively modulating these effects, presumably via the reduction of fungal biomass. Bacteria alone did not affect the formation of aggregates, but enhanced their stability. Adding Amoebae resulted in the formation of larger diameter aggregates and suppressed the stabilising effect of bacteria on soil aggregates. Inoculation with bacteria affected bacterial community composition, but not bacterial biomass. Interestingly, soil aggregate properties were not related to bacterial biomass and community composition, suggesting that effects may relate more to mucilage production and quality. This study provides the first evidence that predators significantly modify the effects of soil microbes on soil aggregate formation and stabilisation.

Carlos Alberto Faúndez Urbina, Jos van Dam, Erik van den Berg and Coen Ritsema

Field estimation of the effective aggregate’s length by Disk Infiltrometer for dual permeability models Part I

The effective aggregate’s length (dag) in a key input parameter for several dual permeability models (DPM) being used to simulate water flow and chemical transport. The value of dag can be analytically determined when we know the macropore length (be) and the relative macroporosity (wf) in different cross sectional areas (AR) over depth. Both variables can be determined by disk infiltrometer measurements in case of cylindrical macropores (CM). The previous measurements can be generalized to other geometries by a transformation factor (e). Our research objective was to compute the transformation factor for rectangular, hexagonal and cylindrical annulus macropore shapes (denoted as “annulus type” shapes or ATS) under laminar flow conditions. The e was computed setting an ATS with a known be, wf and dag. The be from the ATS was used as the radius of a CM. The unitary macropore flow of the ATS (computed by COMSOL multi-physics software) and CM (computed by Hagen-Poiseuille) were used. The procedure was performed for 30 combinations of different macropore and aggregate’s length per each geometry. The flux was computed in the horizontal and vertical direction, therefore 240 combinations were analyzed in total. Previous calculation of dag for CM was compared against the known dag of ATS, generating values of e. The e values obtained were almost constant. The value for

rectangular slabs was 0.17. For cylindrical annulus and hexagonal shapes = 0 .67. This information can be used in databases with disk infiltrometer data at steady state flow conditions.

Carlos Alberto Faúndez Urbina, Jos van Dam, Rob Hendriks, Erik van den Berg, Harm Gooren and Coen Ritsema

Water flow in soils with heterogeneous macropore geometries

Heterogeneous macroporous geometries (HMG) comprise unevenly distributed macropores over depth. A large variety of macropore distributions produces variable water flow and chemical transport that can deviate from expectations. We analysed the measured pressure head and outflux obtained in experiments with a uniform matrix (Exp. I), one central macropore (main bypass, MB) (Exp. II) and HMG (Exp. III) and evaluated the performance of the models HYDRUS-1D and SWAP for HMG. Two replicate packed soil columns were prepared with silty loam above sandy loam soil. Well defined infiltration and drainage conditions were applied to top and bottom boundaries, respectively. Pressure head and outflux were measured at short time intervals and the inverse estimation was performed by PEST. Exp. I was conducted to calibrate the matrix parameters and Exp. II to calibrate macropore parameters. In Exp. III, four dead-end macropores were created around the MB and the models were run using the previously calibrated parameters updating macropore parameters according to the column set up. The results indicated that HMG increased total macropore influx, especially in the internal catchment (IC) domain. Interaction between the IC-MB and matrix domains was identified as important for explaining the change in cumulative and outflux onset observations. The simulations with both models were good for HMG regarding pressure head and outflux. The implicit representation of HMG by HYDRUS-1D improved outcomes for cumulative outflux whereas the explicit representation by SWAP improved results for lateral mass transfer. The ability to model effects of HMG is important for environmental and agricultural studies.

István Fekete, Áron Béni, Imre Berki, Katalin Juhos, Gábor Várgíró, Csaba Varga, Ornella Francioso, Paola Gioacchini, Daniela Montecchio and Zsolt Kotroczó

Influence of different annual precipitation averages on carbon stock, detritus production and biological parameters of soils in dry and humid oak forests in Central Europe

In our study, we investigated the correlation between annual rainfall averages, soil pH, litter production, fungi biomass, enzyme activity and organic carbon content at 18 Hungarian oak forests.The aim of our study was to compare the topsoil of humid (HFor) and dry (DFor) oak forests. The average annual precipitation of HFor is 705mm, for DFor 560 mm, this difference is mainly responsible for the pH difference (pH 5.3 & 6.9). Accordingly, the fungi biomass (ergosterol test) of the HFor topsoil was significantly higher (60%) than that of DFor. Since higher precipitation values result in a much higher leaching rate, so due to the leaching of compounds of alkaline and alkaline earth metals the annual litter production of HFor is 31% higher than in DFor. Thus, the return of these compounds resulting from the litter production is more intense in HFor. Larger leaching is associated with faster degradation, which explains the significantly lower content of organic C in HFor (38%). Arylsulfatase plays significant role in the nutrient cycle, releases sulphate compounds that can be taken up by plants from organic sulfur-containing compounds. In the case of HFor, significantly higher ($p=0.01$) aryl sulfatase activity was measured than in DFor forests, which can be explained by the larger amount of degrading microorganisms, especially fungi. This is supported by the positive correlation between aryl sulfatase activity and fungal biomass.
Project no. 125688 have been implemented with the support provided by National Research, Development and Innovation Fund of Hungary, financed under the KH_17 funding scheme.

Nerea Ferrando, Joanna Clark, Macarena Cardenas, Vicky Struthers and Daphne Parramon-Dhawan

Interlinkages between soil and tree health in the urban environment: a Citizen Science EU research project

Urban forests benefits for people and the environment are now well established, with urban greening high on the agenda in most EU countries for mitigating the negative impacts of climate change and urbanization through carbon sequestration and storage, temperature and stormwater regulation and air purification. However, most urban trees are not managed in a way that can facilitate the ecosystem services they provide resulting in failed or diminished results. This is mainly due to inadequate soil preparation techniques and specifications required for healthy tree growth.
This integrated study aims to address the knowledge gap in urban tree management practices by looking at interlinkages between tree health and productivity, soil hydrology and soil carbon and nutrient conditions. Here, we focus on the impact of management, specifically litter removal, on soil health. The two-year research project is conducted using Citizen Science at six study sites located

in London (Kew Gardens), Birmingham (Cannon Hill) and Campus Serge Kampf Les Fontaines(France).
The preliminary results indicate that higher soil organic litter in unmanaged sites significantly improved measures of soil health, specifically total carbon content, reduced compaction and bulk density. Improvements in soil health were related to increased infiltration. Therefore, both climate and water regulation were improved by not removing leaf litter. Further work is needed to better understand the mechanisms underpinning this, specifically the functional role of soil organisms to identify the best land management practices for the benefit of urban trees and soils and the ecosystem services they deliver.

Nerea Ferrando, Joanna Clark, Hilary Geoghegan and Macarena Cardenas

Understanding the role of public participation in science for protecting urban soils and green spaces and inspiring sustainable actions and behaviours

Irreversible losses and deterioration of urban soil is a global challenge that requires collective mobilization. However, there is a lack of public understanding of the valuable ecological services provided by soil for society, including: water storage, carbon sequestration and flood protection. Thus, soil is often a forgotten part of the urban ecosystem. Nonetheless, enabling the public to participate in science research (e.g. Citizen Science projects) have the potential to transform science and foster change by making it more accessible to the public.
Here, we examine the participation of professional and non-professional scientists in multiple two-day field campaigns where both groups collected scientific research data together at key sites in the UK and France. The purpose of this qualitative research study is to use overt participant observation and follow-up interviews to determine whether this immersive experience increases scientific literacy and influences participants to take positive action for the environment. Conversely, we also explore how scientists perceive, respond and value the data collected by non-professionals. Data collected from participants insights and perceptions will be coded using NVIVO software and systematically compared with other projects.
The outcomes of this unique, two-year study will address a research gap by enabling an in-depth thematic analysis that will provide more robustness to establish causation between project characteristics and observed outcomes. Our aim is to shine a light on the experience of doing science to encourage researchers to engage with the public for scientific advancement and for the development of environmental sustainability.

Oscar Franken, Olaf Schmidt and Saoirse Tracy

Quantifying bioturbation in soils using glass beads and X-ray CT scanning.

In soil ecosystems bioturbation by fauna is of paramount importance in aerating the soil, improving water infiltration, maintaining a high biodiversity by creating novel habitats for other organisms, and transporting decomposing organic matter to deeper soil layers. Yet the process of bioturbation is difficult to quantify. Recently, the use of X-ray Computed Tomography (CT) scanning has emerged as a powerful tool to visualize opaque substrates such as soil. We propose to apply X-ray CT scanning in combination with inert glass beads as physical tracers for the quantification of bioturbation in experiments. We validated the use of this method by scanning seven different soil types, i.e. ranging from artificial to natural and from mainly mineral to fully organic. These soil types were spiked with known amounts of five different sizes of beads, ranging from 150-180µm to 1250-1400µm. Quantification of the beads was conducted by image analysis using a free ImageJ plugin. Detection of beads through image analysis was highly successful in soils that are high in organic matter content, reaching up to 100% detection of the beads in peat and kaolinite samples. Moreover, smaller beads appeared to have a higher recovery rate compared to larger beads. In contract, the detection rate of beads in sandy soils was low, as the density of sand grains is similar to the used glass beads. We conclude that using X-ray CT scanning of soil spiked with beads to quantify bioturbation is promising, but the use of it may depend on the soil type being studied.

Elke Fries, Michaela Frei, Uwe Meyer, Daniel Rueckamp and Malte Ibs-von Seht

Regional characterization of soil properties by combining methods from remote sensing, geophysics and pedology

To ensure health and wealth of people access to clean water and food is mandatory. This implies protection of soils to preserve their properties and functions. Actually, soil degradation is large in vastly overpopulated areas and in regions where formerly cultivated soils decay due to unsustainable management, land grabbing or civil war. The gross domestic product of any country is highly dependent on the knowledge and availability of usable soil. Therefore, high quality soil data at different scales can contribute to reduce conflicts of land use. Airborne surveys and satellite remote sensing techniques are highly promising to support different stakeholders e.g. farmer associations, water suppliers and responsible authorities with information on land coverage. In the project ReCharBo we develop an integrated approach in order to finally use remote sensing data to differentiate topsoils by their surface

properties. This approach combines knowledge from geophysicists, geochemists, soil scientists, and remote sensing experts. We link acquired information such as natural gamma-ray distribution and hyperspectral data to pedological and physical ground-truthing data in pilot areas to use it as a proxy for soil characterisation. The linkage is established by statistical means as cross correlation patterns, multivariate analysis, self-organising map systems e.g. relating hyperspectral response and natural radiation patterns of different soils to their clay mineral, carbon, and water content and to soil texture.

Zisis Gagkas and Allan Lilly

Deriving a set of simple rules to classify soils for predicting hydrological response

The Hydrology of Soil Types (HOST) classification was devised in the UK to model the rate and pathways of water movement through the soil and parent material by linking soil hydrological indicators with dominant surface and subsurface runoff processes. HOST was optimised by regressing the Base Flow Index (BFI: the long-term average proportion of flow occurring as baseflow) against the proportions of HOST classes within test catchments to predict river flows at ungauged catchments.
Classifying soils to HOST classes is based on a complex set of rules and relies heavily on expert knowledge which greatly restricts the application of HOST to soil profile databases within and outside the UK. The objective of this study is to devise and test a simplified, semi-automatic method for assigning HOST classes to soils by using soil morphological information (recorded during soil surveys) known to describe key features of soil hydrology. The simplified rules will enhance the generation of new digital soil hydrological maps that are increasingly in demand for land capability and environmental risk assessments.
The simplified HOST classification is validated: a) by comparing similarity between HOST classes assigned to around 3,000 soil profiles in Scotland using the detailed and simplified HOST classification rules; b) by comparing the performance of digital soil maps, produced using the detailed and simplified HOST profile datasets, for predicting catchment BFIs using HOST class proportions in 90 test catchments in Scotland where BFI values are available from daily flow series.

Annemieke Reurslag Gärdenäs, Urban Emanuelsson, Anna Hessle, Karl-Ivar Kumm, Frida Dahlström and Mats Olsson

Organic beef and other ecosystem services produced at semi-natural pasture and forest mosaics

Semi-natural pastures in Sweden have almost vanished during last century and with them, many ecosystem services are diminished. This study has two major aims; one is to assess possibilities to make organic beef production profitable by designing coherent grazing land in mosaics of pastures and forests. The other aim is to calculate the possible synergies and trade-offs between organic beef production, wood production, biodiversity and climate regulation at the local, regional and national scales. We conducted field studies at five focus farms along a climatic gradient from South to North Sweden, experimental trials, literature surveys, interviews, and used national inventories and geographical information system (GIS).
We found that a farm needs a minimum size of circa 150 cows and calves with at least 50% semi-natural pastures within 100 ha to be economical viable under current agri-environmental payments. However, new EU Agricultural Policy rules may be valid from 2021. The weight gain of calves during grazing season varied among the farms. Biodiversity values, expressed as habitats for birds and insects, were highest for areas with longest continuation in land use and management. The forest ecosystems (biomass + soils) were most efficient in climate regulation.
The possible synergies and trade-offs between the different ecosystem services will be assessed by comparing different scenarios, optimizing one service at a time, at each of the focus farms. Next, the optimal multi-functional land use will be identified. The results will be scaled up to the regional and national scales by means of GIS

Mikhail Gasanov and Marina Eskova

Influence of humic substances on the transformation and degradation of insecticides in rice fields of Bali island

The necessity for intensification of agriculture in densely populated areas of South-East Asia leads to the active use of fertilizers and pesticides. For pest management of rice farms agriculturists often use neonicotinoids. It is known that humic substances affect the behavior of organic pollutants in the environment. Humic substances are able to bind toxicants, changing their migration ability, and have a stimulating effect on the microbial community of soil, accelerating the process of decomposition of organic pollutants. The aim of our work was to assess the effect of the humic product on the transformation and migration of pesticides in soils. The object of the study was widely used on the island of Bali drugs based on neonicotinoid insecticides: thiamethoxam, imidacloprid, and fipronil. During the model experiment, soil samples with insecticides and 0,25% solution of humic substances (5 ml per 25 g of

soil) were incubated for 14, 28, 56 days at a temperature of 25°C. The method of determination pesticides in the soil is based on acetonitrile extraction and determination on a chromato-mass spectrometer (HPLC-Q-TOF).
The results show an increase in methane formation in the soil on day 7, which can be associated with a significant number of methanogenic bacteria in flooded rice fields. As a result of the experiment, after 14 days, a decrease in the content of imidacloprid in the variant with the introduction of humic substances by 30% was revealed.

Yuri Gelsleichter, Elias Mendes Costa, Lúcia Helena Cunha dos Anjos, Robson Altiellys Tosta Marcondes, Paula Debiasi, Mauro Antonio Homem Antunes and Helena Saraiva Koenow Pinheiro

Hyperspectral images in the support of Digital Soil Mapping: Mountain study case

The Itatiaia National Park (INP) is located across the borders of Rio de Janeiro and Minas Gerais states, southeast Brazil. The first national park of the country with 28000 ha, INP was created in 1937. With mountainous relief, endemic species, organic soils, rock formations and rock outcrops, are a common scene among the grassland of the Itatiaia plateau region, ranging from 2000 up to 2791 m. The altitude and climate are favorable to the preservation of carbon in soil. The area contains the springs of twelve major regional river basins supplying water for a large part of Rio de Janeiro state, including during the winter in the dry season. The INP has restricted access of vehicles, and in some months of the year, no vehicles at all are allowed. Which made the field campaigns challenging. Eighty spatial points, to best representing the soil variability, were previously defined for the soil profile collection and classification. Soil samples were analyzed and spectral readings effectuated. CHRIS/Proba hyperspectral images were acquired from the European Spatial Agency. Spectral data and the hyperspectral image were places among covariates, used in the Random Forest model, resulting in the output of several maps soil properties. These maps help to define the most sensitive regions in the park, which can be applied for improving the monitoring, management and conservation of the area. The technique presents good potential of the application, especially restricted areas such as INP.

Giulio Genova, Georg Niedrist, Stefano Della Chiesa, Ulrike Tappeiner, Stefano Cesco and Tanja Mimmo

The effect of copper toxicity on the interaction of trace metals in agricultural soils: South Tyrol as a case study

Agricultural crop production relies on soil properties and is often hampered due to excessive concentrations of heavy metals such as copper (Cu). Indeed, the intensive use of Cu-containing agrochemicals has led to the accumulation of this metal in soils, particularly in vineyards and orchards. Toxic Cu concentrations might lead to synergisms and antagonisms between nutrients affecting crop yield and quality. However, there is a general lack of centralized and long-term soil data covering a large agricultural region. In South Tyrol a peculiar framework for soil data sourcing exists, connecting individual farmers to several stakeholders. The outcome of this framework is a centralized database containing more than 55,000 records of soil characteristics sampled between 2006 and 2016. On this database, we performed an exploratory data analysis to investigate the interactions among the trace elements and soil characteristics, agricultural management and environmental factors. We carried out Principal Component Analysis (PCA) on numerical variables such as the available P2O5, K2O, Mg, Mn, Cu, Zn, percentage of Soil Organic Matter, and pH. Categorical variables such as texture, land-use, plant variety, and agricultural management were used as explanatory variables. In addition, we coupled Cluster Analysis with PCA to further explain the relation between the elements of the dataset and the groups of soils with similar characteristics. Results showed interesting insights on the interactions between trace metals, soil characteristics and land-use. These results combined with georeferenced soil information will allow mapping environmental risk assessment on high Cu in South Tyrolean permanent crops.

Thangavelautham Geretharan, Paramsothy Jeyakumar, Michael Bretherton and Christopher Anderson

Is phosphate fertiliser derived soil fluorine (F) harmful to root nodulation in white clover?

Soil fluorine concentrations are increased in New Zealand's agricultural soils as a result of continuous phosphate fertiliser application since the 1950s. These elevated soil F concentrations may have the potential to negatively affect soil microorganisms which underpin New Zealand agricultural production. Specific concern relates to F's possible effect on Rhizobium leguminosarum which is a Nitrogen fixing soil bacterium of fundamental importance to New Zealand's pastoral farming system. Currently, there is no data available to determine if New Zealand's soil bioavailable F concentrations are harmful to Rhizobium-white clover root nodulation. In order to assess both total and bioavailable F concentrations in New Zealand agricultural soils, standard methodologies were developed at Massey University, to quantify the range of bioavailable F concentrations in New Zealand pastoral

soils which were shown to range from 1.70 to 6.45 mg/kg (F- concentration < 0.58 mg/L). Pottle-based experiments were conducted to examine the effect of F- on Rhizobium-white clover interaction by observing nodule morphology and growth. Results indicate that Rhizobium is able to form healthy nodules at a white clover F- concentration up to 100 mg/L. Plant growth was not significantly suppressed below a F- concentration of 70 mg/L. Both Light and TEM micrographs confirmed that Rhizobium-white clover interaction was not influenced by F- concentrations under 100 mg/L. Recorded toxic F- concentration for Rhizobium-white clover is orders of magnitude higher than those recorded for New Zealand agriculture soils under 'normal conditions'. There appears to be no indication of imminent risk of soil F to Rhizobium-white clover interaction.

Bb Ghaley, Jo Smith, Sally Westaway, Andrea Pisanelli, Marco Lauteri, Elias Fereres, Rocío Calderón, Robert Borek, Rafal Wawer, Sandor Mignon, Adrian Gliga and Lisa Mølgaard Lehmann

Agroforestry systems for multifunctional landscape and provision of soil-based ecosystem services

Agroforestry systems are encouraged in farming systems due to their multifunctional role in enhancing agronomic productivity, co-production of diversity of food products for balanced nutrition and provision of ecosystem services. There are diversity of agro-forestry systems that exists, but the information on these agro-forestry systems are scarce and unavailable. Hence, the objective of the study is to describe agro-forestry systems for production of range of agricultural produce and ecosystem services. In SustainFARM project, a network of six agroforestry systems integrating arable crops, livestock and biomass crops, were identified to assess the range of agricultural products and provision of ecosystem services. The agro-forestry systems produced food crops (e.g. wheat, barley, rye, oat etc.), vegetables (e.g. tomato, paprika, cucumbers, watermelons, lettuce, cabbage etc.), fruits (e.g .apple, pear, plum, apricot, olive etc.), meat (e.g. sheep, duck, poultry etc.) and dairy products (e.g milk, cheese etc.) The agroforestry also produced fodder (grass and legume swards) and non-food products like woodchips or firewood for use as source of energy to meet household energy needs. The study demonstrated that the agro-forestry produces diversity of food products and suite of marketable and non-marketable ecosystem services in different production systems across Europe, which underscores the multifunctional role of agroforestry systems. Hence, the study provided a robust field based evidence on diversity of agroforestry systems and their multifunctional role in terms of provision of diversity of food products and ecosystem services in diverse contexts for informed decision making by land managers, advisory services, farmers and policy makers.

Daniel Gimenez, Matthew Patterson, Helen French, Esther Bloem, Annette Dathe, Johannes Koestel, Ruth Kerry, Anna Angyal, Nicholas Jarvis and Attila Nemes

Will traditional hydro-physical measurements, X-Ray tomography and geophysical imaging identify and quantify soil functional heterogeneity at the meter-scale?

Soil transport coefficients and the proxy properties used to predict them are affected by spatial, and often temporal variability. Cross-scale variations in these properties can be characterized by combining sensory and imaging techniques with different resolving power, in situ sensory monitoring, and intensive sampling and subsequent measurements. We are generally concerned with whether soil properties used to predict transport coefficients capture the field-observed degree of soil heterogeneity, and how many samples are needed to achieve that. Two adjacent 2-m3 soil volumes were surveyed with ERT in 2D/3D electrode configurations, and by 20 TDR-tensiometer pairs in each investigated volume, whose installation was guided by ERT results. Moisture dynamics and field-measured soil water retention characteristics were used as indicators of and proxy for functional heterogeneity. Thirty-eight soil cores were sampled from the proximity of the TDR sensors and used to derive X-ray tomography-based pore network characteristics, water retention, hydraulic conductivity, bulk density, OC content and a quasi-continuous particle-size distribution curve. An additional 83 cores had all but the X-ray data collected. We will focus on (1) discussing the response of various sensors and measurements to ERT- or visually-detected feature(s) within the soil volume; (2) examining the correlation structure in the collected data and investigating similarities between clusters of soil properties and field-observed ERT patterns; and (3) identifying which of the applied measurement types retained comparable degrees of spatial heterogeneity for the soil volume.

Anna Gomes, Alyssa DeVincentis and Jeff Mitchell

Hydrologic Impact of Winter Cover Cropping with Reduced Tillage for Sustainable Farming California's San Joaquin Valley

The future of food production will require the use of farm practices that simultaneously improve soil health, reduce greenhouse gas

emissions, and utilize water efficiently. Winter cover cropping and conservation tillage are two farm practices that may help to meet these needs, but uncertainties remain around their impacts on pre-season irrigation demands, on-farm logistics, and overall soil water content. This study fills a gap in the research by investigating how cover crops and conservation tillage influence water management at the field level. We investigate this question using three years of robust data from a 20 year long-term field experiment in Five Points, CA, comparing standard tillage to conservation tillage and fallow fields, or no cover cropping, to winter cover cropping. Treatment plots have been in place since 1999, providing a robust data set of the long term effects of these practices. Our research questions explore the impact of winter cover crops and conservation tillage on soil water content at varying depths of the soil profile, in addition to quantifying the soil carbon addition by biomass and canopy cover through time. We are currently working to analyze weekly neutron probe data, collected over three winter seasons from 2016 to 2019. This work may suggest that the use of conservation tillage and winter cover cropping on farms with similar climatic conditions and cash crop rotations could offer water-smart strategies that can achieve multiple ecosystem services and climate benefits, contributing to building a climate resilient agricultural sector in California.

Maryam Ghebleh Goydaragh, Ali Asghar Jafarzadeh, Ruhollah Taghizadeh-Mehrjardi, Farzin Shahbazi and Marcos Lado

Mapping soil organic carbon content using FTIR spectroscopy data and proximal soil sensing in soils of semi-arid regions of Iran

The Soil Organic Carbon (SOC) content is a key element for soil fertility and productivity, nutrient availability and greenhouse gas emission.The objectives of this study was to evaluate the performance of four machine-learning algorithms for the prediction of SOC content using ancillary data (i.e. remote sensed data, Fourier Transform Infrared (FTIR) spectroscopy data and a digital elevation model). The techniques applied were Cubist, Support Vector Machine (SVM), Classication and Regression Trees (CART) and Generalized Linear Regression (GLM). 80 soil samples were collected systematically (700 × 1000 m) from 7000 ha field in the Miandoab County, Northern Iran. 75% of the data were used for calibration and 25% for validation. Fourteen remote sensed data were driven from a digital elevation model (DEM) and Landsat 8 with resolutions of 12.5 and 30 m, respectively. Moreover, ten important FTIR bands, which are strongly associated with SOC content were identified by Random Forest model (RF), and then employed as predictors. The performance of the models was compared with the coefficient of determination (R2), concordance (CCC), Mean Squared Error (MSE), and Root Mean Square Error (RMSE). The results indicated that Cubist (R2=0.78, CCC=0.81, MSE=0.19, and RMSE=0.43) obtained the best performance in predicting of SOC content from combination of proximal soil sensing and FTIR spectroscopy data. However, all machine-learning methods were not capable to estimate SOC content from soil sensing data. Importantly, our results indicated that the proximal soil sensing and FTIR spectroscopy data had the highest influence on the prediction accuracy of SOC.

Qiaoling Han, Yue Zhao, Zhao and Lei Liu

Construction of three-dimensional pore skeleton model based on soil CT images

As the computerized tomography (CT) technology has provided an advanced technical mean for the visualization of soil internal structure, the soil pore skeleton model has become one of the focuses in the study of the temporal and spatial evolution characteristics of soil structure. Its structural characteristics can reflect the topological structure and spatial distribution of pores, which has great significance for understanding soil functions and ecological processes. Nowadays, the existing skeletal models are widely used in medical visualization, computer games, rock pore and so forth, but there are few on the construction methods of soil pore skeleton models. Therefore, this paper adopts two representative skeletal methods, namely thinning method and distance transformation method to simulate the pore skeleton model. Based on the soil CT images and the custom images, the performance of the two methods to construct the pore skeleton model were evaluated. The experimental results demonstrate that the pore skeleton model extracted through the thinning method can preserve better centrality and connectivity. And by combining the post-processing of the pseudo-branch deletion, the thinning method has a better ability to describe the pore topological characteristics. This work has laid a technical foundation for the research on soil physical structure and hydrological characteristics, and a theoretical foundation for the understanding of soil function from pore scale as well.

Joost van Heerwaarden and Renske Hijbeek

From soil properties to nutrient requirements: How much can we predict?

The ambition towards sustainable intensification of tropical smallholder agriculture has generated interest in scalable approaches for tailoring mineral fertilisers to local soil conditions. Such approaches typically rely on models that translate soil properties into macro nutrient requirements. Perhaps the most widely used of such models, QUEFTS (Quantitative Evaluation of the Fertility of

Tropical Soils), combines production ecological and empirical equations that integrate data on soil properties, nutrient uptake and biomass production to define levels of N, P and K required for a specified target yield.
While over the years the model has been calibrated for a large number of crops and soils, there have been very few attempts at independent validation of model predictions nor have there been efforts to evaluate the validity of the underlying equations in light of new data. Such critical evaluation is required to assess the model's true potential as a predictive tool for the development of recommendations at scale.
Using stochastic simulations and empirical data from 160 nutrient omission trials, we evaluate the ability of QUEFTS and its components to capture observed relations between yield, plant nutrient composition and soil properties and to predict nutrient responses and agronomic efficiencies across newly sampled soils. We find that some of the core nutrient-yield relations in the model may not provide the most appropriate description of empirical data and that prediction of nutrient availability seems to be remarkably challenging. We discuss the implications for site-specific fertiliser advice as well as possible avenues for improvement.

Jannis Heil, Bernd Marschner and Britta Stumpe

Digital photography as a tool for predicting and mapping soil properties on a soil profile

There is growing interest in the mapping of soil properties, especially at the micro-scale. Here, imaging and spectroscopic methods are promising tools. Soil color is a commonly recorded parameter that is easy to obtain as it includes information about soil organic and mineral composition. With digital photography, there is a way to record color information at a very high spatial resolution. In this study, we took 50 samples plus 3 microplate scale excavations from a profile wall of a Luvisol. Images of sieved and ground soil samples were taken under standardized laboratory conditions. After image correction, RGB colors were obtained for each sample and transformed into different color spaces. Different prediction methods from linear regression to more advanced machine learning algorithms were tested. For linear regression, the highest R2adj was 0.91 for SOC (HSV V) and 0.78 for Fe (CIE u*) for ground soil samples. For sieved samples, R2adj was lower with 0.70 (HSV V) and 0.64 (CIE a*) for SOC and Fe, respectively. Multiple linear regression models could improve those predictions to R2adj of 0.92 (SOC) and 0.79 (Fe) for ground samples and R2adj of 0.84 (SOC) and 0.64 (Fe) for sieved samples. From the best pedotransfer functions, we predicted SOC and Fe contents for the excavated microplates. We found that properly calibrated digital images could be a cost-effective method that has the potential to map the distribution of SOC and Fe on a fine scale.

Jussi Heinonsalo, Bartosz Adamczyk, Rashmi Shrestha, Chao Liang and Kristiina Karhu

The role of plants on SOM decomposition, microbial biomarkers and quality and quantity of DOC

Soil organic matter (SOM) decomposition may be induced by plant in a process called rhizosphere priming effect (RPE), especially in N-limited ecosystems where N can be released to plant-available forms from recalcitrant organic molecules by microbial extracellular enzymes. As a consequence of priming, SOM may be mineralized to CO2. RPE may therefore reduce SOM pools in soil. In contrary, as the driver of the decomposition may also be N scavenging, not the release of SOM-bound energy, SOM can also be degraded into smaller molecules which thereafter move downwards in soil profile as DOC. Another plant-root-dependent process in soil is the increased root and microbial litter production that may counterbalance the SOM losses caused by RPE. There is urgent need to better understand the quantitative importance of RPE and belowground litter formation.
We studied the effects of living root systems of Pinus sylvestris, Calluna vulgaris or their mixture (with non-planted controls) on soil C and N pools, quantity and quality of DOC, biomarkers for microbial necromass (aminosugars) and degradation of abundant N-rich organic matter (15N-labelled fungal necromass). The plants were grown in greenhouse conditions in natural boreal forest humus.
We hypothesize that the presence of plants increase the amount of DOC and proportion of small molecular weight (<1kDa) compounds in DOC. We also hypothesize that in planted soil, there are more microbial biomarkers and more degradation of N-rich fungal necromass.
Preliminary results of the experiment will be presented.

Chantal Herzog, Adrian Honegger, Django Hegglin, Raphaël Wittwer, Hans-Rudolf Oberholzer, Anne de Ferron, Erik Verbruggen, Philippe Jeanneret, Michael Schloter, Samiran Banerjee and Marcel G.A. van der Heijden

Are crop yield and ecosystem multifunctionality affected by the duration of organic management?

Organic farming is gaining importance but it remains unclear whether yield and environmental services change along with

management duration. We compared 34 fields assigned to four groups: 1) conventionally managed farms; 2) farms in transition to organic farming (in the 1st–3rd year); 3) farms converted moderately long ago (9–13 years); and 4) farms subjected to long-term organic farming (15–32 years). Fields were investigated during two years (2011: maize, 2012: wheat) to answer the following questions: 1) Do production, soil fertility, soil microbial activity, biodiversity and biocontrol through spiders as well as multifunctionality differ between conventional and organic farms? 2) Are these parameters affected by organic management duration? We found lower maize (-6%) and wheat yield (-22%) in organic fields but no further decrease with continued organic farming. Soil fertility did not decrease with organic farming duration and we found higher potassium levels under long-term organic farming. Soil respiration and microbial biomass carbon remained unchanged, while wheat root colonization by arbuscular mycorrhizal fungi was increased under organic agriculture (+20%). For biodiversity, we found higher weed species richness in organic fields but no impact on the diversity of spiders and root associated fungi. Multifunctionality did not differ between farm groups, which could be related to high variations within treatments or trade-offs between functions (e.g. yield vs. biodiversity). Overall, our study contributes to a better understanding of the consequences of organic agriculture and reveals a rapid shift of functions that remain stable over time after a conversion to organic farming.

Gerard B.M. Heuvelink, Laura Poggio, Marcos E. Angelini, Zhanguo Bai, Niels H. Batjes, Rik van den Bosch, Deborah Bossio, Johannes Lehmann, Ariadna Martinez, Guillermo F. Olmedo, Pablo Pareja and Jonathan Sanderman

Space-time mapping of soil organic carbon concentration and stock to support land degradation neutrality and climate mitigation policies

To evaluate changes in soil organic carbon (SOC) stocks and land degradation neutrality policies, there is a need for a global web-based platform to inform on the status and trends of SOC. Such a platform requires a statistical methodology for predicting SOC in space and time from point observations and spatial and spatio-temporal maps of environmental covariates. In this presentation we report on the development, implementation and application of a statistical space-time SOC mapping method, using Argentina as a pilot area. We used the Quantile Regression Forest machine-learning algorithm to predict SOC at six standardized depths at 250 m resolution for Argentina between 1982 and 2017, on an annual basis. The model was calibrated using over 9,000 SOC observations from the 36-year time period and using 25 covariates. Most covariates were static and could only explain the spatial SOC distribution. SOC change was modelled using long-term vegetation indices. Prediction uncertainties turned out to be substantial, mainly due to the limited number and poor spatial and temporal distribution of the calibration data, and the limited explanatory power of the covariates. Cross-validation confirmed that SOC prediction accuracy was limited with a Root Mean Squared Error of 12.7 g/kg and 6.7 g/kg for the 1982-2017 and 2002-2017 periods, respectively. In spite of the large uncertainties, results show that overall the SOC stock of Argentina declined from 2002 to 2006 and stabilized from 2006 onwards. Upon further evaluation, results will be made available through a user-friendly web service to a wide variety of stakeholders.

June Hidalgo, Mikel Anza, Lur Epelde, Julen Urra, José María Becerril and Carlos Garbisu

Phytomanagement of polluted sites for the recovery of soil health

Among the different strategies currently available for the remediation of polluted sites, phytomanagement appears as a cost-effective, sustainable option for soils degraded by the presence of organic pollutants. Within phytomanagement initiatives, plants are often inoculated with mycorrhizal fungi to facilitate plant survival and growth, and simultaneously to collaborate in the biodegradation of organic pollutants in the rhizosphere. It must be highlighted that the ultimate goal of biological remediation technologies must be not only to remove the contaminants from the soil but, most importantly, to recover soil health. Soil microbial parameters, particularly those reflecting the biomass, activity and diversity of soil microbial communities, have great potential as biological indicators of soil health.
The main objective of this study was to assess the effectiveness of mycorrhizal inoculation on a phytomanaged soil heavily polluted with a mixture of TPHs and PAHs. For that, we carried out a mycorrhizal-assisted phytomanagement study using an organic amendment, poplar trees and alfalfa. At harvest, we determined different soil microbial properties: microbial biomass carbon, total bacteria and fungi via qPCR, soil respiration, potentially mineralizable nitrogen, enzyme activities and bacterial metabarcoding.
We observed a phytomanagement-induced recovery of soil health. In fact, microbial parameter values increased in inoculated treatments, especially for alfalfa. Besides, microbial activity was enhanced by the application of the amendment. Finally, the sensitivity, rapid response and integrative character of soil microbial properties make them invaluable biomonitoring tools for the assessment of the efficiency of biological remediation processes.
This work was funded by the NANORRIZORREM-2 project (AGL2016-76592-R).

Renske Hijbeek, Marco Trombetti, Wim de Vries and Rainer Baritz

An assessment of soil organic matter thresholds for crop production in Europe

Soil organic matter (SOM) is an important indicator for soil fertility as it relates to soil structure, nutrient supply and soil life. For targeted policies, areas with a deficiency of SOM need to be identified, where increasing SOM can improve productive capacity of soils.
Previously, based on a large scale survey (> 1500 farmers), SOM threshold ranges were established per soil texture in Europe, based on farmers perceptions. In this study these thresholds were further specified, taking into account climate zones. Nine specific SOM threshold ranges - each for a combination of soil texture and climate - were defined. Thresholds were compared with spatial data from the 2009 LUCAS survey, to identify soils with SOM content below the upper bound of the threshold range. To validate the approach, correlations were made with crop productivity data.
Results show that SOM thresholds are lower for Mediterranean (1- 2% SOM) than for Continental (1.8-3.2% SOM) or Atlantic (1.7-3.5% SOM) climates. 14.3% of agricultural soils in Europe currently has less SOM than the upper bound of their threshold range. Results however vary between countries: Denmark, Latvia and Ireland have no soils with a SOM content below their upper threshold while Austria, Czech Republic, Hungary and Slovakia have more than 40% of their soils below it. Comparisons with satellite based crop productivity data show lower crop productivity in the areas with SOM content being deficient. To improve accuracy of this analysis, targeted farm surveys covering larger areas and more specific crop productivity statistics are needed.

Naila Hina, John Gowing, Jeremy Dearlove, Melissa Swartz and Julia Cooper

Using spatially explicit soil mapping and modelling to understand and mitigate nitrate leaching in an agricultural catchment

Nitrate movement from agricultural catchments into drinking water aquifers contributes to diffuse water pollution. Environment Agency monitoring wells indicate nitrate level in Fell Sandstone aquifer in the UK may exceed the allowable limit of nitrate in drinking water in the next 5 to 15 years. Land use in the catchment is mostly agricultural and fertilizer and manure management along with other agricultural activities are believed to be major contributors to groundwater contamination. In this study, we used high-resolution soil sensing to design a better monitoring system for soil nitrate concentration and leaching events. In the first year, we monitored 24 sites using porous ceramic cups to extract soil solution below the root zone in a diverse agricultural system including arable and grass crops. Nitrate leaching from potatoes (159 kg NO3-N/ha) was much higher than oilseed rape (36 kg NO3-N/ha) and grass (2.23 kg NO3- N/ha). Nitrate losses from organic fields were not significantly different from conventional fields. We are continuing monitoring in a subset of locations selected to represent a range of soil texture, perceived depth to bedrock and nitrate concentration in the soil solution. Data collected from these points along with soil and climate data will be used to calibrate the DNDC (DeNitrification-DeComposition) model for local conditions. By running this model within a GIS we aim to investigate the influence of local ‘hot spots’ on the nitrate load reaching the aquifer with the aim of informing a precision agriculture approach to the diffuse pollution problem.

Jing Huang, Jusheng Gao and Huimin Zhang

Interannual variation characteristics of soil available phosphorus, inorganic phosphorus fractions and rice yield in a subtropical paddy soil under different fertilization over 35 years

Phosphorus (P) plays an important role in the stability of double-cropping rice production in subtropical paddy soil. Under the current P application level, the soil is not deficient in P, but it is necessary to strengthen the study on the change of different P fractions in soil to ensure the sustainable use of soil P. A 35 years long-term experiment under early rice - late rice cropping system were undertaken to investigate soil P availability and inorganic P (Pi) fractions (Al-P, Fe-P, Ca-P and O-P) in plough layer (0-20 cm) of a paddy soil in southern China. Three field treatments were examined: cattle manure (M), chemical (NPK) and NPK combined with cattle manure (NPKM). Results showed that continuous fertilization increased soil total-P (TP), Olsen-P and Pi over the years, particularly in NPKM treatment. The maximum Olsen-P in M, NPK and NPKM was about 12.9, 31.7 and 52.7 mg/kg, respectively. Whereas, the ratio of soil Pi to total P under M, NPK and NPKM changed from 62.2% at the beginning of the experiment to 53.3%, 61.9% and 66.2%, respectively. Soil properties significantly influenced Pi fractions distribution. Total P and Olsen-P were more closely correlated to Fe-P, Ca-P and Al-P fractions. This research study confirms that cattle manure is an essential strategy in P fertilization management in subtropical paddy soil cropping system.

Jakob Hüppauff.

First Internationale Bodenbauausstellung

How can we improve sustainable soil use in Europe without an EU framework and emphasize soil protection as an European challenge?
2014 marked the withdrawal of the EU Soil Directive through the European Commission. An ambitious EU framework seems out of reach ever since. Besides legislation as one of the central pillars of the EU Soil Thematic Strategy, several actions have taken place during the last few years throughout Europe. Despite of all these efforts, however, a coherent strategy is still missing. Simultaneously, we need a fundamental change of ongoing processes and routines from urbanisation to agriculture. These paramount shifts are difficult to communicate in a non-threating manner. As such, soil protection is still not part of a broader public debate. This lack of discourse impedes progress on a topic that is critical for the well-being of millions of Europeans, and related challenges which are expected to increase over the next few years. To meet this lack of public debate, my Master Thesis advocates for an informal approach to take a step forward and put soil protection on the public agenda.
Taking the positive messaging employed by the Internationale Bauausstellung [IBA] as inspiration, I developed the concept of the first Internationale Bodenbauaussellung [IB2A]: a process-oriented, experimental exhibition format which allows to present new ways of sustainable soil use to a public audience. I will present the ideas and the structure behind the concept of a IB2A as a basis to discussion and look forward to an engaging conversation with you.

Karoliina Huusko, Anna-Reetta Salonen, Outi-Maaria Sietiö, Kenneth Peltokangas, Subin Kalu, Rashmi Shrestha, Kristiina Karhu, Jari Liski and Jussi Heinonsalo

Effects of wood derived soil amendments on functioning and presence of root and soil microbes

Agricultural soils have drawn particular attention recently because of their potential for atmospheric carbon dioxide (CO2) sequestration and climate change mitigation. Also in agricultural soils, microbes are crucial to soil organic matter (SOM) formation and stability. Microbes decompose SOM, produce CO2, and act as carbon containing biomass in soil. Dead microbial remains seem to form the most stable carbon in soils.
Applying organic soil amendments may help to maintain agricultural systems sustainable, and possibly increase soil carbon stocks. Generally, addition of organic material to the field increases soil carbon content fast and affects positively water holding and cation exchange capacities and biological activity in soil. However, it is not well-known what kind of effects organic soil amendments have on microbes.
In this project, impacts of wood derived soil amendments (e.g. pulp fines and biochars) on soil microbial communities were studied in a three-year long field experiment. The research focus was on the effects on functional and taxonomical diversity of microbial communities in oat (Avena sativa) roots and soil, and their relation to soil carbon stocks. Microbial communities were studied with Illumina Miseq sequencing, and soil biological activity e.g. by measuring soil respiration and exoenzyme activities and by using Biolog® carbon use profiling of soil microbial communities. These results are combined with data on soil chemical and physical properties.
Research is part of Carbon Action initiative. The results on soil microbial biomass, biological activity and structure of microbial communities in roots and soil will be presented.

Srimathie Indraratne, Darshani Kumaragamage, Douglas Goltz and Randobage Dharmakeerthi

Assessment of compost and biochar as amendments to remediate toxic multi-element contaminated soil

Soil contamination by multi-elements coming from metal smelters has received substantial attention due to their toxicity and persistence in the environment. Among different remediation technologies, in-situ stabilization of toxic elements is a promising solution for soil remediation. In-situ stabilization reduces available toxic element concentrations that can pose significant environmental risks. This study evaluated the effectiveness of two organic amendments, namely biochar and compost, in immobilizing toxic elements in soil contaminated with 129 mg kg-1 arsenic (As), 28 mg kg-1 cadmium (Cd), 1590 mg kg-1 copper (Cu), 4500 mg kg-1 lead (Pb) and 7460 mg kg-1 zinc (Zn). A laboratory incubation study was conducted with soil that was unamended (control) and amended with either biochar or compost at 5% w w-1. Moisture content at field-capacity was maintained for six months. Toxic element concentrations were determined in pore water collected at 0, 2, 4 and 6 months after incubation. Available toxic elements were extracted from incubated soils using ammonium acetate after the incubation period. A significant decrease in toxic metal concentrations in pore water were observed with amendments as follows: As and Cu by biochar, Pb by compost and Cd and Zn by both biochar and compost. Both biochar and compost were effective in reducing bioavailable Cd, Cu, Pb and Zn concentrations in contaminated soil while only biochar was effective in reducing bioavailable As. Biochar and compost can be identified as effective amendments for in-situ stabilization of studied toxic elements in soil.

Min Jiang, Ling Xiao, Jun Dai, Xufei Chen, Linlin Zhong, Minghui Li and Chi Zhang

Spatial pattern of soil microbial diversity and soil physicochemical properties along with their application in quality evaluation of cultivated land at county scale

Taking soil microbial diversity as one of indexes for regional cultivated land quality evaluation is fundamental to soil quality management and sustainable utilization of cultivated land. Based on field investigation and laboratory analysis, soil physicochemical properties and microbial diversity of the soil samples taken from northern hilly region, central plain region, eastern plain region and southern hilly region in a county situated in South China were analyzed, and spatial heterogeneity characteristics of these indexes were further discussed. Results showed that soil nutrient contents in the study area were abundant and presented an obvious spatial pattern, although spatial autocorrelation of most physicochemical indexes is weak. The spatial pattern of microbial population structural diversity by means of PLFA analysis was similar to that of soil physicochemical properties. Kriging interpolation analysis showed that the ratio of microbial bacteria to fungi and ratio of Gram-positive bacteria to Gram-negative bacteria decreased towards the direction of northern hilly-eastern plain-central plain-south hilly, and were significantly associated with soil soil organic matter, alkali-hydrolyzed nitrogen and soil CO2 release. Therefore, the ratio of microbial bacteria to fungi along with the ratio of Gram-positive bacteria to Gram-negative bacteria are appropriate indexes for regional cultivated land quality evaluation, though further study is still needed to classify soil quality level based upon those indexes.

S. de Jong, V.L. Mulder and F. van Egmond

Soil spectroscopy for the Dutch Soil Information System

In 2017, the initiative to build a spectral library for the Dutch Soil Information System (BIS) was started. Since then, we are continuously updating and improving our spectral library where new vis-NIR and MIR measurements can be translated to soil characteristics. At present, we have developed and implemented a protocol for the calibration and validation methods for predicting various soil properties like soil organic matter (SOM) and pH by using vis-NIR and MIR spectroscopy and have started data collection with vis-NIR. Results show that vis-NIR spectroscopy can be used as a rapid, inexpensive technique for predicting soil properties like OM and pH for BIS. However, ongoing efforts are needed to further improve the prediction accuracy for various soil properties and include MIR. The main challenges are to overcome issues related to the existing bias and representativeness of the soil sample data used. In order to improve the model performance for a wide set of soil properties, a larger and more representative dataset is needed covering the diversity of soil, landscape and land use characteristics with sufficient samples for model calibration and validation. This work will present several tested solutions aimed to overcome existing bias within the soil legacy data and present the first results comparing vis-NIR and MIR measurement for prediction.

Lisa Joos, Caroline De Tender, Sarah Ommeslag, Lieven Clement, Bart Vandecasteele and Jane Debode

Understanding the soil microorganisms by means of long-term agricultural field trials

The last decades it became increasingly clear that natural soils harbor an extensive range of life. We start to recognize the importance of soil life, mediating many ecosystem functions by controlling nutrient fluxes and plant performances. At the same time, soil biodiversity is under threat due to intensive land use and climate change. It is a challenge to understand how these threats are affecting the soil microorganisms. In this research, the physicochemical properties and bacterial and fungal communities of soils of five field trials with a specific history of organic fertilizer application, soil tillage and/or crop rotation were analyzed using PLFA and high-throughput 16S and ITS rRNA gene sequencing. Differences in soil microorganisms were mostly explained by the field effect (intrinsic aspects of the fields), with carbon, nitrogen and phosphorus as the largest drivers. Additionally the temporal variability of the soil microorganisms was investigated for two fields during one year with monthly measures. First, the speed to which fungal and bacterial communities respond to agricultural practices or environmental changes was studied, and second the representativeness of samples taken on a given timepoint was determined. Preliminary results showed that (1) the species composition changed over time and (2) treatment effects such as compost addition were time-dependent.

Elisabeth Jost, Martin Schönhart, Rastislav Skalsky, Juraj Balkovic and Erwin Schmid

Soil functions assessments as a means for sustainable soil and land use management - Exploring their sensitivity towards processes of global change

The concept of soil functions holds promising potential for purposes of sustainable land use and land management planning, as it comprehensively addresses the multifunctional role soils have for both human and environmental wellbeing. Even though, soil research has advanced majorly in the last decades, the ability of methods in soil functions assessments (SFA) to depict dynamics under the influence of external drivers such as climate or land use change remains a challenge.
We have conducted a review on scientific literature and methodological approaches in European SFAs to identify i) the key soil parameters directly or indirectly involved in changing soil functionality, and ii) if and where these key parameters are incorporated within reviewed methodologies, as the latter rarely overcome depicting a certain state of soil functionality as a snapshot of current conditions. Our analysis reveals responsive parameters such as soil organic matter contents, soil moisture contents, bulk densities, and pH-values as well as identifies the disregard of feedbacks and mutual influencing pathways amongst single functions of soils as a pivotal shortcoming of current SFAs.
We furthermore conduct a simple SFA modeling approach to anticipate the spatio-temporal effect of organic matter dynamics on soil functions using climate change and land use scenarios for a case study region in Austria. This highlights the potential of integrated modeling to broaden the scope of traditional SFAs in guiding target-oriented soil and land use management under climate change for the superordinate goal of land degradation neutrality.

Raquel Juan-Ovejero, Rodrigo Rodríguez Granjel and Maria Jesús Iglesias Briones

The interplay between abiotic and biotic factors regulates carbon losses in peatlands

Climate change projections indicate that peatlands will switch from carbon sinks to sources. However, little is known on how the potential links between abiotic (temperature and moisture) and biotic (soil organisms and plant communities above-ground) factors will contribute to this change in ecosystem functioning. We conducted a 2-year field study at four peatland habitats dominated by different plant communities: ericaceous shrubs, grasses, sedges and mosses in order to quantify the relative importance of abiotic and biotic factors in controlling carbon losses. We investigated the temporal variability in soil temperature, soil water content, pH and C/N ratio at each habitat as well as the changes in above- and below-ground plant biomass, microbial and mesofauna communities and the effects of their metabolic pathways on C release (soil respiration and DOC leaching). By building a structural equation model (SEM) we were able to determine that, with independence of the identity of the plant communities above-ground, abiotic factors (soil temperature and soil moisture) were the primary abiotic drivers of the biological responses to carbon losses. Specifically, below-ground plant and microbial biomass were directly linked to increased carbon exports from these systems. Although we did not find a strong relationship between soil mesofauna and C transformations, animal biomass was a good proxy to measure the contribution of the different functional soil biotic factors to carbon mineralization. Taken all together, these findings suggest that including plant-soil-faunal interactions in carbon models is crucial to better quantify soil carbon cycling processes under future climate change scenarios.

Mulenga Kalumba, Stefaan Dondeyne and Jos Van Orshoven

Performance of parametric and non-parametric pedotransfer functions for soil hydraulic properties in sub-humid conditions in Zambia

Digital Soil Mapping (DSM) has become the preferred approach to generate location-specific soil-related input data for spatially explicit process-based models of the land phase of the hydrological cycle in a river basin. In order to build and calibrate DSM-models, a set of measurements of the dependent soil variable which is representative for the territory of interest is required. However, unlike elementary soil characteristics like granulometry and pH, the more complex soil hydraulic properties that are crucial for hydrological and crop growth modelling are usually not available. To cope with this lack of reference measurements, pedotransfer functions (PTF) are used, which are meant to predict hard or costly to obtain soil variables from more easily obtained ones. In this contribution we first develop and test the performance of parametric and non-parametric transfer functions; Multiple Linear Regression (MLR), Artificial Neural Networks (ANNs), Random Forests (RFs) and Support Vector Machines (SVMs) with our measured 302 samples related to 119 soil profiles spread through the smaller Upper Mulugushi sub-basin in Zambia with a view to evaluate whether they can be meaningfully applied with the elementary soil characteristics data available for the larger Zambezi River Basin. Secondly, a Monte Carlo analysis to assess the effect of the uncertainty of the estimated soil hydraulic properties on the crop water requirements as calculated by the FAO AquaCrop crop growth model will be evaluated. Overall, results so far show that ANNs PTF outperforms all the other evaluated PTFs when our measured and estimated soil hydraulic properties are compared.

Kristine Karstens, Benjamin Leon Bodirsky and Alexander Popp

Global soil organic carbon scenarios for a 2° trajectory

Most mitigation scenarios derived by Integrated Assessment models (IAMs) heavily rely on Carbon Dioxide Removal (CDR), but have mainly focused on afforestation and bioenergy with carbon capture and storage (BECCS).
Both are land-demanding terrestrial negative emission technologies (tNETs), increasing the pressure on the land system and hence affecting sustainable development. The enhancement of soil organic carbon (SOC) on agricultural land represents a rather different tNET option. Large scale SOC enhancement may revert the general trend of declining SOC pools and soil quality, while not competing for land but rather providing co-benefits for agricultural production such as yield increases.
However, soil management is so far not well-represented in global land-use and integrated assessment models. In this analysis, we simulate SOC dynamics within MAgPIE, a modeling framework for global land-systems. MAgPIE combines socio-economic decision-making processes and spatial explicit biophysical constraints. We use the IPCC methodology of stock change factors to track SOC accumulation and decay on cropland and introduce SOC enhancement options such as cover crops.
Here we present future projections for SOC development without and with the inclusion of SOC management options for climate change mitigation. We show implications on sustainability indicators such as food prices and nitrogen pollution.
Our results show under carbon pricing a SOC enhancement of around 20 GtC mostly driven by SOC accumulation under perennial bioenergy grasses. Moderate climate change impacts on SOC sequester additional around 30 GtC.

Kristine Karstens, Benjamin Leon Bodirsky and Alexander Popp

Soil carbon modeling – in an integrated assessment perspective

The depletion of soil organic carbon (SOC) pools is causing high emissions that are so far not well-represented in global land-use and integrated assessment models. While SOC models often represent well the biochemical processes that lead to the accumulation and decay of SOC, the management decisions driving these biophysical processes is still little investigated.
Here we provide a global spatial explicit data set for crop residue and manure management on cropland and pastures. Combined with data on land-use (LUH2) and production (FAOSTAT) we use a simple model for SOC dynamics parametrized with the global dynamic vegetation model LPJmL to calculate OC budget on cropland, pasture and natural vegetation for the historical period from 1965 to 2010.
First results indicate that residue recycling rates have great impact on SOC stock development.
We additionally compare our preliminary results with estimations using the Tier 1 approach for change in carbon stocks in soils from the IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use (IPCC AFOLU).

Raimonds Kasparinskis, Olgerts Nikodemus and Aldis Karklinš

Soil mapping in Latvia and challenges in future

Soil survey in Latvia historically was carried out in three stages during 1959-1992. It includes soil mapping according to genetic approach (including different classifications due its development) and agricultural land evaluation in the large-scale (1:10 000). Soil spatial information includes soil types, subtypes and textural classes as well as descriptions of soil profiles. Forest soils and soils in other non-agricultural use have not yet been mapped on a scale of 1:10 000 in Latvia.
Georeferencing and digitalization of manual maps (including soil subtype, textural classes and land evaluation mapping units, as well as soil profile information) by integration of mapping units with orthophotomaps on a scale of 1:10 000, as well as harmonization of older soil units in the current Latvia Soil Classification System were done during 2014-2016. This database ensures possibilities for new data entry and for its continuous modernization and enlargement.
Cover of digitalized former agricultural soil maps in Latvia on scale 1:10 000 covers 38 787 km2 or 60% from area of Latvia.
Due to the lack of a unified (nationwide) soil information system in Latvia, the challenges in Latvia in future is related to systematization and harmonization of the existing information (soil and agrochemical survey materials and analytical data, etc.), for creation of a national soil database, as well as adaptation of the information to the European Union Standards.
Soil information is necessary for planning of agricultural and forestry activities, natural resources inventory, environmental management, greenhouse gas emissions, changes in soil processes etc.

Thomas Kätterer, Dries Roobroeck, Olof Andrén, Geoffrey Kimutai, Erik Karltun, Holger Kirchmann, Gert Nyberg, Bernard Vanlauwe, Cecilia Sundberg and Kristina Röing de Nowina

Biochar for long-term food security in smallholder farms in Kenya

Application of biochar (BC) has been shown to increase soil fertility and mitigate climate change through soil carbon sequestration. However, little is known about the long-term effects on crop yield responses. reported in the literature from shorter

term trials. To investigate the long-term effect of BC application on soil fertility, we started a series of field experiments in 2006 in Kenya. During 20 growing seasons (10 years) the positive effect on crop yield has been persistent after application of 10 kg BC m-2, both in combination with and without mineral fertilization. Effects of BC and mineral fertilizer were additive. Increases in water holding capacity, pH and nutrient availability were probably the main drivers for the observed yield responses. A series of new experiments were started in 2015 at nine sites based on BC amounts realistically produced in energy efficient gasifier stoves from local feedstocks available at smallholder farms that have limited alternative use. Crop yields consistently increased with BC rates and the yield response did not decline with time. Preliminary results from participatory field trials on 152 Kenyan smallholder farms seem to support our results from the controlled field experiments, i.e., consistent yield increases with application rates of BC. In conclusion, the yield enhancing effect of BC on smallholder Kenyan farms appears to be long-lasting, rather independent of feedstock and proportional to the amount of BC applied. Residues from crops and other biomass waste provide an opportunity for locally producing biochar that will help increasing food security in Kenya.

Sorcha Kelly, David Wall, Eric Paterson, Florence Abram and Fiona Brennan

The effect of farm nutrient management practices on mineralisable nitrogen and enzymatic activity in grassland soils

Nitrogen (N) is a limiting nutrient in terrestrial ecosystems and one of the key nutrients for plant growth. The main store of N for plant uptake is soil organic matter (SOM). The conversion of organic N in SOM to inorganic (plant-available) N is dependent on microbial activity. There is limited knowledge on how plants and microbes interact during this process to mobilise N; it is unknown which microbes mediate this process, what enzymatic activities are involved, the effect of community composition, and how the microbial community interacts with the physical and chemical properties of soil determining the rate of mineralisation. Predicting when and in what form N becomes available from SOM is essential for managing nutrient balances. Farm management affects plant-microbe interactions and this study focused on the effect of liming, chemical phosphorus (P) application and organic P application on the availability of N in a range of grassland soil types as part of a long-term pot trial. The impact of soil type and treatment on the activity of enzymes involved in the carbon, N, and P cycles were examined using a microplate fluorometric assay. Mineralisable N was assessed using a seven-day anaerobic incubation. Soil microbial biomass and total nutrient contents were also examined. Increased understanding of N mineralisation in agricultural soils has the potential to enhance farm management by linking nutrient cycling with plant growth. This has benefits agronomically, reducing reliance on expensive N fertilisers, and environmentally, as N use becomes more soil specific.

Riikka Keskinen, Helena Soinne, Mari Räty, Eila Turtola, Visa Nuutinen, Janne Kaseva and Tapio Salo

Characteristics of high and low productive mineral soils in Finland

Maintaining or enhancing the capacity of existing arable land to function optimally and support crop productivity and environmental quality is essential as the pressure for agricultural production continues to increase. We investigated the relations between soil properties and cereal yield to identify key soil indicators that need to be maintained for securing the productivity of boreal mineral agricultural soils. In total 45 field plots regarded being either high or low in productivity were explored in southwestern and central-eastern Finland. Fields that were classified highly productive, produced significantly higher average yields than those classified as low productive. Mean soil total carbon and nitrogen concentrations and number of roots per cm2 of soil were found to be higher in high than low productive soils. Mean soil bulk density, in contrast, was lower in high than low productive clay soils throughout the soil profile. The influence of different soil properties on yield depended on soil type. In clay soils, structure-related factors, namely bulk density, clay:carbon –ratio and root number, were significant in explaining the yield level. In coarser structured soils, the yield was mostly related to cereal species and fertilization.

Maarten Kik, Frits Claassen, Miranda Meuwissen, Bert Smit and Helmut Saatkamp

Optimization of gross margin and soil quality in Dutch arable and dairy farming – towards the economic value of soil quality

Soil quality is an important determinant for crop productivity. High land prices in the Netherlands force farmers to intensive cropping plans which endanger long-term soil quality through e.g. soil-borne diseases and soil compaction (Hamza and Anderson, 2005; Dogliotti et al. 2003). Technical solutions, e.g. less intensive cropping management, will reduce the short-term gross margins, but in return, increased soil quality will have a positive effect on long-term gross margin of crops. Therefore the key problem is economic: establishing long-term optimization of soil quality at minimized loss of short-term gross margins. The short-term loss in gross margins can be considered as an investment that represents the Economic Value of Soil Quality (EVsq).

This is the first integrated socio-economic study primarily focused on EVsq. It includes the development of a soil quality framework to capture the complex nature of soil quality. Six soil quality indicators where developed e.g. on soil structure. In a case study for a 141 ha arable farm in the Netherlands gross margin was optimized while threshold values of the soil quality indicators were set as constraints. Results showed a 69 k€ decrease in gross margin for a strategy aiming at preservation of soil quality compared to a strategy of maximizing short term profit. The study offered a proof of concept and insight in the trade-off BETWEEN short term profit vs. long-term soil quality. It was concluded that for further application scientific breakthroughs are needed in the fields of soil science, agronomy, resilience and cropping plan optimization.

Rasa Kimbirauskiene, Kestutis Romaneckas, Aida Adamaviciene and Sidona Buragiene

INTERACTION BETWEEN SOIL CHEMICAL, PHYSICAL AND BIOLOGICAL PROPERTIES IN SUSTAINABLE FABA BEAN CULTIVATION

Reduced soil tillage technologies become the most widespread worldwide, however the impact of tillage intensity on interaction between soil properties in faba bean cultivation in cold climate conditions is not established so much. For this reason, in 2016-2018, the investigations on the basis of a long-term stationary field experiment (since 1988) was carried out at the Experimental Station of the Aleksandras Stulginskis University (formally Vytautas Magnus University, 54°52' N, 23°49' E). Five different tillage systems were tested: 1) conventional (22–25 cm) ploughing with a mouldboard plough (control), 2) shallow (12–15 cm) ploughing with a mouldboard plough, 3) deep (22–25 cm) chiselling, 4) shallow (10–12 cm) disking and 5) no-tillage.
Investigations showed strong relations between disposition of pre-crop residues, soil chemical composition, soil structural stability and penetration resistance, soil enzymatic activity and earthworm's biomass. Cultivation of faba bean in reduced tillage conditions caused annual increase of nitrogen, potassium and magnesium proportion in the soil.

John Koestel and Steffen Schlüter

Quantification of the structure evolution in a garden soil over the course of two years

In this proof-of-concept, we demonstrate the potential of quantifying the structural evolution in an individual soil sample with the help of X-ray imaging. The soil sample was acquired in summer 2013 after a manual seedbed preparation and scanned with X-ray CT on six occasions during the following two years. After each imaging session, the soil sample was re-installed into the field. We focused on analyzing the evolution of soil morphologic measures that are thought to be fundamental to air and water flow in soil and quantified deformation of the soil matrix during the experiment. Our results illustrate the effects of several biotic and abiotic process on the evolution of soil structure. A well-connected inter-aggregate pore network after seedbed preparation was replaced by a sparser network of larger biopores. Macro-faunal burrowing activity generally increased morphological measures associated with larger air and hydraulic conductivity as well as a better aeration. Soil settling and the growth of a dandelion tap-root acted in the opposite direction. Other noteworthy observations that appear worth investigating in follow-up experiments were i.) the strong variation in the critical pore diameter, which could explain the commonly noted large temporal variability of saturated hydraulic conductivity, ii) the much greater extent of lateral compaction due to tap root growth than macro-faunal burrowing, and iii.) the short life-span of large biopores. We conclude that the approach presented here shows great potential for quantifying soil structural dynamics pertaining to individual structure-forming and degrading processes under field conditions.

Sándor Koós, Annamária Laborczi, Gábor Szatmári, Béla Pirkó, Péter Csathó, Anita Szabó, Nándor Fodor and László Pásztor

Process model based, joint spatial assessment of agricultural soils' filtering and provisioning function in Hungary

Spatially explicit assessment of soil functions and services is still a challenge. Digital process or crop models properly simulate the soil-plant-water environment conditioned by various factors based on actual, predicted or presumed data. Specific outputs of the modelled processes provide adequate information on certain soil functions. Although these models do not necessarily work in space, they can be built in as engines into spatial inference systems, thus soil property maps can be properly utilized in the spatial inference of soil functions and services.
Good Agricultural Practice describes the elements of the protection against nitrate pollution, according to which farmers are obliged to provide data on their nutrition supply each year in areas classified as nitrate sensitive. Agricultural soils in these areas provide

simultaneously filtering and provisioning functions which are heavily affected by anthropogenic factors.
We carried out the agri-environmental assessment of the nitrate database for the year 2016 using the 4M crop model with appropriate spatial soil information. By the crop production simulation model, the expected yields of the 5 main crops and the amount of nitrogen uptaken by crops were estimated at total of 1.3 million hectares. We estimated the nitrogen balance as well as the nitrate content that leaches under 90 cm using different fertilization scenarios. Our results verified that the nutrition of Hungarian agriculture is environmentally friendly, as the fertilizer doses are adapted to the needs of grown plants or in many cases it is under the requisite. In this context, the nutrient balances are negative.

Katja Kozjek, Dag Ahrén and Katarina Hedlund

Functional genes as a predictor of soil functions

Soil is a very diverse system that comprises microorganisms and their interactions giving numerous functional capabilities. Soil microorganisms carry out key ecosystem functions, including support of plant growth, cycling of carbon and other nutrients. Different agricultural practices and climate change influence the microbial communities, their interactions, functioning and lastly, a number of ecosystem services. To better understand microbial functions and the relation to community composition, we need to study how different factors affect them and how they contribute to ecosystem functioning. When accounting the complexity of the soil natural microbial communities, previously it has not been feasible to study functions by soil microorganisms at a high resolution, due to lack of methods. We suggest that analysis of functional genes is a good predictor of soil functions and a potential key to understand the functional diversity. Thus, advances in metagenomics, such as high-throughput sequencing coupled with recently developed technique “sequence capture”, allow us to study genes of interest i.e. functional genes. Determination and abundance of genes encoding for extracellular enzymes can unravel functional diversity of key microbial players in carbon cycling under different climatic conditions. Moreover, the frequency of expressed genes towards the total presence of genes involved in decomposition of organic material, enables us to determine the links between functional and genetic diversity. Finally, analysing functional genes increase our knowledge of how climate change and different land-use practices affect functional potential of soil microorganisms and how this is related to ecosystem processes.

Zsolt Kozma, Bence Decsi, Miklós Manninger, Norbert Móricz, András Makó and Brigitta Szabó

Evaluation of estimated soil hydraulic parameters at three forestry monitoring sites in Hungary

The process-based hydrological computations have remarkable and continuously increasing data requirement. Access to high-resolution soil hydraulic parameters is frequently the bottleneck of model development. Thus we investigate at soil profile scale (i) the reliability of a currently implemented 3D soil hydrologic database, and (ii) whether it improves the performance of hydrological calculations compared to some of the previously available data sets.
The analysis was carried out for three monitored plots located in the Lake Balaton watershed (Hungary). For all sites two years long meteorological and soil moisture time series were available, while the soil profiles were described via field surveys and laboratory analysis. We set up five-five model variants for the three soil profiles with Hydrus-1D. The variants differed only in their soil hydrologic parametrization: calibration-validation, field measurements, the EU-SoilHydroGrids database, and two sets of pedotransfer function estimates were applied during the model set up. We evaluated the model variants by the goodness-of-fit between the measured and simulated soil moisture time series and the simulated water budget components.
The results from all sites showed both similarities and some differences. After the calibrated versions, EU-SoilHydroGrids maps proved to be the best, while the simulation results based on the measured soil-hydrologic values were the weakest. Major differences occurred in the simulated water budgets. These differences are in line with the defining environmental conditions.
The research was supported by the Hungarian National Research, Development and Innovation Office under grants KH124765, K119475 and the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

Imants Kukuļs, Oļģerts Nikodemus, Raimonds Kasparinskis and Zane Žīgure

Organic Carbon and Total Nitrogen Stock in Humus Forms in Natural and Urban Forests Formed on Dry Mineral Soils in Latvia

Forest topsoil stores significant amount of C. However, forests in Europe are subjected to several factors – N deposition, eutrophication etc. – that may determine further status of SOC pool. To ensure proper management and stability of forest ecosystem it’s crucial to know factors that determines topsoil properties, humus form and SOC stock, and how topsoil properties changes under anthropogenic load. Soil samples from genetic O and A (EA) horizons were analyzed for SOC and NTOT content in the forests on

dry mineral soils in Latvia. 64 study sites were established, 44 of them in natural forests and 20 study sites in urban forest-park in Riga city. General linear model was used to clarify the relationships of spatial distribution of humus forms in the forests. Results show that mor humus with low SOC and NTOT stock are related to the oligotrophic Pinus sylvestris forests, and to the Arenosol soils. Luvisols on glacigenic, glaciolimnic sediments are the main factors that determines the occurrence of mull humus, where significant part of SOC, NTOT stock are accumulated in the A horizon. In the urban Pinus sylvestris forest in the Arenosols humus shifts to moder and mull forms. These changes lead to higher SOC stock in oligotrophic forests, while in mesotrophic sites SOC is significantly lower compared to the natural forests. Soil humus in the urban sites have higher NTOT stock. Overall, our results suggest that environmental pollution induced eutrophication may cause higher litter turnaround and mineralization, and lower SOC stock in topsoil.

Joep Langeveld, Lex Bouwman, Wim Joost van Hoek, Arthur Beusen, Lauriane Vilmin and Jack Middelburg

Including dissolved carbon leaching from soils in the global terrestrial carbon budget

Global terrestrial ecosystems are assumed to sequester ~ 2.1 Pg of atmospheric carbon annually, acting as a sink in the global carbon cycle. However, lateral transport of carbon via terrestrial-aquatic systems, such as leaching of dissolved carbon through soil pore water, is commonly not included the net ecosystem carbon balance (NECB). This could potentially cause an overestimation of the net ecosystem production, which would lead which to an inaccurate quantification of the terrestrial carbon sink. In this study we reassess the global terrestrial carbon balance, now including carbon fluxes through soil erosion, dissolved carbon export via surface runoff and dissolved carbon leaching from soils. We combine the coupled IMAGE-LPJmL model framework with a global model on the processing of dissolved carbon from soil solution. Our results show a global distribution of the relevance of lateral carbon transport via soils with regard to the net ecosystem carbon balance.

Gregory Lawrence, Sara Scanga and Robert Sabo

Recovery of soils from acidic deposition may exacerbate nitrogen export from forested watersheds

Effects of nitrogen (N) deposition on forest N cycling have been well studied, but effects of ambient decreases in N deposition remain unclear as soils recover from acidic deposition. To investigate, results of repeated soil sampling were linked with deposition, vegetation, and stream data, for 1999-2015 in North and South Buck Creek watersheds in the Adirondack region of NY, USA. Concentrations of NO3- in 63 other Adirondack streams were also compared between 2004/05 and 2014/15, and a possible relationship between soil buffering and stream NO3- was investigated with data from over 400 Adirondack streams that were sampled in either 2003/2005 or 2010/2011. No trends in N export were observed in either Buck watershed despite a 45% decrease in N deposition, although South Buck N export was 2 to 3 times higher than in North Buck, where 71% of N deposited from 2000-2015 was accounted for by accumulation in the upper soil profile. In marked contrast, the upper profile in South Buck showed a net loss of N. Increased decomposition appeared likely in South Buck as those soils adjusted to lower levels of acidic deposition whereas decomposition increases in North Buck were likely suppressed by high levels of natural organic acidity. Regional results showed no difference in stream NO3- concentrations between 2004 and 2014, and a negative correlation between NO3- concentration and watershed buffering capacity expressed as the ratio of Ca2+ to SO42-. Ongoing watershed N release appears to be linked to effects of decreased S deposition on soil C dynamics.

Artem Lebedev, Victoria Milichenkova and Tatiana Arkhangelskaya

Thermal diffusivity of sands as related to soil moisture: direct measurements and model estimates

The first part of this study presents the moisture dependence of soil thermal diffusivity for Lammelic Arenosols of the East European Plain. The undisturbed soil cores 7 cm in height and 5 cm in diameter were studied using the unsteady-state method. Thermal diffusivity of capillary moistened soils was from 6.2E-7 to 7.6E-7 m2s-1; that of air-dry soils was about 2E-7 m2s-1, and the peak values were almost 10E-7 m2s-1 for soils with organic carbon content less than 0.3%, and didn't exceed 8.5E-7 m2s-1 for soils with organic carbon content from 0.5 to 0.9%.
At the next step hierarchical pedotransfer functions (PTFs) to estimate soil thermal diffusivity (k) at different volumetric water contents (Q) from available soil data were developed from the data set of 17 samples. The ranges of sand, silt, and clay within the data set were 87–97, 0–8, and 1–6%; organic carbon content ranged from 0.1 to 0.9%.
The first-level PTF is a set of parameters of the average k(Q) curve for sands obtained by approximation of all observed data points

with a 4 parameter function: k(Q) = k0 + a*exp[–0.5*(ln(Q/Q0)/b)^2], where k0 is the thermal diffusivity of dry soil, a is the difference between the highest thermal diffusivity and the thermal diffusivity of dry soil, Q0 and b are shape parameters.
The PTFs of next levels are sets of regression equations to estimate the parameters k0, a, Q0, and b from available data on soil texture, bulk density, and organic carbon content.

Sandra Ledermueller.

Challenges and possible solutions for soil conserving application of organic fertilizer in spring with a special focus on economic aspects

With the amendment of the German Fertilizer Ordinance 2017/2018, the possibilities for the ap-plication of organic fertilizers in autumn were severely limited. As a result, the application of relevant quantities will be shifted to spring. These regulations are in favor of water and climate protection raise a new area of conflict concerning soil protection. The application of organic fertilizer in particular is associated with high mechanical loads and thus with the risk of soil compaction. In Lower Saxony's arable farming regions there is, according to the nutrient balance, the potential to take up manure from the of the most densely populated livestock areas in Lower Saxony's but farmers are willing to do so to a limited extend only. The presented poster will show results of a workshop, held with 19 stakeholders, discussing the challenges and possible solutions related to this topic. The obstacles identified and solutions proposed could be divided into the following areas: 1) evaluation of the soil condition, 2) natural site conditions, 3) organisational/logistical aspects, 4) economic aspects, 5) administrative/regulatory aspects, 6) technical aspects, 7) know-how/knowledge transfer. Since the economic aspects seem to play a crucial role, we conducted an economic modelling for a typical farm in this region. It can be shown on which farm structural parameters (crop size, cultivated area, soil type, crop rotation) the costs of soil-conserving technology for application of organic fertilizers depend and under which conditions it can even bring economic benefits.

Johan Leenaars, Fenny van Egmond, Rik van den Bosch, Maria Ruiperez Gonzalez, Limamoulaye Cissé, Ahamadou Bocar, Gerard Ros, Wim de Vries, Hans Kros, Marius Heinen, Dennis Walvoort, Pepijn van Oort and Kazuki Saito

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

Soil fertility, and particularly phosphorus, is recognised as a prime factor limiting agricultural productivity in sub-Saharan Africa. This soil functioning needs targeted management to deliver the services required by society. OCP Africa recently initiated a long term R&D collaboration with ISRIC World Soil Information to develop and test site-specific fertiliser formulations including micronutrients for important agro-ecosystems in Africa. Spatio-temporal nutrient gap analysis is at the basis of the approach 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. We developed an operational framework integrating soil-crop-response models with a geospatial database of fertiliser trial data (parameters) and relevant maps such as the Africa SoilGrids. This generic framework is made area-specific (locally accurate, precise and valid) by adding locally collected data. 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 spatial recommendation domains. The recommended fertilisers will be blended by OCP and validated onfarm relative to default recommendations.

Blandine Lemercier, Julien Amelin, Yosra Ellili, Sébastien Vincent, Didier Michot and Christian Walter

How similar and accurate are the existing digital soil organic carbon maps in Brittany (France)?

Digital soil mapping approaches (DSM) deliver new soil maps to address environmental, agronomical, land management issues at global and local scales. Several DSM initiatives were developed simultaneously leading to multiple soil maps, without post-hoc evaluation of the consistency and quality of the results. This phase seems however crucial to appreciate the suitability of digital soil maps for operational soil and environment management.
The aim of this work was to provide a comparative and critical analysis of available digital soil maps of soil organic carbon (SOC) produced for various spatial extents and resolutions. Soil maps extracted from (i) global SoilGrids maps at 250m resolution, (ii) European maps at 90m resolution produced by the European Soil Data Center (ESDAC), (iii) national maps at 90m resolution

(French contribution to GlobalSoilMap program, INRA) and (iv) regional maps at 50m resolution (Sols de Bretagne program) were compared in Brittany (France) covering an area of 27,200 km². These datasets were inter-compared. In addition, a collection of 135 soil profiles sampled in 2017 was used as independent validation dataset and a variographic analysis underlined spatial structures differentiation according to datasets. Despite similar large spatial structures, all datasets failed in predicting local SOC and were weakly correlated with each other. Spatial structureof SOC embedded in the maps appeared highly different with only the regional map representing local variability.

Dongchu Li, Huimin Zhang and Jing Huang

Change of soil organic matter in paddy soil and its response to fertilizer application from 1988-2017 in China

As an indicator of soil fertility and carbon pool, Soil organic matter (SOM) was the central of sustainable soil utilization. Variation of SOM at temporal and spatial level in 364 national paddy soil monitoring sites from 1988 to 2017 were studied. The SOM in average in paddy field was 31.2 g·kg-1 in China, and it has significant differences in different regions. The SOM concentration decreased significantly from 1988 to 2003 (0.12 g·kg-1·yr-1, $p < 0.05$), and increased extremely significantly from 2004 to 2017 (0.22 g·kg-1·yr-1, $p < 0.01$). There was a negative correlation between rice yield increase rate and SOM ($p < 0.05$), and was positively correlated between the soil contribution rate and SOM ($p < 0.05$). There was a good response relationship between SOM and annual fertilizer input in paddy fields. Rational fertilize should be recommended under the level of SOM. Measures such as reducing nitrogen, regulating phosphorus, supplementing potassium, returning straw and adding organic fertilizer should utilized to improving soil quality and productivity in paddy field.

Zhijie Li, Rüdiger Reichel and Nicolas Brüggemann

N2O emission as function of C amendment and soil N:P ratio: an incubation study

Balanced N management is important to obtain optimal crop yields and minimal N losses. Easily available C released by high carbon soil amendments (HCA) stimulates microbial growth if N and P are available in the soil. Therefore, HCA might be helpful to immobilize N in the soil after harvest and mitigate deleterious N losses. However, N:P imbalance might accelerate N remobilization. We hypothesized that mitigation of N loss via N2O is controlled by HCA type (H1), is depending on the soil N:P ratio (H2), and soil type (H3). We conducted an incubation experiment with three HCA types, i.e. wheat straw, sawdust, and leonardite (oxidized lignite), applied at a rate of 4.5 t C ha-1, and three soil types, i.e. nutrient-poor silty (PUS), nutrient-rich silty (RUS), and nutrient-rich sandy (RSS) soil. Three N:P ratios were established by applying 150 kg N ha-1 as calcium ammonium nitrate and 0, 406, and 725 kg P ha-1 as triple superphosphate. N2O emission was measured at day 1, 3, 7, 14, 21, 28, and 42. In contradiction to H1, no significant effect of the different HCA on N2O emission was observed. In line with H2, N2O emission was lower at medium P level in RUS. Moreover, consistent with H3, PUS emitted less N2O compared to the other soils, and showed no significant response to HCA and P amendments. We conclude that N losses can be efficiently mitigated if suitable HCA are applied to a particular soil with concomitant optimization of the available soil N:P ratio.

Chao Liang

Soil microbial carbon pump: Mechanism, application and appraisal

Soil carbon transformation and stabilization have received significant interest in recent years due to its potential importance in climate mitigation. Microorganisms are central to biogeochemical processes; however, there remains largely unknown how microbe-mediated processes lead to soil carbon sequestration. Here, I will present the recently-recognized notion on microbial necromass, a significant source for soil organic matter genesis. I will define two microbial channels, ex vivo modification and in vivo turnover, to jointly explain soil carbon dynamics and establish a conceptual framework, consisting of soil “microbial carbon pump”(sMCP), to describe how microbes act as an active player in soil carbon storage. I will inspire new hypothesis-driven topics that utilize sMCP as a conceptual guideline for advancing our relevant knowledge. I will discuss the biomarker approach for investigation of microbial necromass as well as its methodological limitations. Finally, I am eager to call the integration of sMCP at scales ranging from the rhizosphere, where plant-microbial interactions dominate, to the field and landscape scale, which may have implications for understanding the responses of ecosystem carbon processes to global environmental changes.

Yun Liang, Anika Lehmann, Max-Bernhard Ballhausen, Ludo Muller and Matthias C. Rillig

Experimental warming and microplastic fibers jointly influence soil aggregation by saprobic fungi

Microplastic pollution and global warming are two aspects of global change that potentially influence soil quality; yet little is known about their effects on soil aggregation, a key determinant of soil quality. Given the importance of fungi for soil aggregation, we investigated the impacts of rising temperature and microplastic fibers on aggregation by carrying out a soil incubation experiment in which we inoculated soil individually with specific strains of soil saprobic fungi (Chaetomium elatum, Truncatella angustata, Fusarium redolens, Mucor fragilis, and Fusarium sp.). Our treatments were temperature (ambient temperature of 25 or temperature increased by 3, abruptly versus gradually) and microplastic fibers (control and 0.4% w/ w). We evaluated the percentage of water stable aggregates (WSA) and hydrolysis of fluorescein diacetate (FDA). Microplastic fiber addition was the main factor influencing the WSA, decreasing the percentage of WSA except in soil incubated with M. fragilis, and mitigated the effects of temperature or even caused more pronounced decrease in WSA under elevated temperature. We also observed clear differences between temperature change patterns. Our study shows that the interactive effects of warming and microplastic fibers are important to consider when evaluating effects of global change on soil aggregation and potentially other soil processes.

Linda Lilburne, Andre Eger, Paul Mudge, Anne-Gaelle Ausseil, Bryan Stevenson, Alex Herzig and Mike Beare

The Land Resource Circle

Over the decades soil mapping has progressed from mapping of soil types to digital mapping of soil properties and now to a more interpretative mapping of soil functions. In other research work, the contribution of soil functions to ecosystem services has been established. Our extension to this work has been to develop a new framework called “The Land Resource Circle” (LRC) which aims to provide comprehensive land resource information to support decision-making on a wide range of issues relating to environmental outcomes as well as sustainable use of land. It is intended to be used for multiple purposes including spatial planning, land assessment, informing trade-offs between ecosystem services, and increasing awareness of soil related constraints to sustainable use of land. The core soil functions include storage/filtering/transformation of nutrients and water, carbon storage and cycling, biomass production, biodiversity support, physical platform, raw material and historical archive. In addition, the LRC acknowledges that soils differ in their capacity for resisting the various pressures due to land use and/or climate by including four functions characterising resistance to degradation of soil structure, fertility, biodiversity and erosion. It also recognises that the surrounding landscape also provides functionality that can impact on the delivery of ecosystem services from a land parcel and its suitability for different land uses. Four additional landscape functions describe the connectivity of the land to flood zones, water bodies, infrastructure and attenuation. This paper describes early progress with representation of the functions and how they interact with land use pressures.

Frauke Lindenstruth, Michael Kuhwald and Rainer Duttmann

Modeling soil moisture under different tillage practices

Soil moisture influences surface runoff, compaction risks, nitrification and agricultural yields. Although information about soil moisture is important, continuous observations are rarely available. To overcome this limitation, modeling of soil moisture is frequently used to fill this gap.
In this study, we validate the modeling of field internal variations of soil moisture with the MONICA model (Nendel et al. 2011) under different tillage practices for an agricultural site in Lower Saxony, Germany for the period of 2016-2018 for the top (20cm) and subsoil (40cm).
Using a soil moisture sensor network of 60 sensors (PlantCare), soil moisture was recorded half-hourly for two depths (20 and 40cm) for model parametrization and validation. Satisfactory results were obtained for the modeling of soil moisture at 40cm depth and the soil water dynamics are well represented (NSE=0.63, d=0.9). For modeling at 20cm depth, a higher difference between observation and modeling was found (NSE=-0.39, d=0.82). One reason may be the effects of tillage on topsoil properties which results in higher spatial heterogeneity of soil aggregation and soil structure. A sensitivity analysis (One-at-a-time method) showed that the modeled soil moisture depends strongly on the dry bulk density and the content of the organic matter. Performance indicators (NSE, RMSE, d) showed a higher quality of the modeling by using a matric potential of pF 2.2 instead of pF 1.8 for field capacity. Looking forward, variations of dry bulk density by different tillage practices have to be stronger considered while modeling soil moisture on field scale.

Kenneth Loades, Eric Anderson, Tim Daniell, David Roberts, Jim Wilson and Roy Neilson

SoilBio – A new tool for assessing soil physical condition from biological community structure

Measurement of soil quality is vital in the management and monitoring of soil to ensure environmental condition and soil sustainability. Due to the complexity of soils, multiple testing is often needed however the costs associated can be prohibitive. More specifically, measuring soil physical properties is typically time consuming and expensive however the value of such data is widely accepted. To date the cost of soil physical measurement is inhibitive within standardised commercial soil testing. Results will be presented on the use of biological communities to infer soil quality.
Intact soil cores were collected from across the UK and assessed for potential limitations to plant and root growth through both physical and chemical assessment. Samples were collected from different soil textural classes, under differing management regimes and crop types, to understand physical and chemical relationships with the biological communities living within the soil. Biological community structure, crop and soil chemistry has also been compared to recognised measures of soil physical quality including Dexter S, an indicator of soil structure, and penetrometer resistance, an indicator of mechanical impedance to root elongation, amongst others. Understanding linkages between soil biological communities and soil quality has the potential to significantly increase our understanding of spatial and temporal variations and in providing information on several physical and chemical parameters quickly and cost effectively.

Michael Löbmann, Rita Tonin, Camilla Wellstein and Stefan Zerbe

Assessment of the surface-mat effect and the influence of grassland vegetation on shallow slope stability in mountain habitats

Shallow erosion is a common form of erosion in many alpine grassland habitats that can lead to significant losses of grassland and fertile soil. Once the vegetation is removed, it can take decades before the damage is recovered. Over the last decades, an increase of shallow erosion was reported all over the Alps. One of the main reasons for this increase are changes in grassland management due to changes of economic and societal demands. Often remote grasslands are abandoned, while easy accessible grasslands are overused. Both abandonment and overuse lead to changes of vegetation and plant physiology, which often leads to a decreased resistance against shallow erosion.
The vegetation is the most important factor for shallow erosion control. The role of trees and their root systems for erosion control is well understood. Grassland, however, tends to have dense, yet shallow root systems with different slope stabilization dynamics as compared to trees. The dense network of roots, stems, rhizomes, and other clonal structures in and above the top soil layer creates a surface-mat effect that stabilizes the slope. Available methods for measurement of slope stability, such as shear-box tests, pullout tests and singular root tensile strength measurement provide valuable insights in how roots stabilize slopes. However, these methods do not allow measurement of the surface-mat effect. Here we present a new method that allows measurement of the surface-mat effect in the field. We compared the surface-mat effect in different mountain grassland types and discuss general and specific influences of vegetation.

Arnoud Maaswinkel and Ernst-August Nuppenau

Economic Assessment of the Long-Term Agronomic Benefits of the Cultivation of Winter Catch Crops

Over the last 20 years, the total acreage in Germany on which catch crops (CCs) have been cultivated has experienced a reasonably steady increase. Especially the area on which winter catch crops are being grown is apparently expanding. Yet, the underlying reasons for this positive trend are unclear. It can be supposed that the extent of CC-cultivation is considerably correlated with the provision of financial incentives as issued by the EU-common agricultural policy. In addition to those immediate financial benefits, however, it is assumed that farmers who include winter CCs in their crop rotations on a regular, long-term basis will also profit indirectly from maintained of improved soil tilth. For instance, CCs can contribute in the long run to reduce the risk of soil erosion and mitigate yield variances, and costs can be decreased e.g. by a reduced application of plant protection materials and synthetic fertilizers. It is aimed to set up a bioeconomic model which can be used to approximate in economic terms the value of winter CC cultivation over several years. Transition matrices should serve as input data for the model. Site-specific factors such as climate, soil conditions and agronomic aspects should be considered in order to recommend an optimized crop rotation. The outcomes should support stakeholders of arable farming in their decision making.

Daniel Magnone, Vahid Niasar, Alexander F Bouwman, Arthur Hw Beusen, Sjoerd Eatm van der Zee and Sheida Z Sattari

Tackling Sub-Saharan Africa's yield gap: maximising yield potential from phosphorus application

Sub-Saharan Africa (SSA) is predicted to have the greatest food security pressures of any continent during the 21st Century; 2050 cereal production must be triple that of 2007 levels. Achieving this will require both closing the yield-gap (the difference between potential and actual yields) on existing land through intensification and, expanding agricultural lands into new areas [1]. One key aspect of this is an estimated fivefold increase in phosphorus application in 2050 from the 2007 baseline. This is because compared to other continents SSA has had historically low application [2]. Yet, phosphorus efficiency in soils is not evenly distributed with soil chemistry dictating phosphorus availability to plants, thus application in one area will not increase yields at the same rate as another [3].
Phosphorus is an expensive and finite resource therefore targeted application is critical in meeting the challenge of SSA food security [4]. Developments in temporal soil phosphorus modelling have enabled the global mapping of phosphorus flows at a 0.5°× 0.5° scale [5] and more recently include soil-chemical aspects [6]. Using these developments we highlight the areas most likely to be responsive to phosphorus application in SSA and therefore more suitable for intensification and expansion.
1) van Ittersum et al., PNAS 113:14964–14969 (2016); 2) Sattari et al., PNAS 109:6348–53 (2012); 3) Shen et al., Plant Physiol. 156:997–1005 (2011); 4) Cordell et al., GCPS 27:323–343 (2015); 5) Mogollón et al., GEC 50:149-163 (2018); 6) Magnone et al., JAMES 11:327–337 (2019).

Noora Manninen, Kanerva Sanna, Lemola Riitta, Turtola Eila and Soinne Helena

Erosion-transported OC and DOC loads from agricultural soil

A global decline in agricultural topsoil organic carbon (OC) content has been discovered weakening soil structure and increasing the risk of erosion, with negative impacts on soil productivity and quality of surface waters. OC loss via discharge includes both dissolved organic carbon (DOC) and erosion-transported OC. Intensive tillage increases erosion, and thus, is likely to decrease soil OC content, while agricultural managements that increase topsoil OC content may increase the annual DOC loads. The aims of this research were to quantify discharge-transported OC loads from agricultural land in the Boreal zone, and to study the effects of soil managements on OC loss. We sampled both surface runoff and subsurface drainage waters for two years (2015-2017) on two clay soil sites with different agricultural management in Finland. The studied managements on cultivated plots were ploughing, no-tillage, and mineral and manure fertilization. In addition, we studied permanent grassland plots. Annual discharge-exported total OC loads from cultivated plots were 20–70 kg ha-1 and from permanent grassland 50–83 kg ha-1, and were substantially affected by annual precipitation. Total OC loads were higher from ploughed soil compared to no-tillage management only on the first year, but did not differ between mineral and manure fertilization. The share of DOC load was dominant in the total OC load (67–96% for cultivated and 90% for grassland plots) compared to erosion-transported OC load. Topsoil (0-5 cm) OC% correlated negatively with erosion-transported OC load and positively with DOC load, when precipitation was normal.

Gina Marano, Fabio Terribile, Giuliano Langella, Giorgio Matteucci, Alessio Collalti and Francesco Vuolo

The operational implementation of soil functions and sustainable forest management through LANDSUPPORT Web-Based Land Decision Support System

A paradigm shift for soil scientists and public institutions is nowadays crucial to overcome current disciplinary and policy fragmentation over soil issues. It has been proved that decision support systems can offer operational and integrated soil functions knowledge which can be used directly and freely by any end-user. The LANDSUPPORT H2020 project aims at building a web-based smart geoSpatial Decision Support System (S-DSS) which shall provide a powerful set of tools devoted to (i) support sustainable agriculture and forestry, (ii) evaluate trade-off between land uses and (iii) contribute to the implementation, impact and delivery of about 20 European land policies and selected 2030 UN SDGs. One specific tool is under development to support sustainable forestry as required by EU Forestry Strategy by adopting best forest practices with a strong focus on soil management. LANDSUPPORT will use EO data and simulation modelling to: a) map forest productivity; b) identify forest best practices to increase climate change resilience; c) assess the impact of selected forest best practices indicators and criteria with modelling applications; d) quantify forest and soil- related ecosystem services. The above-mentioned objectives will be achieved through the integration of existing databases and the development of high-performance modelling chains. The forestry tool will work at different geographic scales including: 1) European scale; 2) Member States scale (Austria, Italy, Hungary); 3) Regional scale (Campania Region, Zala County and Marchfeld); 4) local scale (Telesina Valley, Keszthely Mountain). LANDSUPPORT aims so far at supporting and fostering decision-making process in forest planning and land management.

Raphael Marichal, Victor Baron, Alexis Thoumazeau, Marie-Sophie Renevier, Jean-Pierre Caliman and Alain Brauman

Effects of compost application on soil macrofauna and soil functions in oil palm plantation – Biofunctool® approach

Oil palm produces about 38.7% of all vegetable oil (palm oil and palm kernel oil, 2016) and its cultivation area reach in 18.7 million ha worldwide (mature plantations) in 2017. While palm oil demand will increase in the future, leading an increase of global production, an adapted fertilization is needed to increase yield while preserving soil multifunctionality. Organic fertilization, by Empty fruit bunches (EFB) or compost is an alternative to mineral fertilization. The effect of EFB application on soil quality has been investigated, however the effect of compost application on soil functions and soil macrofauna in oil palm plantations is poorly known. To investigate the effect of compost application, we compared soil functions and soil macrofauna of two treatments of an agronomical trial (compost application / mineral fertilization), taking into account the zone around the palm tree (harvesting path, circle and windrow). Soil functions were assessed using the Biofunctool® framework, which is a novel set of in-field, low tech and time-effective indicators to assess main soil functions: soil carbon transformation, nutrient cycling and structure maintenance. Effect of the zone around the palm tree on soil functions and macrofauna, was largest than the effect of the treatment and the compost application slightly improved carbon transformation functions in the circle zone. Soil functions and macrofauna functional groups data showed similar co-structures indicating the link between soil functions and fauna. We highlighted the importance of spatial heterogeneity and discussed the effect of organic matter.

Maria Aparecida Marques and Angel Ramon Sanchez Delgado

Analysis of the Brazilian public policies for Agroforestry management in sensitive and risk areas

In Brazil, studies indicate that the intense use of agriculture and livestock farming in sensitive regions are losing their productive capacity in a few years. With this, many farmers end up abandoning that land, due to high expenses to proceed for the recovery, so they move to new areas, bringing more impacts to the environment. These measures of exploring new areas are specified in the Brazilian environmental legislation. The abandonment land stays as fallow. Research indicates that the natural restore of an environmental area, by itself, takes more than 200 years which goes in the opposite direction with mankind needs, since there is an exponential growth of the population and consequently bigger demand for food. The application of Agroforestry Systems can be a protagonist in abandoned areas for the regenerative acceleration, given the evidence that in 40 years there is a reestablishment of unproductive areas. The study aim is the analysis of the current public policies of the environment in sensitive and risk areas, their application and effectiveness in the Brazilian territory. It also sought the application of public policies for the use of Agroforestry Systems, identified the points that are flawed in public policies and pointed out measures that can bring a transformation in the current context that is: increase production with better conservation of natural resources with more quality of life and of food to the producer and population.

Laura B. Martínez García, Lijbert Brussaard and Gerlinde B. De Deyn

Resilience of soil fungal communities to rainfall scenarios

Implementation of management practices that enhance ecosystem resilience to severe drought, or intense rain is a priority to sustain global food production. Soil fungi are main drivers of soil nutrient cycling and water regulation, however, the extent to which soil fungal communities are affected by weather extremes is still uncertain. We aim to study the resilience of the soil fungal communities to different rainfall scenarios. We hypothesized that the resilience of fungal communities will be higher in eco-intensive managed systems compared to conventional management.
We set up a common garden mesocosm experiment using intact soil cores from different agricultural ecosystems (eco-intensive and conventional) across Europe (Switzerland, Portugal, France). The mesocosms were subjected to different rain regimes (control, drought, excessive rain, and drought followed by excessive rain). The rainfall differentiation lasted for 263 days, followed by a recovery period of 89 days to let the mesocosms go back to normal soil moisture. After this period soil samples were collected to characterize the soil fungal community and the arbuscular mycorrhizal fungal (AMF) community using high throughput sequencing. We present preliminary results on the resilience of the soil fungal community and the AMF community to the rainfall events by comparing their community structure and diversity. We also show the prevalence of functional guilds categorized as pathogens, saprotrophs and mutualistic symbionts after the rainfall scenarios.
Our results will shed light on fungal response to climate change and will be useful for policy makers to support sustainable agricultural practices that enhance natural soil biota.

Laura B. Martínez Garcia, Anna Galonska, Henk Martens, Juliette Rembert and Rachel Creamer

HARVEST; Healthy Apples Research: Valuing Environmental Sustainability of Topsoil

The HORIZON 2020 societal challenges highlight the need to innovate on agricultural practices that increase agroecosystem resilience and foster efficient use of available water and nutrients. This is particularly relevant for baby food production systems since they need to comply with stringent European regulations that limit the amount of chemical residue levels in baby food. The HARVEST project will develop a novel soil health strategy to decrease the use of chemicals in DANONE's fruit production systems for baby food that simultaneously enhance soil-borne disease suppressiveness and nutrient/water use efficiency while maintaining fruit productivity.
The HARVEST project is comparing integrated pest management with organic management in apple orchards, and it is testing biodiversity practices consisting of growing plant species mixtures and applying different weeding techniques in the inter-row space between apple trees. HARVEST will test the hypothesis that growing inter-row plant species, mulching, and mechanical weeding have positive effects on the sustainability of apple orchard top-soils, as measured by soil disease suppressiveness, soil fertility and water regulation.
The HARVEST project aims to: i) identify the biodiversity practices that enhance below and above- ground apple orchard properties towards a more resilient and nutrient/water use efficiency orchard, ii) develop a soil health strategy to be applied on fruit production systems, iii) enhance partners and societal awareness about DANONEs sustainability programme and its positive action at decreasing chemical use, enhancing food quality, protecting ecosystems and improving human health.

Vitor Martins, Tatiana Michlovská, Carlos Rodrigues and Polyanna Trindade

Soil chemical characteristics limiting soybean yield under foliar nutrition

This work aimed to evaluate the limitations on soybean yield caused by chemical characteristics in the soil and the effect of complementary nutrition via leaf spray. The work was carried out in the states of Parana and Mato Grosso do Sul in Brazil. The soil was sampled at depths of 0 - 0.2 and 0.2 - 0.4 m in fifteen different areas. The 60 hectares plots were divided into two, one with foliar fertilization and another without it. The foliar fertilization was carried out based on the interpretation of soil chemical analysis and abiotic stress, drought and cold stress. According to the interpretation of the analyses, the main soil factors that could lead to limitation in soybean yield were high exchangeable aluminium saturation in the sites at 0.2 – 0.4 m depth and the low availability of magnesium and boron at 0 - 0.2 m. However, there was no significant correlation between the soybean yield with the chemical characteristics of the soil, at both depths. Foliar fertilization provided a significant increase in soybean yield in 83% of the areas, which had been through drought stress and temperatures below 18oC. In the other areas where no abiotic stress occurred, there was no effect of foliar fertilization supplementation. With the results it is possible to conclude that the chemical characteristics of the soil were not limiting to the soybean yield. In contrast, abiotic stress conditions were limiting, and foliar fertilization reduced its negative effects.

Kirstin Marx and Frank Glante

Recent developments of assessing soil functions in Germany

Soil functions in federal land management and policy application – a hot topic of debate about 10 years ago – has recently regained attention, with German Federal states expressing the need to renew efforts on soil functions. Assessment schemes on soil functions have been developed in some of the Federal states. Led by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, a new working group on soil functions has recently been established. The authors will give an overview on these recent developments in Germany and will outline how soil functions will be assessed and developed in the coming years.

Chris McCloskey, Guy Kirk, Wilfred Otten and Eric Paterson

Partitioning plant and soil carbon fluxes under field conditions

A major obstacle to understanding plant-soil-microbe interactions governing soil carbon (C) turnover is a lack of field-condition measurement systems. Measured soil-atmosphere C fluxes necessarily conflate the flux from the plant and recent plant inputs with that from existing soil C, preventing us disentangling the true responses of soil C turnover to driving variables. We have developed a field laboratory with which to do this, giving near-continuous measurements of plant and soil C fluxes and their drivers.

The laboratory contains 24 0.8-m diameter, 1-m deep lysimeters holding naturally-structured soil monoliths from two contrasting C3 soils sown with a C4 grass (Bouteloua dactyloides). Gas flux chambers atop the monoliths are closed sequentially via an automated system and air is passed through a sampling loop for CO2 concentration and C isotope analysis. The very different C isotope signatures of C4 plant respiration and C3 SOM decomposition allow us to partition net C flux between plant and soil.
We have measured and partitioned C fluxes over 1.5 growing seasons. Our results show clear, repeated patterns in both plant and soil C fluxes at diurnal timescales, with plant respiration varying by a factor of four during the day, and SOM decomposition by a factor of two. Broader seasonal variation in both fluxes is evident. Coupling soil flux data with depth-resolved soil temperature and moisture measurements, we have shown temperature to be the major driver of plant respiration, and found seasonal variation in the relative importance of soil moisture and temperature as drivers of SOM decomposition.

Ali Mehmandoostkotlar, Quirijn de Jong van Lier and Bo V Iversen

Field scale numerical modelling of nitrogen transport for better design of slow release fertilizer

Optimal root uptake of nitrogen fertilizer is more probable when controlled release fertilizers are applied to the farms. However, firstly manufacturing is expensive and secondly, nitrogen availability for plant uptake depends on soil type, weather conditions and farm management. Due to the complexity of the soil-plant-atmosphere system, numerical modelling of nitrogen transport under many different conditions yield valuable results enlightening the path of fertilizer synthesis for producers. Therefore, the fate of slow-release fertilizer with the linear and exponential release behaviour applying in three soil types under two cultivars (grass and maize) and twenty years of weather conditions for the tropical area (Brazil) was studied. Longer temporal availability of nitrogen once using slow release fertilizer reduced nitrogen drainage because of higher nitrogen uptake by plants resulted in crop yield increase (maize). Depends on precipitation or irrigation, when exponential or linear release was assumed in simulations the nitrogen uptake was higher by 15 to 45% than control scenario (normal NPK fertilizer). Simplicity and low cost of numerical simulations could be an initial step before the design of real experiments using manufactured fertilizers.

Lauren Menandro, Luana Moraes, Clovis Borges, Mauricio Cherubin, Guilherme Castioni and João Carvalho

Exploring soil macrofauna as an indicator of sugarcane straw removal effects on soil quality

Crop residues play a fundamental role in sustaining macrofauna communities, which are linked to key soil functions. In Brazil, the potential use of sugarcane straw for bioenergy production encourages its removal from the fields. This bringing new concerns on the impacts of this management on soil quality. This study contemplates a more comprehensive approach on soil macrofauna responses to sugarcane straw removal linked to soil chemical and physical quality and was the first in Brazil to encompass field experiments under different edaphoclimatic conditions. Four experiments were conducted with four straw treatments: no-removal (NR), low removal (LR), high removal (HR), and total removal (TR). The macrofauna was sampled at a 0-0.30 m soil depth by the Tropical Soil Biology method. pH, P, bases sum, SOC, bulk density and macroporosity were also analyzed. Results revealed that the indiscriminate sugarcane straw removal affects soil quality induced by direct changes in macrofauna community and through synergies with soil chemical and physical attributes. TR impairs soil macrofauna by decreasing abundance and inhibiting (V index <0.0) most of taxa compared to NR, consequently showed lower richness and diversity, especially in clayey soils. The PCA analysis revealed that HR and TR are positively correlated to high soil bulk density while best soil fertility, macropores, and moisture are enhanced under NR and LR, associated with good bioindicators such as Oligochaeta, Geophilomorpha and Coleoptera. Thus, our findings indicated that this integrated approach should be adopted to better predict a more sustainable management of sugarcane straw removal for bioenergy production.

Lorenzo Menichetti, Göran Ågren, Pierre Barré, Fernando Moyano and Thomas Kätterer

Decay of decades-old SOC as an emergent first-order general constant: is more mechanistic also more realistic?

Soil organic carbon (SOC) decay has a huge impact on the global C budget and is at the center of attention in the scientific debate. Its kinetic has long been described with first-order functions in the “first generation” of models, seen as representing last century paradigm of SOC chemical recalcitrance. Recently such paradigm has been questioned and a general theory of SOC stabilization is seen more linked to soil ecosystem than SOC chemistry.
This led to a second wave of SOC model development calling for a more mechanistic approach, in particular considering explicitly second-order microbial processes. Although undoubtedly crucial for understanding mechanisms, these models might miss many

emergent properties and present scale related challenges. Our study focuses on asking first of all: is more mechanistic necessarily also more realistic? And do we need to abandon first-order kinetics to update our SOC stabilization paradigm?
We calibrated and tested within a Bayesian framework the Q model, based on first-order kinetics, over five long-term bare fallows in Europe, with differing climates, histories and SOC qualities. We found surprisingly similar parameters describing SOC decay between sites.
The decay of SOC appears therefore a constant process also in very diverse soils, possibly governed by the same thermodynamic limitations, and can be abstracted by constant general parameters. As a last personal provocative statement, I argue that this approach can be more holistic than more mechanistic models, since it captures the complexity of SOC decay as an emergent general property.

Gabriel Moinet, Matthias Moinet, John Hunt, Cornelia Rumpel, Abad Chabbi and Peter Millard

Out with chemical recalcitrance? Insights from the study of the temperature sensitivity of SOM decomposition

Describing the temperature sensitivity of soil organic matter (SOM) decomposition is critical for forecasting whether soils in a warming world will lose or gain carbon, and therefore accelerate or mitigate climate warming. The temperature sensitivity of SOM decomposition is usually described, based on Arrhenius kinetics, as directly proportional to the stability of SOM in laboratory conditions, where the chemical nature of SOM defines its stability. However, in the field, physical and chemical interactions with the soil matrix limit the availability of SOM to decomposition. These interactions, rather than SOM chemical nature, may regulate SOM stability. Here, we assessed the temperature sensitivity of SOM decomposition in situ by measuring soil CO2 efflux at a range of temperatures from root exclusion plots of increasing age and, therefore, with SOM of increasing stability. The temperature sensitivity decreased significantly with increasing SOM stability, to become lowest (Q10 < 1.2) in long-term root exclusion plots. Measurements of 13CO2 suggested that the positive temperature response of decomposition in short-term plots was largely due to the decomposition of readily available root litter. We argue that the physicochemical protection of SOM in the undisturbed soil matrix contributes significantly to defining its stability and that, consequently, the sensitivity of SOM decomposition to short-term changes in temperature may be small or null in the field. Our results provide empirical evidence to suggest that redefining pools of SOM with different turnover times according to their availability rather than chemical structure will improve model predictions of soil carbon-climate feedbacks.

Elly Morriën and Boris Jansen

Potential carbon stabilization by fungi in a human disturbance gradient of temperate grasslands

In a gradient from agricultural fields to natural grasslands on sandy soils, fungi play an important role in the soil food web. Fungi use most of the recent photosynthesized carbon from plants via the rhizosphere. Moreover, plants and fungi interact via secondary compounds in root exudates as plants from early successional stages tend to stimulate different fungal types than later successional plants. This feedback loop between plants and fungi and their higher trophic levels seem to drive secondary succession after land abandonment. However, also in agricultural fields fungi seem to be important in passing through large amounts of carbon. Although the carbon in fungi is mostly in de upper layer of the soil core, it can still be stabilized as fungi among other microbes, can stimulate soil aggregation. Soil aggregation can protect soil organic matter from further decay through physical protection. Extended hyphal networks from fungi to deeper parts of the soil core might play a role in stabilizing carbon in deeper soil layers. As a large part of the grasslands are managed, fungal-friendly management of grasslands might enhance carbon stabilization due to soil aggregate formation by glomalin production or encapsulating soil clumps by the mycelium. Next to the so far explored mycorrhizal fungi, we also explore whether the even more widely distributed saprotrophic fungi might play an important role in this process. We propose some qualitative and quantitative measurements to explore whether fungi can contribute to carbon mitigation in soils.

Mahmoud Morsy, Gamal Mostafa Eldawwy, Hassan Ali Hassan and Kather Jaron Mohamed

Possibilities of exploiting the waste material CKD for improving plant growth and nutrients uptake by corn plants grown in sandy soils of Egypt

The cement kiln dust (CKD) is one of the by-products of cement industry.The CKD is beneficial for improving the sandy soil properties. Pot experiment was carried out to study the effect of CKD on plant growth, water use and uptake of N ,P and K by the corn plants grown in sandy soil. The leached white CKD was applied to the sandy soil at six concentrations (0, 2 , 4 , 6 , 8 and 10 g kg-1). Application of CKD at 8 g kg-1 to the sandy soil increased the plant height, fresh and dry weights of the corn shoots, water

use efficiency and uptake of N,P and K by the plants. In general, application of the modified white CKD improves the sandy soil properties, decreases the lost water by leaching, rationalizes the irrigation water use, and enhances the corn growth and uptake of N, P and k nutrients. It could be recommended to use the leached white CKD at 8 g kg-1 as an amendment for the sandy soils under the conditions of EL-Minia Governorate , Egypt.

Mahmoud Morsy, Gamal Mostafa Eldawwy, Hassan Ali Hassan and Kather Jaron Mohamed

The Residual Effect of the Modified White CKD on Peas Plants Grown in Sandy Soil

The reuse of cement kiln dust (one of the by-products of cement industry) prevents or at least reduces the environmental pollution. The CKD is beneficial as a raw material, construction material, absorbent, and improving the sandy soil properties. Pot experiment was carried out in Soil Sci. Dept., Faculty of Agric., Minia Univ., El-Minia , Egypt to study the residual effect of fine CKD on the second crop (peas) grown in the same pots , that were previously treated with CKD at rates 0, 2, 4, 6, 8, and 10 g kg -1 and used for the first crop (corn). In this experiment , peas seeds were planted in each pot . In general, treating the sandy soil with the different application rates of fine CKD increased the vegetative growth parameters (plant height, fresh and dry weights), water use efficiency and uptake of N, P, and K by peas plants grown in the treated sandy soil, compared with the untreated control. The increase in almost the studied parameters, was proportional to the increase in the application rate of CKD up to 8 g kg-1. It could be concluded that it is possible using the white CKD at application rate of 8 g kg-1 as a soil amendment for sandy soils in Egypt . Also , it is possible to use CKD only once for its initial and residual effects on the successive crops grown in the newly reclaimed sandy soils in El-Minia Governorate, Egypt .

Powell Mponela, Grace Villamor and Lulseged Tamene

High resolution mapping of soil organic carbon and major nutrients within smallholder farms using randomForest and satellite imagery: towards improved soil fertility management.

Much as the declining trends of soil fertility is recognised as a major threat to food production for the rural smallholder farmers in malawi; the knowledge of the status and gaps at the management scale of a managed plot is limited. This study uses measured soil attributes collected from 219 locations within 10 x 10 km sentinel site in rural Malawi in 2013 and 2018 to predict soil conditions for plant growth. We used randomForest regression model with Sentinel2 imagery and Shuttle Radar Topography Mission (STRM) terrain attributes as predictors. Findings suggest that there are pronounced spatial variations with most soils deficient in soil organic carbon (SOC) and total nitrogen but have low to adequate phosphorus and potassium. The predicted mean±sd for SOC and TN of 1.06±0.27%, 0.07±0.01 % are lower than the critical levels of 2.0 and 0.15 whilst for P and K, 35.99±33.04 mg/kg and 132.87±23.15 mg/kg are within the low to high (>11 and >17) and deficient to moderate (<125 and >190), respectively. The C:N and C:P stoichiometry and structural stability index show that the limited SOC could potentially affect retention and availability of both N and P but also lowers soils physical stability. Hence, organic input sources should be integrated in the currently inorganic fertilizer dominated soil management to minimise soil degradation risk and ensure agricultural sustainability.

Vera Leatitia Mulder, Alexandre Wadoux, Jetse Stoorvogel and Gerard Heuvelink

Understanding soil-landscape functioning to support Land Degradation Neutrality

Knowledge about soil-landscape functioning is essential for global environmental studies, particularly to model the impact of climate change on natural resources, land degradation and soil carbon sequestration. Few studies addressed soil-landscape functioning as a controlling factor to support such global studies. This study focused on soils and its controls on land productivity within all ecoregions of the world. The findings were analysed within the frame of reaching global LDN by 2030. We developed a spatial model of the mean annual cycle of the NDVI (i.e. a proxy of land productivity) as a function of long-term average monthly climatic conditions and static soil and landscape variables, for each of the 846 ecoregions of the world. The spatial models for the ecoregions build on the rationale that LDN should be considered as a land system equilibrium.
From the fitted regression coefficients of the spatial models, we identified a set of baseline soil properties for each ecoregion and demonstrate how this information can be used to identify potential mitigation areas. Overall, soil depth and soil carbon were key soil properties supporting land productivity, while pH and CEC were the most limiting ones for land productivity in most ecoregions. Moreover, areas for mitigation measures in Africa were identified, taking into account soil-landscape functioning. Finally, this study

identified potential pathways for improving the information provided to governance bodies for policy making. Hereby, it may substantially improve our prospects of achieving LDN by 2030.

Ana Natalio, Simon Jeffery, Matthew Back, Andrew Richards and Mohammed Ahmed

Soil nematodes as soil bioindicators: analysis comparison and applicability in an arable system

Soil organisms are essential to the functioning of natural ecosystems. As such, interest in developing ways of monitoring soil health using bioindicators is increasing. Soil nematodes are a well-established group in soil food web studies aimed at determining the biological status of a soil.
Ecological indices using nematodes have been developed using morphological characteristics and life strategies. These indices have potential in their application in monitoring agricultural systems. However, doing so requires rare taxonomic expertise. Alternatively, identification of nematode trophic groups using morphological adaptations can be used to characterise nematodes to feeding guilds. It has been suggested that doing so may facilitate the use of nematodes as bioindicators of soil health without the expertise requirement necessary for identification to genus level, as required by ecological indices. This study investigates these two different approaches to see whether identifying to feeding group alone provides enough information to draw robust conclusions.
This study demonstrated that nematode trophic groups were not suitable when assessing changes in management practices. Inputs could be discriminated by trophic group analysis if analysis were done post-application. The results obtained from food web analysis, offered more detailed information applicable to an agricultural farming system and allowed more effective long-term monitoring. As such, while utilisation of trophic groups appears an attractive solution it only offered limited information and their application was linked to quantifying short term soil management practices and were not well suited to long term soil health monitoring.

Aukjen Nauta.

Tracks in the landscape – creating awareness by the public of the changes in a landscape

This project aims to investigate how knowledge acquired through scientific research can be used to create awareness and interest by a larger audience of the beauty and uniqueness of a landscape that changes naturally through time or is deeply impacted by human action.
The focus of this research is the Bourtangermoor in the north of the Netherlands, once one of the most extensive raised bogs areas in Northwest-Europe. Before large-scale peat extraction, it extended from the Hondsrug in the west (a NNW-SSE-trending push moraine) to the N-S running river Ems in Germany. Four centuries of peat digging left a completely changed landscape with little or no reference to its former glory.
The two research questions are (1) what methods and techniques are available to explain and visualize the changes in the Bourtangermoor through time, and (2) how can this be offered to the public outside the confines of a (open air) museum, making it easy to find, accessible and entertaining. Different fields of expertise will be used, such as environmental psychology (how do people react to landscapes), educational sciences and innovative computer technologies (e.g. virtual and augmented reality).
This research is part of the WUR Home Turf project focusing on the former raised bogs in the Netherlands in a multidisciplinary approach to link the development of the raised bogs to their use and perception by man in historic times.

Gregory Obiang Ndong, Isabelle Cousin and Olivier Therond

Using structural equation modeling to understand the relationships between ecosystem services and their underlying drivers in French agricultural landscapes

The analysis of the relationships (trade-offs or synergies) between ecosystem services (ES) and their underlying drivers represents one of the main issues in ES research and in the decision-making process for land management and planning. Numerous approaches are available including multivariate analyses (e.g. correlation, PCA, ANOVA), but these methods appear often limited to identify explicitly the drivers underlying the relationships between services.
In this work, we analysed and quantified the underlying drivers of the relationships between five ES: water quality regulation (nitrogen content), green and blue water provision, climate regulation via the soil organic carbon storage, and nitrogen supply to crop plants. We used the STICS crop model, to assess the ES level of 30580 production situations spread over the cropping zones of

whole French territory during 30 years.
Then we used structural equation modeling approach to quantify relationships between these ES according to i) climate, ii) soil properties, and iii) cropping systems (crop sequence and crop management). We demonstrated that this method is appropriate to deal with the complexity of the relationships between ES, due to its capacity to integrate both statistical principles and scientific knowledge of the functioning of the studied system.
The results of this work provide researchers and ecosystem managers with key information to design ecosystem management strategies promoting a bundle of ES.

Natalie Oram, Gerlinde B. De Deyn, Jan Willem van Groenigen, Hans Cornelissen, Paul Bodelier and Diego Abalos

Harnessing trait-based plant combinations to mitigate nitrous oxide emissions in a changing climate

In the last 100 years, humans have drastically altered the global nitrogen cycle. The invention of synthetic nitrogen fertilizer enables agriculture to feed 7.5 billion people, while contributing to climate change via emissions of the potent greenhouse gas nitrous oxide (N2O). Climate change leads to more extreme weather events, e.g. floods, which can exacerbate N2O emissions from agroecosystems. This highlights a pressing question: can we design resilient plant communities that mitigate N2O emissions in the face of a changing climate? We tackle this question in intensively managed grasslands, important agroecosystems with high nitrogen losses. We show that plant community flood resilience and N2O emissions depends on plant species composition, and plant traits related to their resource acquisition strategy. Slower-growing communities with conservative traits were more resilient and emitted less N2O in response to flooding than fast-growing plant communities with acquisitive traits. In ambient conditions, acquisitive plant communities that efficiently take up nitrogen have been shown in previous research to mitigate N2O emissions. In flooded conditions, the relationship between a plant's resource acquisition strategy and N2O emissions may shift as the importance of decomposing plant litter increases relative to nutrient uptake. Therefore, conservative species that have less decomposable litter could mitigate N2O emissions in flooded conditions. We conclude that inclusion of conservative grass species in intensively managed grasslands may be the key to safeguarding productivity while mitigating N2O emissions as the climate changes.

T.L. van Orsouw, V.L. Mulder, J.M. Schoorl, G.B.M. Heuvelink and G.J. van Os

Usability of Ground Penetrating Radar with Complementary Sensors for 3D Mapping of Bulk Density in an Agricultural Field with Variable Subsoil Compaction

Scientific understanding of the effect of subsoil compaction on soil functioning has greatly increased in the past few decades. However, the lack of spatially exhaustive data hinders the assessment of the threats that excessive compaction pose to the environment and food security. The data shortage is mainly caused by the time-consuming nature of field measurements. In this work we tackle this problem by using a non-invasive method to construct a 3D soil bulk density map of a 3 ha agricultural field in Flevoland, the Netherlands.
Recent studies indicate that ground-penetrating radar (GPR) can capture the spatial distribution of soil compaction. Data gathered in controlled experiments show a relation between bulk density and the dielectric properties of the soil. Using the attenuation and reflection of an electromagnetic signal, information can be obtained on layers with contrasting water content and/or porosity. Mixing formulas can be used to model the density of both single and multi-layer systems, provided quantitative information is available on soil water content and the permittivity.
In this study we used a combination of GPR, electromagnetic inductance (EMI) and gamma-ray spectrometry for 3D mapping of bulk density. These techniques were complementary due to the overlap of inferable soil properties. Abrupt transitions in signal reflection were extracted using statistical changepoint detection methods and linked to field observations of soil textural changes. Soil moisture was estimated using EMI and gamma-ray spectrometry, allowing for modelling of bulk density using mixing formulas. The resulting 3D model was compared to field measurements of bulk density.

Fausto Andrés Ortiz - Morea.

Conservation management for sugarcane production influences yield and soil properties in northwestern Colombian Amazon region.

Colombia is the 5th biggest producers of sugarcane in the world after Brazil, India, China, Pakistan and Mexico. In contrast with trends in other countries, almost half of the area used for sugarcane crop in Colombia aims to produce "panela", an unrefined non

centrifugal brown sugar used as sweetener. However, despite its importance role in the food security for Colombian population, the production system presents problems of sustainability due to traditional management of the crop. Here, we assessed the impact of different conservation management practices on sugarcane yield and soil quality. A long-term experiment was established in Caquetá state, located in northwestern Colombian Amazon, where two tillage systems: i) conventional tillage and ii) minimum tillage, as well
as, fertilization sources: i) inorganic fertilization and ii) organic amendment were tested. Crop yield and soil quality were evaluated one and a half years after planting. Physicochemical properties such as soil bulk density, porosity, penetration resistance, water infiltration, active and exchangeable acidity, phosphorus, calcium, magnesium, potassium and total organic carbon content were measured at soil samples collected at each treatment. Our results indicated that conservational management improve soil quality, with notorious changes on soil chemical attributes. Higher stalks productivity was obtained for treatment where combined conventional tillage and organic amendment.

Lilian O'Sullivan, Rogier Schulte, David Wall, Arwyn Jones, Jan Staes, Dirk Vrebos and Maria Victoria Ballester

Matching supply and demand for sustainable land management with recommendations for the proposed post-2020 CAP

Guaranteeing higher ambition on environment and climate action is a core priority in the proposed post-2020 EU CAP. The EU has granted member states increased subsidiarity to develop performance based strategic plans that meet EU goals, through better targeting of policies reflective of territorial and sectorial specificities. To support better targeting, this research explores governance opportunities for land based soil functions at three scales:
•Linking farm to national scale
•Linking national and European scale
•Linking EU to the global economy
A combination of methodological tools was used to assess the governance context at different scales. At local level, Pillar I cross-compliance/greening measures with Pillar II measures are key signals. Social network analysis of soil governance indicates that farm scale is the primary point of initiative. Decision support tools, advisory services and remuneration schemes are recommended for meeting higher ambitions. At national scale, an assessment of historic spending highlights opportunities to target funding for soil functions. Countries with lowest demands already designate the highest percentage of funding on Pillar 2. National and European scales are linked primarily through the administration of shared management such that all soil functions must be met at national scale. Further research should explore whether this is the optimal scale of management for all soil functions. At global scale, the EU exhibits high dependency on imported protein generating major global impacts environmentally. This work recommends greater attention at EU policy scale to take indirect land use change consequences into account and close nutrient cycles

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Wilfred Otten, Xavier Portell-Canal and Ruth Falconer

The role of habitat connectivity in fungal mediated processes: a biophysical model

Activity of the microorganisms involved in decomposition of soil organic C takes place within the complexity of soil. Soil structure determines how microorganisms and the physical environment they inhabit are closely coupled. Connectivity between habitats is often considered a driver for diversity both above and below ground. However, evidence of specific micro-environmental influences on microbial dynamics and activity is only now beginning to emerge.
The question of what constitutes a connected habitat in soil and how this affects soil processes may not be easy to address. For example, if we consider fungal mediated processes, habitat connectivity is determined by various characteristics, namely: (i) the total volume of the connected pore space; (ii) the connected air-filled pore volume, through which fungal spread predominantly occurs and gasses diffuse, (iii) the connected water phase volume, through which dissolved C diffuses, (iv) the distribution of particulate organic matter that fuels fungal growth, and (v) biological traits such as those enabling translocation through for example fungal hyphal networks. Exemplified for fungi, we present a mechanistic pore-scale model for the effect of habitat connectivity on microbial growth and CO2 evolution. Uniquely we consider fungal interactions at scales directly relevant to the organisms (micro-meters) in order to predict ecosystem services, such as the evolution of CO2, as an emergent property of these interactions. We demonstrate how various aspects of habitat connectivity differentially impact on two contrasting fungal species, representing R and

K strategists. The results allow us to understand how habitat connectivity will select for fungal traits.

Deepika Pandey.

Element mobilisation in weathering profiles as a process of soil formation

Weathering is the basic geochemical process which leads to the formation of soil. The formation soil constituents such as clay and other secondary minerals are a factor of bed rock composition and climate of the region. In the present study, weathering profiles of two different rock types were studied for distribution of 15 elements in 7 defined fractions. The weathering profiles of Amphibolites and Gneisses were carefully chosen in the humid and arid regions of tropical India. The elements were analyzed for their occurrence in different defined fractions in the successive samples of a weathering profile. The standard method of step by step sequential extraction (Leleyter and Probst, 1998) was applied to study element distribution in progressive weathering of the two rocks It was observed that elements chose to exist in different phases which was either defined by their elemental properties or chemical behaviour of the species in which they were transformed during weathering. V, Cr, Mn, Fe, Co, Ni, Cu, Zn were found to be associated with crystalline and amorphous Fe oxide fractions along with organic fraction. Na, K, Mg, Ca, Sr and Ba were significantly concentrated in exchangeable and organic fractions. Carbonate fraction incorporated Cu, Zn and Ni. However, the differences in the behaviour of elements due to difference in rock type or climate was found to be insignificant.

Daphne Parramon-Dhawan, Macarena L. Cárdenas, Ana Mijic, Wouter Buytaert, Joanna Clark, Nerea Ferrando Jorge and Steven Loiselle

Citizen Science delivering insights to urban soil health

Soil functions, such as carbon and nutrient retention and habitat, are strongly impacted by climate change and urbanisation. The rapid growth of urban areas requires a new understanding of its potential effects on soil function and health, as well as the identification of the most appropriate urban land management. Healthy soils, providing key functions related to flood attenuation and habitat, are fundamental to creating resilient cities. Here we present a multi-city citizen science project to determine optimal land management in urban parks, supporting soil functions and health, supporting SDG 11, 13, 15 and 3 of the Sustainable Development Goals.
We examine soil health around trees in urban parks in the outskirts of Paris, London and Birmingham with respect to three key land management alternatives (around street trees, leaf litter-managed and leaf litter-unmanaged parks). These aspects are then analysed in relation to the services and functions that these ecosystems provide: attenuating pluvial flooding events, carbon fixation and nutrient retention. Our unique approach consists of training and engaging citizen scientists to take diverse measurements of soil conditions simultaneously, which are fed into a geographic database for comparative analysis.
In this presentation, we will share our simple yet powerful approach of data collection using citizen science acquired information, including qualitative and quantitative soil characteristics for hydrology and carbon storage functions. The success of our data collection methodology strongly suggests that it can be extrapolated to create and support other soil function studies in urban environments around the world.

María Blanca Pascual de Vega, Miguel Ángel Sánchez-Monedero and María Luz Cayuela

Mechanisms involved in N2O formation in agricultural soils amended with biochars with contrasting properties

Over the last decades, the agricultural contribution to the global anthropogenic nitrous oxide (N2O) emissions has increased due to the increasing use of N fertilizers, and soil degradation among others (Kammann et al., 2017). The main processes leading to N2O emissions from soil are nitrification, denitrification and dissimilatory nitrate reduction (Baggs, 2011) and their relative contributions depend on soil characteristics and environmental conditions. Biochar is a carbon-rich product produced by heating biomass in the absence of oxygen (Lehmann, 2007). The application of biochar in combination with nitrogen (N) fertilizers has been found to reduce the total emissions of N2O (Cayuela et al., 2014). Nevertheless, due to the high complexity of the N-cycle in soil and the enormous variety of biochars than can be produced, the effectiveness of biochar mitigating N2O emissions depends on both soil and biochar characteristics. Understanding the mechanisms involved is crucial to implement effective mitigation strategies.
An experimental approach was set up to differentiate among the different sources of production of N2O in soil after adding eight contrasting biochars. Laboratory incubation experiments with mixtures of soil, biochar (2%) and labelled K15NO3 were carried out under denitrification conditions (90% WFPS and 25°C). The concentration of N2O and N2 originating from the added 15N-NO3- were measured to understand the changes in the mechanisms involved in N2O formation. The results will help us to determine the most relevant biochar properties leading to a shift in N2O formation pathways after biochar application.

Project: CTM2015-67200-R from the Spanish Ministry of Economy and Competitiveness.

László Pásztor, Annamária Laborczi, Gábor Szatmári, Sándor Koós, Zsófia Bakacsi, Nándor Fodor and Brigitta Szabó

Support of national mapping and assessment of ecosystem services by functional digital soil maps

As a member state of the EU, Hungary is also obliged to asses and map its most important ecosystem services. The Hungarian national ecosystem service assessment was started in 2016, a four-year project led by the Ministry of Agriculture and co-financed by the EU. After several steps of involvement (interviews, stakeholder analysis, participatory prioritizing workshops) thirteen ecosystem services were selected for detailed study. Majority of the thirteen prioritized ecosystem services is related to the state and functions of soils. Additionally, characterization of ecosystem condition as well as the elaboration of the high resolution ecosystem base map, which constitutes the fundament of the spatial assessment process, also demand the proper spatial representation of the soil mantle.
Our poster presents, how formerly elaborated together with intentionally targeted digital soil maps have been supporting the national mapping and assessment of ecosystem services in Hungary. Beyond the application of primary soil properties as indicators in the four level cascade model used as general framework of the assessment, we demonstrate the applicability of process based models in the mapping of provisioning and various regulating services. Example is given for the creation of a target-specific, bottom-up indicator by data-driven aggregation of soil hydro-physical maps.

Carsten Paul, Anja-Kristina Techen, James Scott Robinson and Katharina Helming

Rebound effects in agricultural land and soil management: review and analytical framework

In agriculture, more efficient use of natural resources is at the heart of sustainable intensification. However, technical improvements do not directly translate into resource savings because producers and consumers adapt their behaviour to such improvements, often resulting in a rebound effect, where part or all of the potential resource savings are offset.
Rebound effects are particularly complex in agricultural management, where multiple resources are used simultaneously. Nevertheless, their quantification is a prerequisite for generating realistic scenarios of global food provision and for advancing the debate on land sparing versus land sharing. Our paper reviews the current state of knowledge and develops a framework for a structured appraisal of rebound effects. As a test case, the framework is applied to emerging technologies and practices in agricultural soil management in Germany.
We found substantial evidence of rebound effects with regard to efficiency increases in land productivity and irrigation water use. Only few studies addressed rebound effects from efficiency increases in fertilizer use, pesticide application, agricultural energy use, and greenhouse gas emissions. The test case revealed the potentials for direct and indirect economic rebound effects of emerging technologies and practices, such as improved irrigation technologies, which increase water productivity and may thereby contribute to increases in irrigated areas and total water use. The results of our study indicate that rebound effects must be assessed to achieve realistic estimates of resource savings from efficiency improvements and to enable informed policy choices. The framework developed in this paper is the first to facilitate such assessments.

Laura Poggio, Luis de Sousa, Gerard B.M. Heuvelink, Bas Kempen, Niels H. Batjes, Johan G.B. Leenaars, Stephan Mantel, Zhanguo Bai, Ulan Turdukulov, Maria Ruiperez-Gonzalez, Eloi Ribeiro, David Rossiter and Rik van den Bosch

SoilGrids: consistent soil information to assess and map soil functions at global scale

Soil is key in the realisation of a number of UN Sustainable-Development-Goals providing a variety of goods and services. Soil information therefore is fundamental for a large range of global applications, including assessments of soil and land degradation, sustainable land management, and environmental conservation. In this work, we present an initial assessment of several soil functions derived from SoilGrids, a source of consistent soil information to support global modelling. The new version of SoilGrids used here uses a larger set of point data standardized and quality-assessed and an updated set of covariates. It provides global assessments of prediction uncertainty quantified with the 90% prediction interval and has an improved validation procedure providing more realistic metrics of map accuracy. We show preliminary results on how we addressed the modelling of soil functions at global scale using the new SoilGrids layers as input data. In particular, we followed three principles: 1) use of simplified models

to derive soil functions from basic soil properties; 2) use of models meaningful for the different pedo-climatic regions; and 3) providing an indication of low/high risk areas to support sustainable soil management planning. We include a preliminary assessment of the uncertainty of the mapped soil functions from the computed 90% prediction interval limits of the input data and highlight some challenges of assessing soil functions at global scale. The geo-computational framework developed for SoilGrids offers great flexibility in application of a diverse array of soil function models to generate soil information products tailored to specific user needs.

Mirjam Pulleman, Andrew Margenot, Rachel Creamer, Richard Dick, Rich Ferguson, Candiss Williams and Skye Wills

Soil mass and grinding strongly affect permanganate-oxidizable carbon (POXC) values

Active soil carbon (ASC) is measured during soil health assessments as a potential indicator of microbial food sources. The permanganate oxidizable carbon (POXC) method for determining ASC is popular for its rapidity and low cost. However, variation in methodological parameters may compromise comparability of POXC values amongst soils. Using a set of 42 soil samples from the USA with varying soil organic carbon (SOC), this study quantified the effects of varying sample mass and grind size on POXC values. Ten treatments consisting of combinations of five soil sample masses ranging from 0.25 to 5.00 g, and two grind sizes, < 0.18-mm and < 0.2-mm, were evaluated for POXC according to Weil et al. (2003). Depending on the treatment, 12-79% of the samples analysed yielded results falling outside the method quantitation limits. The highest number of valid results for the diverse samples analysed was found at a sample mass of 2.5 g (88 and 79% for the <2 mm and <0.18 mm grind, respectively). POXC values consistently increased with decreasing sample mass analysed and grind size, and the extent of these effects were sample-specific. The comparisons of POXC among soil samples varying in SOC suggest the need to perform POXC measurements on a SOC mass – not soil mass – basis, while controlling grind size. This study further indicates that the chemical and biological characteristics of the SOC fractions being oxidized require further investigation.

Laura Quijano, Giacomo Crucil and Kristof Van Oost

Remote sensing of soils from UAV platforms: comparing multispectral and laboratory hyperspectral soil reflectance data from Mediterranean cultivated soils

Multivariate regression techniques applied on spectral data and the recent development of UAV-capable spectral sensors provide new opportunities for the estimation of soil properties at unprecedented spatial and temporal scales. Laboratory based VIS-NIR spectroscopy is now established as a cost-effective and accurate method to traditional laboratory analysis. In this study, we tested whether spectral soil characteristics derived from UAV-platforms are compatible with spectral analysis of sieved samples in a laboratory under controlled conditions (i.e. using sieved soils, constant light conditions and high-end laboratory spectrometers). We compared the reflectance of cultivated Mediterranean soils from multispectral imagery on i) 2 mm sieved soils in outdoors conditions ii) undisturbed soils in field and iii) laboratory-based VIS/NIR spectroscopy. In July 2018, a UAV flight was performed on bare soils in the northeast of Spain with a MicaSense RedEdge-M camera. The images were processed to produce multispectral orthomosaics. For the laboratory spectral analysis, three replicates of topsoil samples (5 cm) were collected from 22 plots and their reflectance was measured with an ASD FieldSpec 3. Results showed that the reflectance data obtained from the camera on the ground/sieved soil samples was systematically higher in 3 of the 5 spectral channels (red +10%, rededge +11% , NIR +31%) and this can be attributed to radiometric calibration model of the images. In the flight campaign, the difference was sensibly higher (red +42%, rededge +48%, NIR +59%). This increased change in albedo can be attributed to the difference between non disturbed soils under field conditions and laboratory-treated soil.

Kálmán Rajkai, Tünde Takács, Bettina Kelemen, Anna Füzy, Ramóna Kovács and Imre Cseresnyés

Simultaneous detection of soil water use and plant root activity

Electrical capacitance measurement is increasingly applied for detecting root growth and activity directly in the soil without damaging the plant. The parallel root electrical capacitance (CR) and whole-plant daily transpiration (DT) were monitored during the plant ontogeny for eight, indeterminate soybean cultivars under pot conditions. DT, related to root water uptake, was calculated by measuring the evapotranspiration water loss on the weight basis. CR and DT increased from the seedling emergence to the beginning of flowering, and then became nearly constant. The temporal patterns of the measured parameters proved to be cultivar-specific. A direct relationship between the CR and DT was established. Terminal CR was strongly correlated with the root dry mass,

shoot dry mass and green leaf area for the cultivars. The results suggest that CR measurement could be an adequate method for in situ monitoring the root growth and water uptake activity, and for studying the disparities in root development and functional intensity among various plant cultivars. By supplementing the conventional investigations, the technique is potentially useful in agricultural research, including cultivar breeding for higher soil water use and stress tolerance. Great effort is being taken to adapt the present approach to field conditions.
The research was financed by NKFIH (K-115714) and a János Bolyai Research Scholarship from the Hungarian Academy of Sciences.

Dilani Chathurika Rathnayake Mudiyanselage, Randobage Saman Dharmakeerthi and Warshi Shamila Dandeniya

Effect on soil C mineralization and soil biological properties after addition of corn cob waste biochar into two contrasting soils in Sri Lanka

Low soil organic carbon (SOC) reserves is a major constraint that limits productivity in agricultural lands of Sri Lanka. Application of pyrogenic organic material (PyOM) into soil has been identified as a sustainable approach to increase the SOC. However, the quality of the produced PyOM mainly depends on the PyOM production conditions and feedstock composition. In order to study the C mineralization in PyOM amended Sri Lankan soils, a long term laboratory incubation study was conducted using an Alfisol and Ultisol unamended or amended (2% w/w) with two types of PyOM made from corn cob waste (PyOM-CC) using a top-lit updraft (TLUD) stove and a retort method. Soils and PyOMs were analyzed for their d13C signatures, total bacteria and fungi counts, permanganate oxidizable carbon (POX-C) and dehydrogenase activity at the end of the incubation period. FT-IR and SEM analyses of PyOM samples were also done. Application of PyOM significantly altered the dehydrogenase activity, fungi, and bacteria cell counts and POX-C content in the two soils. It was observed that a higher proportion of native SOC was mineralized from the PyOM-CC amended Ultisol (34.9%) than that from Alfisol (21.4%) and it was not affected by the pyrolysis method. Application of PyOM significantly increased total organic carbon (OC) remained in the soil at the end of 370 days incubation by 50% to 39% in Alfisol and Ultisol respectively, suggesting its potential to increase OC stocks in degraded Sri Lankan soils while contributing to climate change mitigation.
Acknowledgment: grant No. RG/2014/01/Ag.

Gidena Reda, Rachel Creamer, David Wall, Abbadi Reda, Eyasu Elias and Girmay Gebresamuel

Linking up diagnostic features to assessing soil nutrient dynamics: Case of Ethiopian soils

Ethiopia is one of the Sub-Saharan Africa countries with the highest rates of nutrient mining and severe nutrient depletion. Farmers in Ethiopia do not have wide access to soil testing services for nutrient management planning. Different soil maps have developed, with limited area coverage, mainly used for the development of irrigated agriculture. However, the soil type classification on these maps has not been harmonised or categorised into bands for nutrient management decision support for farmers, advisory or policy stakeholders. The objectives of this study we to apply the innovative soil diagnostic features approach as a method of classifying soils bases on their nutrient cycling and supply potential. We also wanted to provide a proof of concept for application of this soil diagnostic approach under Ethiopian settings. A total of 602 soil profiles were harmonised using the soil diagnostic approach based on available soil chemical properties information taken from published sources. Different diagnostic horizons were coded as 1 if present and dominant within the soil profile, 0.5 if present but not dominant or 0 if not present. The analysis revealed that vertic, argic and Nitic were dominant diagnostic horizons. Generally, highest value of organic carbon and TN were found at argic horizon of dominant properties while the CEC and exchangeable base were found at the vertic horizon at both scoring probabilities except Na. Thus, the soil diagnostic approach could be a useful tool for nutrient management planning and as a basis for sustainable land use management in Ethiopia.

Stephanie Rehschuh, Martin Fuchs, Javier Tejedor, Ruth-Kristina Magh, Heinz Rennenberg and Michael Dannenmann

Admixing fir to European beech forests improves the soil greenhouse gas balance

Admixing deep-rooting silver fir has been proposed as a measure to increase the resilience of beech forests towards intensified drying-wetting cycles under climate change. The goal of our study was to quantify the effect of fir admixture to beech forests on the soil-atmosphere-exchange of greenhouse gases (GHGs) (CO2, CH4 and N2O) and the soil organic carbon (SOC) stocks by comparing pure beech (BB) and mixed beech-fir (BF) stands in the Black Forest, Germany. To account for the impact of drying-wetting events, we simulated prolonged summer drought periods by rainout shelters, followed by irrigation. Admixture of fir to pure

beech stands reduced soil respiration, especially during autumn and winter. This resulted in increased SOC stocks down to 0.9 m depth by 9 t C ha-1 at BF. The mixed stand showed an insignificantly decreased sink strength for CH4 (-4.0 under BB and -3.6 kg C ha-1yr-1 under BF). N2O fluxes were very low and remained unchanged by fir admixture. The total GHG balance of forest conversion was strongly dominated by changes in SOC stocks. Extended summer droughts significantly decreased soil respiration in both stands and increased net CH4 uptake. Overall, this study highlights the positive effects of fir admixture to beech stands on SOC stocks and the total soil GHG balance. In view of the positive impact of increased SOC stocks on key soil functions such as water and nutrient retention, admixing fir to beech stands appears to be a suitable measure to mitigate climate change stresses on European beech stands.

Sabine Reinsch, David A Robinson, Per Ambus, Claus Beier, Timo Breure, Christiana A Dietzen, Marie F Arndal, Inger K Schmidt, Klaus S Larsen, Anders Michelsen, Fiona M Seaton and Bridget A Emmett

Soil microbes and carbon stocks respond to climate-driven changes in the physico-chemical soil matrix

Soil carbon stocks are vulnerable to climate change. Climate change modulates the soil physico-chemical environment with direct consequences for microbes and soil carbon stocks. Extreme droughts change the physical soil structure, and change the microbial carbon and nutrient supply. Warming affects the microbial activity and their substrate use.
Here we highlight results from two long-term manipulation change experiments and the effects of drought, warming, and elevated CO2 on soil carbon stocks. Precipitation (drought) and temperature (warming) were manipulated in an Atlantic heathland on seasonally waterlogged organo-mineral soil in Wales, and in a temperate heathland on dry sandy soil in Denmark. The latter included the increase of atmospheric CO2 concentration in a full factorial design with drought and warming.
The aboveground plant community showed little response to drought or warming at both sites. At the wetter organo-mineral site, drought and warming changed the soil physico-chemical environment for microbes over time. Drought permanently decreased the soil water content, increasing the activity of the soil microbial community, which resulted in soil carbon loss, specifically during winter.
At the drier Danish site, the microbial community composition was largely unaffected by drought or warming. However, the pathway of carbon through the microbial community changed in all climate manipulations. Soil carbon was only accumulated under elevated atmospheric CO2 concentration, and was unaffected by warming and drought.
We show that responses of the soil microbial community adopt to climate-driven changes in the physico-chemical soil matrix, affecting carbon stocks and maintaining overall ecosystem functionality.

Sara Remelli, Emma Petrella, Alessandro Chelli, Fulvio Celico, Cristina Menta and Fabio Gatti

Soil biodiversity characterization and its hydrodynamic connection in an active landslide complex

Landslides are common processes in the Northern Apennines (Italy). They depend on geological factors and their reactivation is often related to rainfall frequency and intensity. Resulting changes in soil structure affect edaphic fauna diversity which activity has, at the same time, different effects on soil structural stability and water-holding capacity. The aim of this study was to assess the soil fauna community of different areas involved in landslide process, connecting soil biodiversity with geo-hydrological information. The surface morphology of the study area, within the River Taro valley, was modelled and the hydraulic head fluctuations and the groundwater Electrical Conductivity were measured, in addition possible infiltration of surface water in the shallow landslide deposit was analysed. Soil investigation was carried out for seven sites: three grassland, a wheat cultivated field, an overgrown area, one site subjected to rotational slide and another to earth flow; pH and soil organic matter (SOM) were performed and soil fauna community composition was assessed. Results on the hydrogeological behaviour suggested higher permeability of the shallower aquifer system. Soil characterization showed similar pH in all sites considered and variations in SOM and fauna biodiversity and composition were observed. Lower values were found in earth flow area, followed by cultivated and rotational slide sites. Fauna composition suggested that earth flow and rotational slide are environments similar to cultivated areas, with low biodiversity and abundance, were the arthropods most susceptible to extreme conditions, such as drought, are absent.

Cyrine Rezgui, Isabelle Trinsoutrot-Gattin, Marie Benoit, Karine Laval and Wassila Riah-Anglet

Composition and functional shifts in microbial communities due to different crop residues qualities

Crop residues inputs may be a sustainable and cost-efficient management tool in agricultural practices. Crop residues have been

proposed as an alternative to maintain the soil organic matter levels; to increase soil fertility and to enhance agriculture productivity. The present work aimed to evaluate, under controlled conditions, the effect of the addition of three crop residues; pea, rapeseed, and wheat on soil microbial communities, enzyme activities and C and N mineralization. The incubation experiment was performed at 28°C for 90 days. The biochemical characterization of crop residues showed contrasting qualities in soluble, hemicellulose and lignin fractions. Crop residues inputs leads to an increase in C mineralization with a marked increase under soil with wheat residues. For N dynamic, a net N immobilization was observed in amended soils. Among crop residues, soil with wheat residues produced the highest N immobilization.
The addition of crop residues induce a decrease in the abundance of bacterial and fungal communities and in β-glucosidase and arylamidase enzyme activities after 90 days of experiment. Furthermore, the study of bacterial diversity by metagenomic sequencing showed a significant increase in α and δ-Proteobacteria phyla while a decrease was observed for Bactroidetes and Actinobacteria between amended and non-amended soils. In most cases, the less abundant phyla (Armatimonadetes, GN02, WPS-2, and OD1) increased in amended soils. Some order and genera were identified only under one crop residue, Rubricoccus and Inquilinus in soils with pea residues, Thermacetogenum and Glycomyces in soil with rapeseed residues and Rubrobacer in soil with wheat residues.

Goetz Richter, Nikolaos Vavlas and Giacomo Fontanelli

Using backscatter of Synthetic Aperture Radar (SAR) to characterize soil effects on crop productivity?

Soil maps are essential for productivity assessments using models; however, often these don't reflect field or farm scale variation. The new high frequency and high-resolution satellite borne data, especially SAR, could not only provide soil proxy-data but also help understanding their impact on crop development. Here, we provide in situ evidence for soil surface moisture (SSM) and roughness (SSR) as related to SAR-VV, during the 2016/17 and 2017/18 seasons. We measured volumetric SSM (TDR, 0-7 cm) and SSR (chain method) in spring- and autumn-sown cereals before crop emergence and after harvest, which were evaluated against SAR backscatter (VV). The impacts on crop development were visualized using the crop-polarization ratio (CR) taken from the VH/VV of the morning or evening passing of Sentinel-1 backscatter. Weather and management data were available to model and analyse soil surface effects. Results show that on average SAR-VV backscatter increases by 1-2 dB per 10 vol% increase of SSM. The relationship between backscatter and SSM was affected by cultivation and roughness and crop residues, little, however, by emerging vegetation. Uncertainty comes from time of satellite passing: Over similar ranges of SSM, average morning (descending) VV backscatter was 1 dB higher than observed with evening (ascending) passing. Average VV backscatter during the period of saturation was much higher on bare soil during spring, which agreed with simulated SSM. SSM(VV) seemed an important indicator possibly regulating germination, emergence and crop establishment, showing variation within fields due to changes in soil texture, elevation and drainage.

Carlos Rodrigues, Polyanna Trindade, Guilherme Goulart, Tatiana Michlovská, Gustavo Castoldi, Thomas Cavalcante, Rilner Alves and Virginia Damim

Chlorophyll and fluorescence portable devices to estimate nitrogen nutrition in soybean

The aim of this work was to evaluate if the indexes obtained with chlorophyll and fluorescence sensors correlate with the nitrogen nutritional state of soybean under different doses of nitrogen applied through leaf spray. The experiment was conducted in two different areas. Both of them received nitrogen fertilization through leaf spray at the R2 development stage in the following doses: 0, 4, 6, 8, 12, 16 e 20 L ha-1. In general, in both areas, the plants responded to N fertilization with an increase in grain yield. The stimulus in sinks, due to the nitrogen fertilization, led to an increase in photochemical efficiency, with lower the energy losses due to fluorescence. The incentive on the plants' sink led to a restructuring of the chloroplast, where in Area 1, with lower productivity, the genetic potential of the plant was able to restructure the photosynthetic process to respond to the demands of the plant without leading to the destruction of the system. In Area 2, with higher productivity, leaf nitrogen fertilization generated a very strong sink, which anticipated plant senescence, a result observed by the reduction of PSII efficiency with the increase of N contents in the tissue. In conclusion, the chlorophyll indexes obtained by the chlorophyllmeter did not correlate with the nitrogen nutritional state of the soybean plants and the fluorescence indexes that correlated, in both areas, with the metabolic variations in the plant caused by the nitrogen fertilization were Ss, ABS/RC, TRo/RC and ETo/RC.

Anna-Reetta Salonen, Karoliina Huusko, Helena Soinne and Jussi Heinonsalo

Potential of organic amendments to enhance soil aggregate formation and carbon storage

Organic soil amendments are utilized in agriculture as they are believed to improve the arability of soils. They may promote soil physical, chemical and biological quality through various mechanisms, for example by enhancing soil aggregate formation and increasing prevalence of arbuscular mycorrhizal fungi (AMF). Improved soil quality may lead to enhanced carbon sequestration by promoting plant growth and therefore reduce atmospheric CO2 concentrations. Soil aggregate stability is directly linked with the ability of soil to store carbon. Carbon turnover rate decreases when soil aggregation increases. AMF can contribute to soil aggregate formation and AMF abundance is shown to correlate positively with soil carbon content. In this study we aim to find out a) the ability of wood-derived soil amendments, e.g. pulp fines and biochars, to increase soil aggregate formation and stability b) whether these organic soil amendments reduce the risk of surface soil erosion, hence also reducing loss of SOC and c) whether there is an impact on the AMF abundance, effecting soil carbon sequestration. Soil and oat (Avena sativa) root samples were collected during growing season 2018 from a field experiment established in September 2016 in South-West Finland. Soil samples (55 % clay, 12 % silt and 33 % coarser soil fractions) were analyzed for aggregate size distribution, aggregate-associated organic carbon and wet aggregate stability (WSA %). Root samples were analyzed for AMF colonization rate. Preliminary results will be presented.

Taru Sandén, Aneta Trajanov, Heide Spiegel, Vladimir Kuzmanovski, Christian Bugge Henriksen and Marko Debeljak

Can multifunctionality of soils be enhanced by improved agricultural management practices?

Agricultural long-term field experiments (LTEs) act as living laboratories where effects of different management practices on soil functions including primary productivity, nutrient cycling, water regulation and purification, climate regulation and habitat for biodiversity can be evaluated over time. We know that preceding crop, crop of the current year and plant-available Mg were crucial attributes for primary productivity in Austrian tillage, compost and crop residue incorporation LTEs (Trajanov et al., 2018). These LTEs are ideal to further increase our understanding of multifunctionality of soils and in facilitating transfer of knowledge to farmers and farm advisors.
We investigated the influence of tillage, crop residue incorporation and compost amendments on the five soil functions in Austrian LTEs. The evaluation was carried out with the newly developed the Soil Navigator decision support system (Debeljak et al., 2019) that is based on the concept of Functional Land Management (Schulte et al., 2014; 2015). We wanted to use this decision support system as a platform and an educational instrument to demonstrate farmers how to optimize long-term primary productivity while simultaneously accounting for management effects on other important soil functions. Improved knowledge on the effects of other soil functions on primary productivity and vice versa can help farmers and farm advisors to develop decisions on how to manage their soils more sustainably and how to promote multifunctionality of their agricultural landscape. When adopting new management practices, farmers will, however, first consider a range of other factors including cost-effectiveness, usability and relevance, before changing their current management.

Teresa Sauras-Yera, Jacqueline Estevez, Jorge-Santiago Espinoza, Nuria Roca, Miquel Vidal and Anna Rigol

Using biochar and biochar-compost mixtures to improve the quality of an agricultural sandy soil.

Soil is an essential resource for sustainable agriculture and food production. Improving the quality of infertile soils has increasingly been recognized as a vital option for promising the food security. Furthermore, the sequestration of carbon in soil is essential for the enhancement of soil quality. Use of biochar and biochar-compost mixtures from different alternative organic sources have been proposed as an option for improving soil fertility and restoring degraded land. This research work evaluated the effect of applying mixtures of biochar plus compost in soil functioning and plant performance in soil-plant rizontrons in greenhouse conditions. Results obtained show that the addition of biochar and biochar-compost to a sandy soil increased soil water holding capacity, soil cation exchange capacity (CEC) and soil nutrient availability. Furthermore, adding biochar and biochar-compost increased soil organic carbon and stimulated soil microbial activity. The addition of biochar and biochar-compost increased plant growth and plant nutrient content. Our experiment highlight the potential of using biochar-compost mixtures as a management option for improving soil fertility and soil carbon sequestration in degraded agricultural soils.

Teresa Sauras-Yera, Ivette Sanchez, Lidia López-Santiago, Carles Tobella and Pere Pons

Impact of post-fire management practices in soil functioning

The project Anifog aims to provide answers, recommendations and new questions about the management of burned forests and the

conservation of its biodiversity and ecosystem functions. As part of this research project, we aim to assess the impact of three contrasted post-fire logging treatments on soil functioning in a 31-ha wildfire occurred in July 2016 in Blanes (Girona, NE Spain). Three experimental post-fire treatments have been tested (1) Non-intervention, experimental plots of burned forests that were not managed at all; (2) Sustainable logging, plots of burned forests managed leaving the branches on-site as piles of branches and (3) Conventional logging, plots of burned forests harvested as is usual in the region for industrial purposes such as salvage logging. Main results on soils functioning show that soil water infiltration in Non-intervention plots is 0,05 L m-2 s-1, conventional logging significantly decreases water infiltration while sustainable logging significantly favours soil water infiltration specially around the piles of branches. Principal component analyses show that visual symptoms of erosion are related to conventional logging and Non-intervention treatments while plant cover and presence of forest floor are related to Sustainable logging treatment. Our results suggest that the effect of the mechanical disturbance that occurs with logging operations could promote soil compaction, lower soil water infiltration and increase visual erosion symptoms. On the contrary, using light machinery and keeping the branches in the soil surface forming piles, as is done in Sustainable logging, can be an effective short term soil conservation practice for burned sandy soils.

Schierholz, van Orsouw, Mulder, Schoorl and Heuvelink

Evaluating different soil compaction measurement techniques: simplicity versus complexity

The problem of soil compaction in agricultural fields through trampling, drying and wetting processes, and tillage is well known in the Netherlands. It leads to a change in soil structure which impacts soil properties and processes. Consequently, crop yields will reduce causing financial losses to farmers. Therefore, there is a need for cost-effective soil compaction measurement techniques. However, soil compaction cannot be directly assessed by a specific measurement technique. Therefore, a reliable proxy is needed allowing to identify and quantify soil compaction. For this, a field experiment was set up involving 31 persons and four contemporary methods were tested for the estimation of in-situ soil bulk density 1) core sampling, 2) the ‘knife method’, 3) Penetrologger, 4) RhoC.
In this field experiment various sources of error were accounted for using basic statistical analysis, including the uncertainties in the measurement equipment, human error or small-scale variability. Results show that the Penetrologger was capable to identify the start of the compacted layer but was not capable to estimate the depth of the layer and was prone to ‘human’ error. Therefore, the Penetrologger was deemed the least suitable method. Considering the simplicity of the knife method it performed very well, even inexperienced people were able to identify the start of soil compaction. Yet it remains a qualitative and more uncertain method, due to its subjectivity of the human’s perception of changes in bulk density and soil strength. The RhoC was the best alternative method compared to the core samples to quantify bulk density.

Marcus Schmidt, Marife D. Corre, Leonie Göbel and Edzo Veldkamp

Integrating productivity and soil nutrient availability to evaluate the nutrient response efficiency of cropland monoculture versus agroforestry systems

Efficient use of nutrients is a key requisite for the sustainable intensification of agriculture in order to meet the increasing global crop demand while minimizing deleterious environmental impacts. Nutrient response efficiency (NRE), the ability of plants to convert available nutrients into biomass, adds an important ecological benchmark to assess the impact of agricultural systems on the environment. Agroforestry systems exhibit tree/crop interactions, potentially contributing to efficient nutrient cycling. However, such interactions do not automatically translate into nutrient-efficient agro-ecosystems. We compared changes in productivity, nutrient availability, and NRE, six to nine years after cropland monocultures were converted into alley-cropping systems with rows of short-rotation coppice. Despite high nutrient availabilities caused by fertilizer applications and NREs exceeding optimal values, the alley-cropping systems had overall higher NREs than monocultures. Furthermore, the NREs of the alley-cropping systems provided enticing indications that fertilizer inputs can be reduced without sacrificing productivity. We anticipate that optimizing fertilizer input will make alley-cropping a productive and profitable agro-ecosystem that contributes to the sustainable intensification of agriculture.

Laura van Schöll, Gerard Ros, Sander Janssen, Henk Janssen and Josien Kapma

SoilIndex: evaluation tool for soil quality

A tool that evaluates the soil quality can be an important management tool for farmers. Important features are that such a tool is easy to use, outcomes are directly understandable for farmers, and input tasks for the farmer are minimal. Most importantly, the tool

should not only provide insight in the good and weak properties of the soil but also specify management options.
The core of the tool developed for The Netherlands (SoilIndex/Dutch:BodemIndex) are algorithms that provide an integral and weighted assessment of soil quality, based soil characteristics and general site characteristics. The soil data are routine measurements as these are of good quality, relatively inexpensive, and available in an automated manner. In the Netherlands, site specific data (groundwater level and soil type) are available as open source maps. The algorithms used to evaluate the soil quality are based on scientific knowledge and insights and practical expertise from applied research.
The SoilIndex is developed as an online application and can run on a computer, smartphone or tablet. The various components (data, algorithms/ calculation rules, online SoilIndex) that make up the SoilIndex are worked out in a technical infrastructure. This includes a website with background information about the tool, an online environment for sharing developed algorithms and a user forum.
Farmers -as the end users- are involved in the development of the SoilIndex from the start. This is seen as a prerequisite for a successful development, implementation and adoption of the SoilIndex in Dutch agricultural practice in coming years.

Loekie Schreefel, Rogier Schulte, Hannah van Zanten, Imke de Boer and Pablo Modernel

REGENERATIVE AGRICULTURE – THE SOIL IS THE BASE

Can we develop an agricultural approach which encourages synergies between the different soil functions? The key challenge nowadays is to produce enough safe and nutritious food for a growing and wealthier population within the carrying capacity of the planet. An increasing body of literature concludes that regenerative farming might be a solution. But what is regenerative farming? Regenerative farming is one of several approaches towards a sustainable food system. Characterisation of the term is still challenging since a variety of actors (e.g. scientists, governmental agencies, sector organisations, industries and farmers) perceive this term differently and a clear definition is missing in the scientific literature. The aim of this study was, therefore, to define regenerative farming with respect to environmental, economic and socio-cultural aspects. We, therefore, performed a systematic literature review. We found that the term regenerative farming was first proposed in the 70s as an option for farmers to contribute to a circular agriculture system. It centralizes soil quality and is marked by tendencies towards closed nutrient loops, greater biodiversity, more perennials instead of annuals, greater reliance on internal rather than external resources and builds on the integration of plant and livestock farming in mixed farming systems. Our review will culminate in the definition of a common set of criteria that leads to the creation of indicators for farmers, industry and policy makers to assess regenerative farming, which will represent a first step towards fostering the transition towards regenerative food systems.

Lena Schulte-Uebbing and Wim de Vries

Necessary changes in nitrogen use efficiency in European agriculture to reconcile agricultural productivity with water quality objectives

Agricultural nitrogen (N) losses are one of the main contributors to water pollution in Europe. Using a spatially explicit N balance model, we assessed where agricultural N losses currently lead to an exceedance of critical N concentrations in groundwater and surface water. We then calculated the N inputs at which critical N concentrations are just not exceeded (‘critical’ N inputs). Meeting water quality objectives by reducing current N inputs to ‘critical’ N inputs, however, implies a reduction in yields. Even though Europe is one of the most food secure regions worldwide, yields will probably need to increase in the future in order to meet European and global demands without converting natural areas to cropland. This can be achieved by closing the gap between current yields and the biophysical “yield potential”, defined as the maximum yield for a given climate and soil, assuming optimal management.
We derived water-limited yield potentials (Yw) for 30 crops in Europe and assessed the required N inputs in order to achieve 80% of Yw at current N use efficiency (NUE). Wherever current or required N inputs exceeded critical inputs, crop production and water quality goals can only be achieved simultaneously through an increase in NUE. We calculated the increase in NUE that is needed avoid exceeding critical N concentrations in groundwater and surface waters while also obtaining current yields or 80% of the yield potential. We present the approach and resulting maps showing the spatial variation in the required NUE to sustainably intensify European agricultural production.

Hannah Schutte, Titia Mulder and Marjolein Lof

Improved ecosystem accounting by incorporating soils for quantifying ecosystem services

Wageningen University and Research and Statistics Netherlands (CBS) started to develop the first full ecosystem account for the

Netherlands in 2013, following the framework of the United Nations System of Environmental Economic Accounting - Experimental Ecosystem Accounting (SEEA EEA). This account presents indicators to measure the condition of ecosystems by state indicators (e.g. water) and indicators that put pressure on ecosystems (e.g. eutrophication). In the current account, little attention is paid to the state indicator 'soil'. However, soils do play an important role in the condition of various ecosystem services, and thereby potentially affect ecosystem service delivery, such as crop production and carbon sequestration. Knowledge on the effect of soils on ecosystem service delivery could be applied in policy to manage and possibly improve the ecosystem service delivery.
This research functions as a first step towards investigating the influence of soil properties on ecosystem services, in the Netherlands. The aim was to investigate the influence of soil properties (e.g. pH, soil texture and aluminium content from the Dutch Soil Information System) on the condition of 8 ecosystem services. Statistical analyses were done to determine possible significant relationships between soil properties and ecosystem services. The results proved that certain relationships between ecosystem services and soil properties exist (e.g. potato production and soil texture, net primary production and soil carbon) and that soil properties can negatively or positively influence the condition of these services. Mapping the derived relationships for ecosystem services allowed to refine the current maps of the ecosystem service conditions.

Muhammad Shahbaz, Thomas Kätterer, Barry Thornton and Gunnar Börjesson

The role of fungal vs. bacterial communities in SOM dynamics during cropping season of maize grown for 17 years on C3 soil

The relative contribution of different microbial groups to soil organic matter (SOM) turnover is the subject of debate, which also highlights implications for belowground C inputs (rhizodeposition) on SOM over cropping season. Several studies have been invoked to explain different microbial groups' role in SOM resources exploitation, few have been empirically tested/quantified in agricultural soils. We investigated microbial community dynamics and their dependence on SOM resources utilisation every 2nd week of maize cropping (June–Oct), grown for 17 years on C3 soil (including bare-fallow) under unfertilised, fertilized or farmyard manure (FYM) additions. Extracted soil phospholipid fatty acids (PLFAs) were analysed for the abundance of delta-13C and pooled into bacteria (gram-positive, gram-negative) and fungi (18:2w6,9) groups. Total PLFA amount corresponded to the SOM contents (highest in FYM), with an increase over cropping season in fertilised and FYM addition. Further, delta-13C of PLFAs significantly increased after August (peak growing period with frequent rain events) from –24.00 to –21.00‰ and –26.10 to –24.00‰, respectively. This clearly indicates a shift in microbial utilisation from old to young SOM sources, which was mainly linked to increased fungal biomass. In bacterial PLFAs, a seasonal trade-off was observed with an increase in gram-positive and decrease in gram-negative abundance till August and vice versa thereafter. The mean delta-13C values were highest in fungi (corresponding to fungal-biomass pattern) followed by gram-positive and gram-negative bacteria. Results clearly demonstrated that irrespective to fertilisation type, fungi were the main player in seasonal SOM dynamics and strongly influenced by soil moisture and cropping stage.

Rakiba Shultana, Radziah Othman, Ali Tan Kee Zuan and Mohd Rafii Yusop

Salt tolerant characters of Bacillus arryabhattai in reducing the salinity effect on paddy

The coastal saline region can bring under cultivation by exploring the mechanisms of salt tolerant plant growth promoting rhizobacteria (PGPR). In this study, a potential salt tolerant plant growth promoting rhizobacteria were identified which is isolated from coastal salt affected paddy field under the state of Kedah in Malaysia. This promising bacterial isolates were evaluated for the production of salt tolerant properties against different level of NaCl (0M, 0.5M, 1M, 1.5M and 2M) in laboratory condition. The results reveal although the survibility of this isolates decreases with the increase of salinity, still, it can endure the toxicity effect of salinity upto 2M of NaCl. This bacterial isolates uptakes highest amount of sodium (13.49g) at 1.5M of NaCl. This may because of its higher production of exopolysaccharides (22.79 g/L) and floc yield (20.67g/L) at 1.5M of sodium chloride. Following the 16s rRNA sequencing this isolates were identified as Bacillus aryabhattai . Subsequently, inoculation of this targeted bacteria to three different rice variety (BRRI dhan67, putra-1 and MR297) at early seedling growth exhibited its increased dry matter production by 36.76%, 48.15% and 49.02% respectively, total chlorophyll content by 13.29%, 20.82% and 49.02% respectively, relative water content by 21.74%, 37.29%, 50.61% respectively. Besides decreased the electrolyte leakage by 55.04%, 39.03% and 43.92% respectively, compared to the uninoculated control. Because of its promising preliminary results, this salt-tolerant rhizobacteria could be used to ameliorate the adverse salinity effect on rice cultivation in the coastal saline areas.

Adriana Marcela Silva Olaya.

SILVOPASTORAL SYSTEMS IMPROVE SOIL CHEMICAL QUALITY IN

NORTHWESTERN COLOMBIAN AMAZON

Livestock production is an important economy activity developed in Colombian Amazon. Traditionally this activity is performed through the establishment of large areas of pastures after slash-and-burn of native vegetation, without any fertilization or agricultural management of grasses. In that production system the yield of pastures decreases along time due to the no reposition of nutrients, acidification, compaction and lost of soil organic matter. To counteract those negative effects, silvopastoral systems where trees and grasses grown simultaneously are being promoted in Colombian Amazon region. Here, we evaluated the changes on soil chemical properties due to the adoption of traditional and silvopastoral systems for livestock production in two municipalities of Caquetá State, an important hotspot of deforestation of Amazon region located at Northwestern Colombian Amazon region. A chronosequence involving three study areas representing the typical land use change of the region was established in each municipality: i) native vegetation, ii) 30 years old pasture and iii) 10 years old silvopastoral systems. Soil samples were collected at each study area at three soil depths: 0 – 10 cm, 10-20 cm and 20- 30 cm and then soil macronutrients, micronutrients and soil acidity attributes were measured. Our results suggested that transition from pastures to silvopastoral systems promotes improvements on soil chemical quality by increasing soil nutrient levels and reducing the soil acidity. Although in pastures areas a decrease on exchangeable acidity was observed probably because the ash inputs during forest burning, the nutrients content are still lower than critical limits for plants development.

Kamilla Skaalsveen, Julie Ingram, Lucy Clarke and Julie Urquhart

ASSESSING THE IMPACT OF NO-TILL ON WATER RELATED SOIL FUNCTIONS AND THE ROLE OF FARMER NETWORKS IN KNOWLEDGE EXCHANGE AND IMPLEMENTATION: RESULTS FROM INTERDISCIPLINARY RESEARCH

No-till is a non-inversion farming practice that is becoming more widely used in farming and often considered to enhance soil functions. Studies have shown that no-till affects soil functions of water purification and water retention and can reduce erosion rates and inputs from agriculture to water bodies, however evidence from north western European countries is still limited. Alongside this gap in evidence about the physical impacts of no-till, knowledge about how farmers share knowledge about no-till, a knowledge intensive practice, and the role of farmer networks is still growing.
This paper presents results from interdisciplinary (PhD) research which is measuring the effect of no-till on water related soil functions in a UK case study and analysing the distribution of no-till knowledge through farmer networks. The field-scale monitoring compares two neighbouring farms (one using conventional ploughing and the other no-till) with similar soil and topographic characteristics to assess spatial and temporal changes in soil and water variables. The 2-year monitoring includes soil physical and chemical assessments and analysis of Phosphorous inputs to downstream waters. Farmers' networks are mapped using Social Network Analysis to reveal the nature and extent of their knowledge exchange about no-till. The soil and water data shows varying impact of no-till on water related soil functions with different soil types and climate, and the Social Network Analysis shows that farmers' networks expanded with the conversion to no-till. Their main influencers were normally more experienced no-till farmers and we question the role of external organisations in stimulating no-till adoption.

Helena Soinne, Riikka Keskinen, Mari Räty, Sanna Kanerva, Eila Turtola, Asko Simojoki, Visa Nuutinen and Tapio Salo

Soil organic matter and productivity of boreal clay soils

Soil organic matter plays a key role in soil functions by maintaining biological activity, increasing water holding capacity and enhancing formation of stable structure. Although the post-glacial soils of Northern Europe have a relatively high OM content, a continuous reduction of organic carbon content of cropland soil has been detected. In this study, we aimed to quantify beneficial effects of organic carbon on clay soil productivity in boreal conditions. Nitrogen (N) mineralization and soil respiration were measured in an incubation study with soil samples having varying clay and carbon (C%) contents. Yield measurements were conducted on field plots that had been divided into two plots: unfertilized plot and plot receiving fertilization. Surface soil samples were collected for aggregate stability measurements. Higher soil C% increased the aggregate stability whereas higher clay%/C % -ratio increased the colloid detachment. The net N mineralization correlated negatively with clay%/C% ratio. Similarly as the N mineralization rates, spike yields decreased as the soil clay%/C% ratio increased. In soils with lower nitrogen mineralization, the yield increase gained with one kg of fertilizer N varied considerably and was not, on average, higher than in soils with higher N mineralization rates. This suggests that in soils with high clay%/C% ratio, growth can also be limited by poor soil structure. Our results indicate that for clay soils in cool and humid climate, the higher the clay content the more organic C is needed to be able to produce higher yields in an environmentally sustainable way.

Heide Spiegel, Taru Sandén, Laura Essl and Francesco Vuolo

Sensor and satellite technologies as a basis to improve the performance of selected soil functions

Sustainable agriculture aims to improve important soil functions such as primary productivity, nutrient cycling, water purification and regulation, climate regulation and habitat for biodiversity (Schulte et al., 2014). Innovative tools and techniques are needed to e.g. increase plant productivity without negatively affecting nutrient cycling and water purification.
In the Horizon 2020 project FATIMA, we used different sensor and Sentinel-2 satellite data to examine test fields in the Austrian pilot area "Marchfeld", east of Vienna. In this intensively used agricultural region efficient, site-specific N fertilisation strategies are needed that take into account the actual spatial variability of soil properties and plant growth. To test and validate innovative methods, AGES conducted large-scale field trials with winter wheat and different mineral N-fertilizer stages 2016 and 2017. We investigated how to derive winter wheat yields from the leaf area index (LAI). The correlations between ground-based LAI and satellite-derived LAI showed a significant positive relationship of R2 = 0.83 (2016) and R2 = 0.93 (2017) for all measurements. Correlations between satellite-derived LAI and winter wheat yields were also significantly positive.
Sensor data and Sentinel-2 images allow the growth of plants and the yield of various field plots to be observed. As a further result of the FATIMA project, productivity maps based on Sentinel-2 images were created, which depict the conditions of the soil and thus enable site-specific N fertilisation. These new technologies may contribute to improve selected soil functions, such as productivity, nutrient cycling and water purification.

Jan Staes, Rogier Schulte, Lilian O'sullivan, Dirk Vrebos, Francesca Bampa and Arwyn Jones

Demands on land: mapping competing societal expectations for the functionality of agricultural soils in Europe

The Common Agricultural Policy (CAP) of the European Union (EU) has been highly successful in securing the supply of food from Europe's agricultural land. However, new expectations have emerged from society on the functions that agricultural land should deliver, including the increasing expectations that land should regulate and purify water, should sequester carbon to contribute to the mitigation of climate change, should provide a home for biodiversity and allow for the sustainable cycling of nutrients in animal and human waste streams.
Here, the variation in the societal demands for soil functions across EU Member States, based on an extensive review of the existing policy environment relating to sustainable and multifunctional land management is mapped. We show that the societal demands for primary production, water regulation and purification, carbon sequestration, biodiversity and nutrient cycling vary greatly between Member States, as determined by population and livestock densities, geo-environmental conditions and landscape configuration. Notably, the total societal demands for multifunctionality differs between Member States, with the lowest demands found in Member States that have designated the higher shares of EU CAP funding towards 'Pillar 2' expenditure, aimed at environmental protection and regional development.
We conclude that the devolution of planning to Strategic Plans at national level provides an opportunity for more effective and targeted incentivisation of sustainable land management, provided that these plans take account for variations in the societal demand for soil functions, as well as the capacity of contrasting soils to deliver on this multifunctionality.

Luc Steinbuch, Thomas Orton and Dick Brus

Model-based geostatistics from a Bayesian perspective: Investigating area-to-point kriging with small datasets

Area-to-point kriging (ATPK) is a geostatistical method for creating raster maps of high resolution using data of the variable of interest of much lower resolution. The dataset of areal means is often considerably smaller than the size of dataset conventionally dealt with in geostatistical analyses. In contemporary ATPK methods, uncertainty in the variogram parameters is not accounted for in the prediction; this issue can be overcome by applying ATPK in a Bayesian framework. Commonly in Bayesian statistics, posterior distributions of model parameters and posterior predictive distributions are approximated by Markov chain Monte Carlo sampling from the posterior, which can be computationally expensive. We therefore implemented a partly analytical solution. We used this implementation to (i) explore the impact of the prior distribution on predictions and prediction variances, (ii) investigate whether certain aspects of uncertainty can be disregarded, simplifying the necessary computations, and (iii) test the impact of various model misspecifications. We compared several approaches using simulated data, real-world point data that we aggregated ourselves, and a case study on aggregated crop yields in Burkina Faso. We found the prior distribution to have minimal impact on the disaggregated predictions.We found that in most cases with known short-range behaviour, an approach that disregarded uncertainty in the variogram range parameter gave a reasonable assessment of prediction uncertainty. However, we found some severe effects of model misspecification in terms of overly conservative or optimistic prediction uncertainties, highlighting the

importance of model choice or integration in ATPK.

Jonas Steinfeld and Rogier Schulte

Complex farming systems: more ecosystem services and higher labour requirements

Environmental changes require sustainable agriculture to provide a suite of functions such as primary productivity, carbon sequestration & climate regulation, habitat for biodiversity and nutrient cycling. There is evidence that more complex farming systems provide more of these functions. However, this might come at the cost of higher labour requirements. This hypothesis was tested in a case study in North-Eastern Brazil, involving a highly complex agroforestry farm, a mixed farm, a cattle ranch and a single crop monoculture farm. Proxy indicators were chosen to apply whole farm analysis and the Functional Land Management framework. Results of this assessment indicate high primary productivity for the agroforestry and monoculture systems, whereas carbon sequestration & climate regulation, habitat for biodiversity and nutrient cycling increased with higher complexity. Labour requirements were found to follow the same trend, supporting the hypothesis that complex farming systems yield more functions while also requiring more labour input. Additionally, a transition from a pasture to a complex agroforestry system was modelled. Results indicate an increase of all functions, but a drop in operating profit per hectare in the first year of transition. It is concluded that complex farming systems such as agroforestry could play an important role in adapting to environmental change and thus deserve more academic attention and policy incentives.

Elizabeth Stockdale and Abby Rose

Scorecards for soil health on-farm - promoting understanding and discussion of soil function

The management of soil health in agriculture needs to balance the production of a healthy and profitable crop with environmental protection and improvement. However, the spatial and temporal heterogeneity of soils, and the complexity of biological, physical and chemical interactions therein, makes predicting management effects on soil health challenging. Although the general principles underlying effects on soil health are well understood, they still need interpretation in a local context and the inclusion of site-specific details. As part of the UKRI-Sustainable Agriculture Research and Innovation Club funded knowledge exchange project, we have worked with stakeholders to develop and evaluate a scorecard-based approach that allows farmers to view and compare rotational soil health on a site-specific basis. Such comparisons can inform the investigation of the impacts of management practices and the selection of locally-adapted practices that represent the best soil husbandry to optimise soil function for society as a whole. Initial consultation with growers and the wider industry has confirmed the value of such local on-farm monitoring to support on-farm improvement and the opportunity to align such approaches with national scale co-ordinated monitoring of soils to provide the basis for sound policy making.

Cathelijne Stoof, Jasper Candel, Laszlo van der Wal and Gert Peek

Soil lacquer peel DIY: simply capturing beauty

Visualization can greatly benefit understanding of concepts and processes, which in soil science and geology can be done using real life snapshots of soils and sediments in lacquer peels and glue peels. While it may seem complicated, anyone can make a soil peel for use in classrooms, public places, homes and offices for teaching, outreach, decoration and awareness. Technological development has considerably simplified the making of soil peels, but this methodological innovation has not been described in the literature. Here, we report a thoroughly tested and simple method for taking peels of sandy soils using readily available tools and materials. Our method follows the main previously published steps of preparing a soil face, impregnating the soil face with a fixation agent in the field, extracting the resulting peel and mounting it. Yet instead of using lacquers and thinning agents, we use strong though flexible contact adhesive (glue), which has the major advantage that it no longer requires use and mixing of toxic chemicals in the field or reinforcement of the peel to prevent breaking. The preservation potential is much higher than with the old method. This new twist to old methods makes creating of soil peels more safe, simple and successful, and a thereby true DIY (do it yourself) activity. The resulting increased accessibility of making soil and sediment peels can benefit research, teaching, and science communication and thereby bring the value and beauty of the ground below our feet to students, schools, policy makers, and the public.

Tünde Takács, István Parádi, Ramóna Kovács, Zsuzsanna Pohner, Bettina Kelemen, Imre Cseresnyés, Péter Mikó and Anna Füzy

PHYSIOLOGICAL RESPONSE OF WHEAT CULTIVARS TO PEA INTERCROPPING

In conventional and organic farming systems (Martonvásár, Hungary) the effect of winter wheat (Triticum aestivum L. ssp. Mv-Nádor, Mv-Kolompos and YQ-GE2016) and pea (Pisum sativum L. ssp Aviron) intercropping was investigated on the physicochemical properties of soils, the functional diversity of rhizosphere microorganisms and root colonization of soil indigenous arbuscular mycorrhizal (AM) fungi in relation to physiological parameters of wheat. The pH(KCl), AL-P2O5, total N, AL-K2O and humus content of the chernozem soils from organic farming were significantly higher compared to the conventional farming. However, the NO3-N were significantly lower in organic farming. No differences were found in fluorescence induction parameters and biomass among samples originated from differently managed soils and wheat-pea intercropping. Intensity of AMF root colonization was poor in roots of wheat cultivars. Fungal colonization of YQ-GE2016 wheat root was higher in organic soils than in conventional soils. The principal component analysis of the microbial community-level physiological profiles generated by Biolog EcoPlate showed a slight separation of the organic and conventional soil samples. Rhizospheric microbes of organic soils can be characterized by higher utilisation levels of D-galacturonic acid, D-galactonic-acid--lactone and D-xylose. For the separation of conventional soils the greater decomposition rate of L-serine and L-asparagine is responsible. Significant differences were found in P, K, Mg concentrations of cultivars. Pea caused a positive effect on chlorophyll content of leaves, N-, P-, Cu-, Zn-, and K- content in wheat shoots.
The research was financed by the European Union's Horizon 2020 research and innovation programme under grant agreement N.727217(REMIX).

Anselme Bertin Takoutsing, Gerard Heuvelink, Jetse Stoorvogel, Keith Shepherd and Ermias Aynekulu

Accounting for measurement errors in soil observations to improve the accuracies of digital soil mapping outputs

The increase in the demand for soil spatial information has stimulated the use of proximal sensing to derive soil observations used in digital soil mapping (DSM). Most DSM studies account for spatial interpolation errors and the limited predictive power of environmental covariates, while the uncertainty in soil observations is usually ignored. However, soil observations generated using proximal sensing techniques like diffuse reflectance spectroscopy may have substantial analytical and spectral measurement errors that need to be accounted for. This study developed a DSM approach that quantifies and incorporates measurement error variance in the covariance structure of the spatial model to weigh observations in accordance with their accuracy and assesses the effect of measurement errors on the final outputs. The methodology was applied in the Western Highlands of Cameroon, where a stratified hierarchical systematic field sampling was used. Soil pH and soil organic carbon were measured by chemical analysis and mid infrared spectroscopy. Measurement errors were incorporated in regression kriging and applied to predict targeted variables using environmental covariates. Variogram parameters and regression coefficients were estimated using the residual maximum likelihood method. Four data scenarios were evaluated: 1) using only laboratory data, 2) using only spectral data, 3) using analytical and spectral data without taking measurement error into account, and 4) using analytical and spectral data while taking measurement error into account. A cross-validation showed that scenario 4 yields the most accurate results and provides the most realistic measure of the prediction accuracy.

Shuhao Tan and Xingyue Zhang

How Tenure Reform Aggravated Grassland Degradation in Northwest China?

Grassland is the basic livelihood asset of herders and an ecological barrier in northwest China. However, severe grassland degradation is threatening the sustainable development of pastoral areas and the ecological security of vast regions. Maintaining natural capital in a highly variable and fragile environment is required for a green economy. To explore how to maintain animal husbandry without reducing grassland natural capital under the current land tenure arrangements, this paper analyzes the impacts and mechanisms of Chinese tenure reform on grassland degradation. The paper reveals that tenure reform affects grassland degradation through two mechanisms: "livestock distribution – increased livestock – the Tragedy of the Commons" and "grassland distribution – grassland fragmentation – fence trap". The "interaction scale" theory further explains how tenure reform-caused land fragmentation affect grassland degradation. Both regional and case studies confirm the hypotheses. The grassland distribution aimed at solving the "tragedy of the commons" caused by livestock distribution not only effectively stopped grassland from degradation, but has brought fragmentation – which further aggravated the degradation. Reducing fragmentation and improving the "interaction scale" can improve the "labor - grassland - livestock - productive assets - water resources" balance so as to green the whole economy with grassland animal husbandry.

Darrell Tang and Sjoerd van der Zee

Nonlinear Multicomponent Biodegradation in Heterogeneous Unsaturated Soils under Transient Infiltration

Aerobic biodegradation is an important mechanism of organic contaminant removal from soils. In this study, we consider soil complexity by integrating processes that have been scarcely combined in the literature. We simulate aerobic biodegradation of a contaminant subject to nonlinear Monod kinetics being transported down autocorrelated heterogeneous soils under transient rainfall conditions. These kinetics depend nonlinearly upon changing contaminant, oxygen and biomass concentrations. Such complexities induce emergent phenomena due to interactions between the spatial distributions of water, biomass, and reactants. Even when reactants are introduced simultaneously, behaviour is found that differs essentially from simplified models. Accordingly, the long-term response and management of soil contamination under regular or seasonal input of biodegradable contaminants need to be modified, compared with guidelines developed using simpler models. For instance, effective contaminant half-lives can fluctuate over orders of magnitude, even when the reaction rate is approximately first-order relative to contaminant concentration, due to the behavior of the mixing process. This combination of complex processes makes the identification of relationships between the introduced processes to overall, or even short-term, biodegradation efficiency very difficult.

Anja-K. Techen, Katharina Helming, Nicolas Brüggemann, Edzo Veldkamp, Barbara Reinhold-Hurek, Marco Lorenz, Stephan Bartke, Uwe Heinrich, Wulf Amelung, Katja Augustin, Jens Boy, Marife Corre, Rainer Duttmann, Robin Gebbers, Norman Gentsch, Rita Grosch, Georg Guggenberger, Jürgen Kern, Ralf Kiese, Michael Kuhwald, Peter Leinweber, Michael Schloter, Martin Wiesmeier, Traud Winkelmann and Hans-Jörg Vogel

Soil research challenges in light of emerging agricultural soil management practices

Agricultural management is a key force affecting soil functions. Triggered by biophysical, socioeconomic and technological drivers, such as climate change, policies and smart farming technologies, new management practices emerge with largely unknown impacts on soil processes and functions. In a joint effort, 25 experts from a range of soil science disciplines as well as agronomy and economics have identified research challenges to better understand how emerging soil management practices affect soil functions. We distinguish four categories of soil management practices: spatial arrangements of cropping systems, crops and rotations, mechanical pressures, and inputs into the soil. Key research challenges identified for each management category include nutrient efficiency in agroforestry versus conventional cropping systems, soil-rhizosphere microbiome elucidation to understand the interacting roles of crops and rotations, the effects of soil compaction on soil–plant–atmosphere interactions, and the ecotoxicity of plastics, pharmaceuticals and other pollutants that are introduced into the soil. The assessment shows that the implementation of the soil research challenges can contribute to sustainable intensification by increasing the production-oriented soil functions while maintaining or improving the other functions, such as the habitat for organisms. We present an interdisciplinary, systemic approach to soil science including cross-cutting research activities related to process modeling, data management, stakeholder interaction, sustainability assessment and governance. This identification of soil research challenges from the perspective of agricultural management facilitates cooperation between different scientific disciplines in the field of sustainable agricultural production.

Babacar Thioye, Isabelle Trinsoutrot-Gattin, Lisa Castel, François Hirissou, Anne Cauchois and Marc Legras

Beneficial soil bioindicators and technical itineraries on walnut trees mycorrhization under agroforestry and agricultural systems

Soil microorganisms play a central role in biological soil functioning. One of the beneficial microbiota that have a symbiotic association with most of the plants is arbuscular mycorrhizal fungi (AMF). Nevertheless, the influence of soil bioindicators in plants response to mycorrhizal colonization is still poorly documented. The impact of cover crops, widely used in conservation agriculture or organic farming on native mycorrhizal fungi, is little known. In order to find whether native AM fungal community associated with walnut trees is influenced by soil bioindicators, root, rhizosphere soil samples and technical itineraries were collected from the agroforestry plots in Dordogne and the experimental station of Creysse (South-western France). Five modalities (Walnut in Conventional with and without vegetal cover, Walnut in Organic farming with and without vegetal cover, Walnut and maize in Agroforestry) and soil physico-chemical and biological analyses were studied. Our results showed a higher mycorrhizal colonization in walnut trees in organic farming in comparison with those in conventional farming. Whatever the modality, the highest percentage of total AMF colonization was recorded for walnut trees in the presence of faba bean. Multivariate analysis based on principal component analysis revealed that only the ergosterol content was mainly correlated to mycorrhizal colonization and hence relevant to explain walnut trees mycorrhization. The use of faba bean showed the great role played by vegetation cover in the enhancement of

mycorrhizal colonization of plants. Identification of the functional traits of mycorrhizal fungi sensitive to walnut trees is required to inform decisions in specific agricultural practices.

Amy Thomas, Bernard Cosby, Emmett Bridget and Pete Henrys

Competing drivers of Soil Carbon change at a national scale

Soils are large temporary stores of carbon; losses may exacerbate climate change, whilst sequestration could provide mitigation. Projected changes in soil organic carbon (SOC) focus on climate and land use as drivers, however atmospheric deposition and modulating effects of geology may also be important. Here we explore potential drivers of SOC change using data from Countryside Survey (CS), a national long term survey of soils and vegetation. Past studies have identified habitat level trends related to management practices.
We construct models to explore variation in topsoil SOC concentration across CS sites using explanatory variables with known importance for SOC, including pH, geology, atmospheric deposition, climate and land use. Land use change was very important at sites where it occurred.
Models for the remaining sites suggest that pH and land use are the most important predictors of SOC. We were also able to detect relationships with climate variables and atmospheric deposition, and nonlinearities and thresholds in the influence of variables. Differences between models for different time periods enable us to interpret change in influence of drivers over time. For example, pH was more important in acid soils, with the threshold shifting from 4.8 (1978) to 5.5 (2007). This shift in the pH/SOC relationship, may either reflect a decadal lag in SOC response to pH change, or permanent disruption of this relationship by other drivers. This work will help inform development of new process-based modelling approaches. Appropriately structured ongoing monitoring is crucial, to inform parameterisation of these models and to detect trends.

Alexis Thoumazeau, Cécile Bessou, Phantip Panklang, Nopmanee Suvannang, Philippe Thaler, Florent Tivet, Frédéric Gay and Alain Brauman

Biofunctool®: a new set of indicator to assess the impact of land management on soil functioning

The concept and methods to assess soil quality have been widely debated in the literature for the last twenty years. We developed a new framework to assess soil quality following an integrative approach based on the measurement of soil dynamic functions rather than stocks, namely Biofunctool®. Biofunctool® accounts for the interactions between soil physico-chemical properties and soil biological activity. It consists of twelve in-field, time- and cost- effective indicators to assess three main soil functions: carbon transformation, nutrient cycling and structure maintenance. Firstly, the capacity of Biofunctool® to assess the impact of land management on soil quality was validated through a reliability, redundancy and sensitivity analysis. The results over 250 sampling points in Thailand showed the relevance of each of the twelve indicators to assess soil functioning. Secondly, we applied Biofunctool® and aggregated the indicators in a Soil Quality Index that synthetize the impact of land management on soil quality. Biofunctool® was applied within various contexts (tree plantations, agroforestry, conservation agriculture etc.) and two cases study will be presented: i.) impacts of a disturbance gradient based on various land uses and rubber tree stands in Thailand ii.) impacts of conservation agriculture practices in Cambodia. The overall results proved that Biofunctool® index provides a synthetic soil functioning score that is sensitive to land management and is robust in various pedo-climatic contexts. Therefore, Biofunctool® is a reliable tool to assess the soil integrated functioning, i.e., soil quality, and could be included within larger environmental impact assessment frameworks.

Hao Tian, Zhitao Gao and Yandong Zhao

Study on Influence and Compensation Method of Soil Compactness on Soil Volumetric Water Content Measurement

Volumetric water content measurement based on soil dielectric properties is affected by soil tightness. The main commercial products currently in common use basically do not consider the influence of soil tightness on the measurement results that has larger measurement error. So on the basis of the principle of standing wave, this paper designed a portable soil volumetric moisture content sensor based on the principle of standing wave rate and the soil compactness is measured simultaneously. The coupling relationship between soil compactness and soil volumetric moisture content can be observed more easily by innovatively converting them into polar coordinates, and a modified soil volumetric moisture content model based on the soil compactness that was established.

Mia Tits and Annemie Elsen

Maintenance of small landscape elements in Flanders can contribute to soil quality - the wood chips story

The agricultural landscape in Flanders is often characterized by a mosaic of fields, meadows and orchards, bordered with small landscape elements such as wood edges, shrubs, tree rows, hollow roads, etc. Historically, these landscape elements had several practical functions: prevention of wind erosion, production of firewood, demarcation of fields, fencing of meadows etc. They are also important habitats for all kinds of plant and small animal species. However, in the last decades these landscape elements are disappearing because of intensification of agriculture. The remaining elements are not properly maintained anymore, although regular maintenance of the hedgerows is needed to maintain a sustainable use of the adherent fields. The wood waste resulting from this maintenance is often used as biofuel, but the small fractions are not suited for this. Instead, they could be shredded and applied in agricultural fields to improve soil organic matter content and soil quality in general. In Flanders we see indeed that low soil organic matter contents are an actual issue, so the application of ramial wood chips could offer an interesting solution.
In this contribution and based on results from experimental fields we will discuss the possibilities of this technique for improving the physical, chemical and biological soil quality of Flemish arable plots. In addition results will be presented in the broader context of closing nutrient cycles and providing ecosystem services: landscape management, carbon storage in the soil and biodiversity.

Ana Paula Turetta.

A methodology to assess the impact of agricultural practices in the Water-Energy – Food Nexus

By 2030, it is estimated that the world population will be 8.3 billion people, increasing the pression in energy, water, food, land use and mineral extraction, especially in the developing world. These estimates indicate the immediate need to adopt interventions that can minimize these impacts. There is a lot of talk about sustainability, but it is still rare to make the results of integrated evaluations available on various topics. When considering the integrated Nexus Food-Water-Energy (F-W-E) assessment, this fact is even more challenging.
Considering the importance of the agricultural sector in Brazil and the existence of areas in different stages of degradation, it becomes strategic for interventions that can generate socio-economic and environmental benefits and positive impacts to the tripod F-W-E. Thus, the present proposal will be based on the Ribeirão das Lajes dam (RJ), a core area for the water supply of the second largest city in Brazil – Rio de Janeiro.
A methodological approach able to generate an integrated assessment tool to evaluate the impact of agriculture practices in the Nexus F – W - E will be presented. We used secondary official dada as the main input for this tool. One of the reasons is to make it accessible for different stakeholders and decision makers. It can help to get better decisions regarding land use intervention - which may be technical or political.

Kristine Valujeva, Aleksejs Nipers and Rogier Schulte

Functional Land Management for identifying regional transition pathways for sustainable development: an example from the Nordic region

The increase in the demand for biobased products worldwide is providing an opportunity for Eastern European countries to recover their agricultural and forestry activities, which previously collapsed as a result of historic political changes. At the same time, such economic recovery must be congruent with the long-term climate and biodiversity objectives of the EU. As a country rich in bioresources, Latvia is a highly relevant case study of the Eastern European region, and faces a choice of transition pathways to meet both economic and environmental objectives. The expansion of the agricultural sector gives an immediate economic return, but at the expense of increased GHG emissions. Contrastingly, expansion of the forestry sector leads to long-term investments in the economy, increased carbon sequestration and the provision of habitats for biodiversity. In order to assess the trade-offs between short term investments in the bioeconomy and the achievement of long term climate and biodiversity objectives, we used the Functional Land Management framework for the quantification of the regional supply and demand for the primary productivity, carbon regulation and biodiversity functions.
Our results shows that the balance between the supply and demand for soil functions varies at regional scale, depending on land use and soil characteristics. This, in turn, defines local land use changes and improvements in management practices that are most likely to meet the socio economic and environmental targets simultaneously. Changes in the CAP post 2020 provide opportunities to create targeted and region-specific instruments for the development of the agricultural and forestry sectors.

Karen Vancampenhout, Johan Ceusters, Ilse Delcour, Bart Vandecasteele and Jane Debode

Carbon-aware growing media in the horticultural sector: turning a problem into an opportunity?

The horticultural sector has an important role to play in the reduction of harmful emissions. One important aspect are emissions related to the use of peat for growing media of ornamental plants: the annual emission due to the use of peat for agricultural purposes in Europe is estimated at 4,5 million ton CO2, transport not included. Excavation of peat moreover is an important threat to wetland ecosystem functions and biodiversity. Hence, our research into carbon-aware horticulture focusses on the development of growing media and amendments with more climate friendly alternatives, such as composts, wood chips, heathland sods, clippings or chopper. Moreover, we look for synergies with other soil functions, i.e. the role of soil biodiversity in disease suppression, in an effort to reduce pesticide use. By changing the composition of the organic components in growing media and soil amendments, we aim to create an environment where diseases and pests are less likely to develop. The research encompasses a screening of the chemical, physical and biological properties of potential peat alternatives. Moreover, in on-station experiments, we compare the biological properties of the growing media and amended soils to disease progression and severity in ornamental plants. Finally, we evaluate how to design 'smarter' growing media that can stimulate the growth of certain microbial antagonists.

Karen Vancampenhout, Ellen Desie, Bart Nyssen, Leon van den Berg and Bart Muys

Can the use of support species in forestry improve soil quality, nutrient cycling and tree health?

Due to the combined effects of land use changes since the Neolithic and more recent atmospheric deposition, many West-European forests are located on degraded and acidified soils. The adverse effects of soil acidity are far reaching, and have resulted in hampered ecosystem functioning and lower delivery of ecosystem services. Today, many of those forests are species poor, uniform and low productive stands. The admixture of 'support species', i.e. tree species with nutrient rich litter, is hypothesized to restore the degraded soils and improve forest vitality, productivity and resilience. But how to define 'nutrient rich litter'? Most studies summarize litter quality by a single variable, C/N ratio, which proves not always the most relevant. In this study we explored the concept of support species as a soil restoration intervention and defined which litter properties contribute most to an improved belowground ecosystem functioning.

Karen Vancampenhout, Sam Ottoy, Suzanna Lettens, Ward Swinnen, Nils Broothaerts, Gert Verstraeten, Bas Van Der Veken, Jan Bastiaens and Bruno De Vos

Carbon-aware management of forests and nature conservation area's

Land-use, land-use change and Forestry (LULUCF) have long been recognized as essential drivers and potential mitigators for climate change. Nevertheless, realizing this potential in actual field conditions is not straightforward. In the framework of the Climate Plan of the Flemish government, an initiative was set up to evaluate how nature conservation areas, including forests, could contribute to lowering or even offsetting emissions. A major hurdle however is that conservation areas have to accommodate multiple ecosystem functions and often have a strong focus on safeguarding endangered biodiversity. Hence, drastic changes in management techniques, vegetation or soil amendments are not feasible. An earlier study by the authors identified the importance of hotspots in a conservation context: these are small land units with considerably higher carbon stocks compared to the surrounding landscape matrix. Hence, we propose a spatially specific approach, aimed at predicting the location of the hotspots using remote sensing data, maps and legacy measurements. Existing models typically evened out extremes of soil carbon content in the landscape, especially at plot level. Hence, several adaptations to the model were evaluated for their potential to improve predictions. Second, a framework was proposed to assess the hotspots' relative inertia to management. Finally, we reviewed typical management practices for conservation areas in Flanders for their potential impact on soil carbon stocks. By adding a spatially specific compound at landscape level to the discussion, zones of priority can be established both for current management as for future research.

Jovica Vasin, Jordana Ninkov, Snežana Jakšic, Stanko Milic, Milorad Zivanov, Branka Mijic and Dušana Banjac

Decrease of soil fertility in Vojvodina (Northern Serbia) in the function of food production

The province of Vojvodina (the southern part of the Pannonian Plain) is an area with dominant agricultural use of land (80% of 21,506 km2) for food production. Pedogenesis processes produced fertile soil types (chernozem - about two-thirds of the surface and black hydromorphic soil (by FAO-WRB Vertisols and Gleysols) - 17%).
Comparative soil fertility studies were done using the same methodology in order to compare fertility of soil at the beginning of intensification of agriculture (half of the last century) to date. A grid superimposed on Vojvodina land by means of a GIS tool (GIS ArcView 10) has divided land into 4 × 4 km units, each representing an area of 16 km2. Total number of 1,370 disturbed soil samples (0-30 cm depth) were taken from agricultural land and analyzed.
The decline in humus content (depending on the type of soil and over 2%) was determined, while the content of plant macro-and micro nutrient elements (phosphorus, potassium, zinc, coper…) was different depending on the type of agricultural production and applied principles of good agricultural practice (application of mineral fertilizers according to soil analyzes).
Despite the decline in soil fertility, yields have so far grown, primarily due to the improvement of the genetics of cultivated plants. Decrease of soil fertility on some land plots in Vojvodina Province represents a limiting factor for yielding high, stable yields of cultivated plant species, as well as their quality.

Carmen Vazquez, Rachel Creamer, Ron de Goede and Michiel Rutgers

A balancing act: soil functions in different farming systems

Humans derive multiple benefits from the soil. They are not just responsible for the provision of food and fibre, but they regulate and filter freshwater, act as a carbon sink, support the cycling of nutrients and provide a habitat for numerous species. Future soil quality assessment tools should aim to include all these functions to fully reflect the soil's status. One such tool was recently developed by the Landmark 2020 project. Inputting information such as crop rotation, pH, soil texture, tillage routine, pesticide application, biodiversity, etc. into expert driven decision trees, one can score a field's soil functioning, and study the synergies and trade-offs between the afore mentioned functions. Using the same algorithms, we validate three of these functions (primary productivity, soil biodiversity and habitat provisioning and provision and cycling of nutrients), and explore the state, trade-offs and synergies of these soil functions in 64 farms across the Netherlands.

Simone Verzandvoort, Dorothée Van Tol, Gerben Mol, Paul Römkens and Erik Van den Elsen

An index for healthy urban soils in the Amsterdam Metropolitan Area

Urban soils are intensively used for various functions: they support buildings and conduits, provide space for green areas, urban agriculture and habitats, can buffer pollutants and store or drain precipitation. A well-functioning soil can perform multiple functions simultaneously.
The Amsterdam Metropolitan Region is an intensively used urban area. The region is confronted with problems partly due to non-optimal soil functioning. These include deteriorating green spaces, soil subsidence causing damage to constructions and buildings, and flooding resulting from intense rainfall events.
Information is needed on which properties soils require to function for different designated purposes. This need is reinforced by the ambition to adapt cities to climate change, and by an increasing demand for the production of high-quality food in and near cities.
The HS4AMS project aims to develop a tool to assess soil health in urban and per-urban areas (Soil Health Index–Urban, SHI-U). The index will estimate the capacity of the soil to perform various functions by means of quantification a set of key soil properties.
Interviews were held with 9 representatives of organizations responsible for assets and green spaces in urban areas. The respondents indicated more than 60 issues related to soil functioning and 50 soil properties as relevant for their work. In this presentation we will outline the major structure of the SHI-U, the main soil functions it addresses, and essential soil information needed to evaluate those functions.

Saskia Visser, Titia Mulder and Claire Chenu

A knowledge framework to structure the roadmap of EJP SOIL: defining research demands and barriers

The main aim of the EJP SOIL is to construct a sustainable framework for an integrated community of research groups working on related aspects of agricultural soil management. One important aspect of agricultural soil management to be addressed in the EJP SOIL is to strengthen the European research community on agricultural soil management, through a concerted alignment of research, training and capacity building; and co-construct with stakeholders a roadmap for agricultural soil research;
To develop a structured roadmap EJP SOIL works with a version of the knowledge management framework of Dalkir (2005). The EJP version uses four compartments: i) Knowledge development, ii) knowledge harmonisation, organisation & storage iii)

knowledge sharing & transfer and iv) knowledge application. The four segments are part of a cyclic process to enhance the development and use of knowledge on agricultural soils. Knowledge development comprises of assessing new knowledge needs to achieve the expected impacts of EJP SOIL. Therefore, using stakeholder involvement, knowledge gaps across Europe will be identified to work towards adoption of Climate-Smart Sustainable Agricultural Soil Management (CSSASM).. Within the knowledge sharing & transfer compartment the capacity of scientists and non-academic stakeholders will be enhanced. EJP SOIL will work towards network set ups and capacity building for different stakeholder groups. The knowledge harmonisation, organization & storage compartment of the knowledge framework ensures linkages with all stakeholders to ensure data harmonization and standardization. The last compartment, application of knowledge, will be facilitated by creating better guidelines, awareness and capacity for CSSASM adoption

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Udaya W.A. Vitharana, Darshani Kumaragamage, Srimathie P. Indraratne and Doug Goltz

Application of magnesium sulfate reduces the release and mobility of phosphorus from soils to floodwater under prolonged flooding

Loss of soil phosphorus (P) to waterways during spring snowmelt flooding can contribute to accelerated eutrophication of surface water bodies. Application of amendments that have the capacity to immobilize P has the potential to reduce P loss from soil to surface water bodies. This study evaluated the potential of MgSO4 as a soil amendment to reduce the release of P to pore water and mobilization to floodwater under simulated spring flooding conditions using intact soil columns (15 cm depth) collected from eight calcareous agricultural soils collected from Manitoba, Canada. Unamended, and amended soil columns with two rates of surface-applied MgSO4 (2.5 and 5 Mg/ha), in triplicates, were flooded to a water head of 10 cm and incubated at 4 0C ambient temperature to simulate spring snowmelt flooding conditions for 8 weeks. Surface floodwater and pore water dissolved reactive P (DRP) concentrations were measured immediately after flooding and at weekly intervals thereafter. In all soils and treatments, floodwater DRP concentrations increased with time of flooding, in general. Application of MgSO4 reduced the floodwater DRP concentration in the majority of soils with relative reduction compared to the unamended treatment of 26%-57% at 2.5 Mg/ha and 14-47% at 5.0 Mg/ha. Similarly, application of MgS04 at the rate of 2.5 Mg/ha showed a greater reduction of pore water DRP in all soils (17%–71%) in comparison to 5.0 Mg/ha application only in six soils (3%-76%). This study revealed the potential of MgSO4 amendments to reduce P mobility under spring flooding conditions.

Dirk Vrebos, Jan Staes, Rogier Schulte, Lilian O'sullivan, Arwyn Jones, Emanuele Lugato and Patrick Meire

Optimizing soil functions on agricultural land by means of a Bayesian belief network across the European Union.

Soils are a finite resource that provides a range of ecosystem services known as "soil functions". Functions relating to agriculture include: primary productivity, water regulation & purification, carbon-sequestration & regulation, habitat for biodiversity and nutrient provision & cycling. The soil functions are related to each other through different underlying soil processes. Trying to increase/maximize one soil function generally affects, also the other soil functions. Which can result in unexpected outcomes and costs.
To better understand the variations, it the relationships between these soil functions, we developed a statistical Bayesian Network model (BN) through data learning from the LUCAS dataset and detailed process-based DayCent modelling results. The BN allows us to evaluate these soil function through the use of various indicators and evaluate both positive and negative feedbacks when one or more soil functions are increased or optimized. This BN was then applied across the European Union to map the current soil function supply. In a second step various spatial scenarios were developed to assess the impact of EU policy scenarios on each of the soil functions.
Our analyses show how the supply of soil functions varies across the EU. The trade-offs that are associated with policy scenarios equally vary throughout the EU, depending on climate, soil properties and farming system.

Wim de Vries and Paul Romkens

Assessment and mapping the sustainable soil storage capacity of metals at European scale

The combined effect of storage and degradation processes in soil is referred to as the 'filtering function' of soils. For many pollutants, including heavy metals, the amount that can be stored in soil depends on the chemical equilibrium between the concentration in the soil solution and in the soil solid phase. Consequently, at maximum soil storage capacity, soil concentrations of potentially toxic metals can be substantially higher than critical threshold levels in view of impacts on terrestrial or aquatic

ecosystems or human health. Hence, it is more relevant to derive the sustainable soil storage capacity, being the maximum amount stored in soil beyond which adverse effects related to a given end-point will occur.
We assessed the sustainable soil storage capacity at European scale of the metals cadmium, lead, copper and zinc by comparing the actual amount of these metals stored in the soil with risk-based maximum acceptable amounts. The latter amounts were based on limit values in view of impacts on (i) soil quality (NOEC values in view of impacts on soil organisms), (ii) food quality (food quality standards) and (iii) water quality (drinking water standards, NOECs for surface water organisms). Food and water quality standards were combined with soil-plant relationships and soil-soil solution relationships, respectively, accounting for variations in soil properties (organic matter content, clay content, pH-H2O and pH-KCl) to assess critical soil concentrations. We present the approach and resulting maps of the spatial variation of the ability of soil to sustainably store metals in agricultural soils in EU27.

Jakob Wallinga, Tony Reimann and Alice Versendaal

Optically stimulated luminescence dating in soil science

Optically Stimulated Luminescence (OSL) dating methods are widely used in Quaternary Science to date the time of deposition and burial of sediments. The method is based on tiny light signals from quartz and feldspar grains; these signals build up in response to natural background radiation and are reset by light exposure. In this contribution we show examples how OSL methods provide valuable information on soil development and functioning. Here we list main applications in soil science:
- By dating the time of deposition of deposits in which soils formed, the duration of soil formation can be accurately determined. For palaeosols, both the deposit in which the soil formed and deposits capping the soil can be dated to infer the period of soil formation.
- Rates and intensity of soil mixing can be determined using recently developed feldspar-based single-grain methods. Rational of this approach is that the luminescence signals are reset when grains surface, and build up again after burial. Luminescence measurements can reveal what portion of grains at certain depth have surfaced, and how rapidly the matrix is mixed.
- When soil formation and deposition occur simultaneously (e.g. fimic soils), deposition rates can be determined using OSL dating.
Wageningen University hosts the only luminescence dating facility that is embedded in a soil science environment. We are keen to collaborate on novel projects in soil science, so please approach us with ideas.

Christian Walter, Denis Angers, Yosra Ellili, Maxime Fossey, Blandine Lemercier, Didier Michot, Nicolas Saby and Gilles Warot

Assessment of soil ecosystem services for territorial planning

The soil resources and their variability are still poorly considered to support decisions regarding major territorial challenges (e.g., urbanization, climate change mitigation, water quality protection, biodiversity conservation, agricultural systems management). Reasons given by land planners include the lack of soil information at adequate spatial resolution and the difficulty to relate classical soil description to services delivered by soils which could be easily considered while comparing different planning scenarios.
The Soilserv project combines biophysical and socio-economic approaches to assess ecosystem services of agricultural soils (SES) at different spatial scales and to analyse their implementation at territory level. The presentation will focus on two main questions: (i) can we down-scale existing soil information for valuating targeted soil functions and ecosystem services, using recent advances in digital soil mapping approaches? (ii) can we estimate and map changes in soil ecosystem services in order to compare different scenarios of territorial planning?
Both questions will be illustrated by applications in rural and peri-urban areas of western France where soil and SES estimates are required by decisions makers at several scales, from agricultural plot to landscape unit or small watershed. The final goal is to develop a SES assessment framework in order to include SES into decision making and to provide guidelines for land management optimizing SES at regional scale.

Bing Wang.

Effects of near soil surface characteristics on soil detachment by overland flow in a natural succession grassland

Vegetation restoration probably has great effects on the process of soil detachment. This study was conducted to investigate the effects of near soil surface characteristics on soil detachment by overland flow in a 7-year restored natural grassland. Four treatments were designed to characterize the effects of dead roots, live roots, biological soil crusts (BSCs), and plant litter-stems in succession. For comparison, an undisturbed bare Loess soil was used as a baseline. The testing area of each treatment was subjected to flow scouring under five different shear stresses ranging from 6 to 13 Pa. The results showed that near soil surface properties of plant litter-stem, BSCs, and plant roots enhanced the resistance of soil to water detachment significantly. With these factors

subsequently superimposed, soil detachment capacity decreased progressively. Taken together, the 7-year restored natural grassland would decrease soil detachment capacity by 98.9 % compared with the bare Loess soil, in which plant litter-stem, BSCs, and total roots contributed to 30.3 %, 14.9 %, and 53.7 %, respectively. Furthermore, for the total root effects, chemical bonding of root exudates accounted for 14.7 % while physical binding of root systems accounted for 39.0 %. Results also indicated that BSCs were unable to protect the soil from detachment when the shear stress was greater than 11 Pa, and tended to accelerate soil erosion. This paper developed an equation for adjusting WEPP's rill erodibility for use in natural succession grassland in the Loess Plateau of China, and the result seemed satisfactory.

Fang Wang, Rongxiao Che, Shu Guo, Zhihong Xu and Xiaoyong Cui

Utilizing archived soils to study long-term microbial community structural dynamics

Soil microbial communities are responsible for ecological processes in soils, while their responses to long-term environmental changes differ from short-term pulses. Drawing on research from zoology and botany, archived soils make it possible to delineate microbial community dynamics from 1840s up to now. However, accessing microbial community variation from air-drying process or environmental changes has not been adequately identified. We aim at revealing microbial community temporal patterns during air-drying process, establishing a methodology for comparison of fresh and air-dried soils, and characterizing long-term microbial community responses from archived soils. Fresh soils in five treatments were collected from long-term experiment station, air-dried and sampled at specific times (0 h, 1 h, 2 h, 4 h, 8 h, …, 8192 h), with DNA extraction, Illumina sequencing and bioinformatic analyses. Results showed that the overall microbial community profile was clustered according to treatment instead of air-drying time. In particular, the relative abundance of Actinobacteria displayed significant positive correlations in five treatments with air-drying time ($r = 0.79 - 0.91$, $p < 0.01$), following an overall inversion formula: relative abundance = 10^0.6067(1+ air-drying time)^0.0864-1 ($R^2a = 0.67$, $p < 0.01$), while Nitrospirae and Proteobacteria showed significant negative correlations. These results suggest that archived soils can be used to study long-term response, adaptation and feedback of microbial communities to environmental changes.

Wietse Wiersma, Gerard B.M. Heuvelink, Mirjam M. Pulleman and Miguel A. Romero Sanchez

Understanding the spatial distribution of soil organic carbon pools in a degraded Amazonian landscape to guide land use interventions towards improved soil quality and climate change mitigation

Degraded landscapes in Caquetá, located in the Colombian Amazon region, show great potential and urgent need for improved soil quality and climate change mitigation through land use interventions. To inform and monitor such interventions, it is necessary to understand the dynamics and spatial baselines of different soil carbon pools. To achieve these goals, soil samples were taken from over 150 locations in a 1300 km2 area from three depth layers. Sand content, pH, soil organic carbon (SOC) and permanganate oxidizable carbon content (POXC) were measured. Linear mixed models were fitted to describe the relations between land use and intrinsic soil properties on SOC and POXC. Stepwise linear regression and random forest modelling, both with regression kriging, were compared to predict the spatial distribution of SOC and POXC based on remotely sensed environmental covariates. Results showed that land use explained relatively little variation in SOC and POXC. Regarding spatial baseline creation, stepwise regression outperformed random forest, but was more prone to overfitting. The amount of variance explained for SOC and POXC in the 0-10 cm layer was 38 and 34%, respectively, and 61 to 53% for the bulk density of consecutive depth layers. In conclusion, for the Caquetá study area land use and intrinsic soil properties provided limited insight into the soil carbon dynamics. Possible explanations for these observations will be discussed. Areas in the spatial baseline with relatively low SOC content can be focused on by policy makers to guide landscape management towards improved soil quality and climate change mitigation.

Skye Wills, Kristen Veum, Carmen Ugarte and Deann Pressley

Using Soil Survey and Dynamic Soil Properties to set Soil Health Benchmarks

Interest in soil health indicators as a tool for land management continues to expand within government agencies, the larger scientific community, and with the public. Producers and managers look to compare management practices and track changes over time with both quantitative and qualitative field and laboratory metrics. However, guidelines that facilitate testing and interpretation are not widely available for soil health assessment. The NRCS Soil Survey provides limited interpretation frameworks of soil properties as they relate to soil health but does not provide references or benchmarks for most soil health metrics. To bridge soil health assessment and soil survey products, the Soil and Plant Science Division of NRCS is coordinating a project called Dynamic

Soil Properties for Soil Health Assessment as part of a broader Science of Soil Health Initiative. The project consists of nine individual cooperative agreements with common protocols and procedures. The primary goal is to assess the accuracy, repeatability, and utility of a set of proposed soil health metrics across a range of geographic regions, soils, and land management systems. A secondary goal is to link benchmark and reference soil health indicator values to soils and soil survey. Results to date, including challenges with the study design, standardization of laboratory protocols, and database development will be discussed as well as Initial summaries of field and laboratory assessments. Ultimately, the data from this project will be incorporated into soil survey products and the information will enhance soil health management recommendations.

Kening Wu, Lisi Zha and Qijun Yang

Assessment of Soil's Cultural Heritage Carrying Function: A Case Study of the Yangshao Village, China

Soil is an important carrier of cultural heritage. This study intends to accurately identify the cultural heritage carrying function of soils in cultural heritage sites by semiquantitative analysis, providing a scientific basis for the protection and study of this type of soil. Based on the differences in remains, relics and soil properties between the soil profiles disturbed by ancient human activities and the natural soil profiles in Yangshao Village, a qualitative and quantitative indicator system of soil's cultural heritage carrying function assessment was established. It consists of three categories: (1) ash pits, ash layers and cultural layers were selected as remains indicators; (2) pottery shards, stoneware and human remains were selected as relics indicators; (3) magnetic susceptibility, particle size, total P, bulk density, sporopollens, phytoliths and charcoals were selected as diagnostic indicators. According to the archaeological significance of the three types of indicators, the soil with this function in the site is divided into six grades based on soil survey data. And protection and development solutions for each grades of area are proposed. The method realizes a semiquantitative assessment of soil's cultural heritage carrying function, and helps to clarify the protection strategies and archaeological significance of functional soils at different grades.

Mingxiang Xu and Guobin Liu

Soil quality response to erosion and vegetation restoration on the Loess Plateau: the key for soil conservation

Soil conservation is an important part of soil management and is of great significance for farmland fertilization, soil desertification control and degraded soil restoration. In order to clarify the sensitive factors and key limiting factors of soil erosion and soil restoration, the soil quality erosion and degradation process and the soil quality restoration characteristics during vegetation restoration were studied in the Loess Plateau, China. The results showed that: 1) After the forest land reclamation, the soil erosion caused the soil quality to decrease rapidly in a short time, and the soil quality index decreased by 40% in 10 years. Wind and water cross erosion accelerated the process of soil degradation, with fine soil particles reduced by 10% and organic matter and total nitrogen by 14% compared to water erosion alone. 4) The restoration of soil organic matter, nutrients, microbial characteristics, soil permeability and erosion resistance during vegetation restoration is faster, but the recovery of soil aggregates and microaggregates and soil fine particles is relatively slow; 5) The soil quality recovery has long sequence and it takes hundreds of years for the soil quality of the plantation to return to its original state. In short, the deterioration of soil quality is much easier than recovery. Relative to the loss and recovery of soil nutrients and organic matter, the destruction and restoration of soil structure and texture is particularly important. Soil structure and texture are the key to soil conservation and the core indicators of soil quality on the Loess Plateau.

Gaowen Yang, Cameron Wagg, Stavros Veresoglou, Stefan Hempel and Matthias Rillig

Soil biota drive the temporal stability of plant primary productivity

Understanding the factors that determine the stability of ecosystem functioning when faced with a changing environment is a focal point in ecological research. It is well known that plant diversity is a major factor regulating ecosystem stability. However, it is not clear whether and how soil biota affects ecosystem stability. The temporal stability of plant community productivity is widely used to represent ecosystem stability in previous studies. We introduce a framework that soil biota drive temporal stability of ecosystem functioning under environmental changes through their direct and indirect effects on plant diversity, the net productivity of an ecosystem, and compensatory dynamics among plant species, and via altering ecosystem resistance and resilience. The dilution-to-extinction approach was used to create a realistic gradient of soil biodiversity which inoculated the grassland microcosms. We investigated whether soil biodiversity can regulate the temporal stability of plant community productivity under simulated environmental variation in precipitation. We found that the loss of soil biodiversity decreased the temporal stability of plant primary

productivity in experimental grasslands. Furthermore, soil biodiversity played an important role in maintaining the abundance of herbs and legumes under climate change factors (e.g. warming, drought and nitrogen deposition). We conclude that soil biota may be a neglected factor determining the temporal stability of plant primary productivity, which needs to be considered in future researches.

Yanfen Yang, Bing Wang and Suhua Fu

Reliability of the global climate models during 1961-1999 in arid and semiarid regions of China

General circulation models (GCMs) are useful tools for investigating mechanisms of climate change and projecting future climate change scenarios, but have large uncertainties and biases. Accurate models are of significant importance for agriculture, water resources management, hydrological simulation, and species distribution. In this study, we examined the precipitation and temperature reproducibility of 34 GCMs during the period from 1961 to 1999 over arid and semiarid regions of China. The study area was divided into eight sub-regions; each represented a specific topography. The evaluation was conducted for the whole study area and the sub-regions. Spatial and temporal indices and weighting methodology were used to comprehensively illustrate the models' reproducibility. The results showed that the simulation ability during winter outperformed than that during summer. Precipitation was more accurately simulated during spring than during autumn as opposed to temperature. For precipitation, the simulation ability in the basins was the best, followed by plateaus and mountains; the weights were 0.462, 0.308, and 0.231, respectively. For temperature, the mountains and plateaus had the best and poorest reproducibility, at weights of 0.446 and 0.198, respectively. The top models for precipitation and temperature at different spatial scales (whole study area, three topography types, eight sub-regions) were recommended. The results served as a reference for model selection in future studies regarding impacts of climate change on eco-hydrology.

Xiuqin Yin and Tianyu Zhang

Diversity and Ecological Distribution of Soil Fauna in Basalt platform of the Changbai Mountains, China

Soil fauna play an important role in terrestrial ecosystems. An investigation of diversity and ecological distribution of the below ground soil fauna was conducted in the basalt platform of the Changbai Mountains with four habitats types. The results showed that the secondary conifer and broad-leaved mixed forest had the highest diversity of soil macrofauna among the four habitats in spring. For soil macrofauna, in summer and autumn, original conifer and broad-leaved mixed forest had the highest diversity among the four habitats. However, in spring, summer, and autumn, the arable land had the lowest diversity among the four habitats. For soil meso-microfauna, in spring and autumn, original conifer and broad-leaved mixed forest had the highest diversity among the four habitats. In summer, secondary conifer and broad-leaved mixed forest had the highest diversity among the four habitats. However, in spring, summer, and autumn, the arable land had the lowest diversity of soil meso-microfauna among the four habitats. A significantly lower abundance and richness of soil fauna was evident in the arable land when compared to all other habitats in spring, summer, autumn ($P < 0.05$). However, abundance and richness of soil fauna did not respond significantly to variations in seasons ($P > 0.05$). The diversity of soil fauna in each habitat was shown that it was decreased with the increasing soil depth. Redundancy analysis (RDA) showed that diversity and ecological distribution of the below ground soil fauna was correlated significantly with soil temperature, available P, organic matter, soil moisture.

Mehretab Yohalashet, Rachel Creamer, Christy Van Beek, Rogier Schulte, Abbadi Reda, Girmay Abreha and David Wall

Developing the framework for On-farm Fertiliser Management Decision Support Tool based on soil diagnostic properties in Northern Ethiopia

In Ethiopia it has been standard for many decades that a single rate of fertilizer nitrogen and phosphorus only, are recommended irrespective of the soil type and crop demand for nutrients. However, a recent soil fertility maps reveal that other nutrients may also be deficient. As a result, region specific fertilizer blends are now being recommended; however, there is very little guidance for farmers to select the correct fertilizer blend and application rate. The objective of this research was to develop fertilizer decision support information to select correct fertilizer type (i.e. appropriate fertilizer nutrient blend) based on soil diagnostic properties (Tasew et al. WSC 2019 abstract) and fertilizer rate required to produce target crop yield. To achieve this, legacy crop response data from N-P-K fertilizer trials, for the dominant crops tef (Eragrostis tef) and wheat (Triticum aestivum) were collected along with their soil diagnostic properties. The grain yield responses to different levels of NPK were characterized by fitting (minimizing

residual R2) saturation curves to identify parameters Y0 (yield at N=0), Yr (maximum response of the yield to fertilizer N, i.e. the asymptote minus Y0) and K (the amount of fertilizer resulting in half of the maximum yield response, as an indicator of responsiveness). The parameters Yr and K were both assessed as functions of soil diagnostic properties. Overall results show that soil diagnostic properties and organic C levels provide a method for selecting fertilizer blends for specific soils. These results will be discussed further in the conference paper presented.

Madaline Young, Wim de Vries, Gerard Ros and Malte Lessmann

Development of a decision support framework to evaluate the impacts of agricultural management on crop, soil, and environmental quality

In the context of arable farming, we develop a decision support framework to evaluate the impacts of improved management practices on indicators for crop quality (yield), soil quality (organic carbon (SOC), nutrient balance, and compaction), and environmental quality (nutrient losses). Reviewing existing databases and decision support tools we observed a lack of coherence and holistic approaches, in particular in relation to site factors (climate, soil, and land use) that control the effects of agronomic measures on these indicators. Using data from long-term experiments within a meta-analytical regression, we estimate short- and long-term effects of various measures, while accounting for site-specific factors. Agronomic measures include different types of tillage practices, fertilizer sources, and crop rotations. Nitrogen (N) losses to the environment are included via process-driven models. Our framework evaluates the effect of management practices using two concepts. First, we consider trade-offs between different indicators in relation to meeting target values or critical limits, which depends on site-specific conditions. In a second later stage, we aim to estimate the relative importance of indicators. This is subjective to the “user” perspective or prioritized goals on the indicators, such as environmental protection, farm livelihood (e.g. costs of measures), or policy (e.g. 4 per mille initiative). We present results for meta-regression and modelling of impacts on yield, SOC and N losses, as well as the first-stage evaluation approach. Comparing applications of our framework in various regions around Europe illustrates the importance of generating location-specific management recommendations to ensure sustainable agricultural intensification.

Ado Yusuf.

Long term effect of cropping sequence, tillage and nitrogen fertilization on micronutrients concentration of an Alfisol in the Nigerian savanna

Long term soil fertility studies can provide reliable information in explaining the mechanisms involved in crop performance under different management systems. Soil micronutrients were measured after 12 years in three cropping sequences [soybean (Glycine max L.)-maize, cowpea (Vigna unguiculata (L.) Walp-Maize and continuous maize (Zea mays L.] each under reduced and conventional tillage at two nitrogen (N) fertilization rates (0 and 90 kg N ha-1). Phosphorus (P) and potassium (K) were applied to all crops at recommended rates. Soil sampling was done at 0-10 cm, 10-20 cm and 20-30 cm depths. Nitrogen fertilization had a greater impact on the soil properties than cropping and tillage systems, with the effects most pronounced at 10-20 cm depth. Addition of N fertilizer resulted in significantly lower copper (37%), zinc (36%) and iron (16%) concentration compared to zero N-rate. Crop sequence had significant influence only on manganese and zinc at 0-10 cm and 10-20 cm respectively with continuous maize having the highest concentration while conventional tillage system had the highest copper concentration at 20-30 cm. The results of this study indicate that continuous N fertilization depleted soil micronutrients and the impact was higher in the effective root depth. This was attributed to rapid utilization by crops to meet their nutritional requirements in response to the N fertilizer. It is concluded that under the current management practices, addition of micronutrients in the NPK fertilizer formulation is necessary to avoid micronutrient deficiency in the long run.

Caio Fernandes Zani, Geoffrey Abbott, James Taylor, Julia Cooper and Elisa Lopez-Capel

ASSESSING THE EFFECTS OF CONVENTIONAL AND ORGANIC ROTATIONS AND FERTILISATION PRACTICES ON SOIL CARBON STOCKS AND STABILISATION

Agricultural activities are vitally important for sustaining food production, but it has been also affecting our environment, including substantial soil carbon (C) loss. It has been suggested that soil C stocks can be increased with the adoption of organic over non-organic (conventional) agriculture, i.e. inclusion of different crop rotation scheme and fertilisation sources. Crop rotation schemes and fertilisation sources might also affect the decomposition process and hence soil C stabilisation, which plays a key role in its long-term maintenance. However, the current literature findings comparing conventional vs organic soil C stocks are often

contradictory and mostly do not consider soil C stabilisation. A long-term trial (Nafferton Factorial Systems Comparison) was established to compare mineral fertiliser for conventional agriculture and compost amendments for organic with conventional and organic crop rotation schemes. Soil samples were collected from the 0-0.6 m depth interval in 2011 and 2018, the first and the final year of the rotation, respectively. Soil C concentration was determined by dry combustion method and stocks were computed on an equivalent soil mass basis. Soil C stabilisation was assessed using thermal analysis combined with differential scanning calorimetry and a quadrupole mass spectrometer. Compost amendments under both conventional and organic crop rotation increased soil C stocks over the years through the soil profile (top 0-0.3m and subsoil 0.3-0.6m layers). Preliminary results also showed that soil C stabilisation might occur in the subsoil layers (0.3-0.6m) evidencing the needs for a more scrutinised evaluation of fertilisation strategies within the conventional and organic rotation schemes.

Mojtaba Zeraatpisheh, Ruhollah Taghizadeh-Mehrjardi, Kamal Nabiollahi, Shirin Moradian and Ming Xu

Spatial prediction of soil salinity using machine learning algorithms in semi-arid region of Iran

In most of the arid and semi-arid regions in the world, soil salinization is one of the main serious problems for agriculture and sustainable land use management. This study assessed the applicability of digital soil mapping (DSM) using a combination of terrain attributes and remote sensing data to predict and map soil salinity in Kurdistan Province, Iran. Using the randomized sampling method, 150 soil locations were chosen from the study area, and then from surface layers (0-30 cm) and subsurface layers (30-60 cm) soil samples were collected. First, using Boruta algorithm the most relevant environmental covariates were selected. Then, the relationship between EC contents and the selected environmental covariates were constructed using Random Forest (RF), Support Vector Machine (SVM), and Cubist models. Also, 10-fold cross validation method was used to evaluate models. Results showed that the increment of EC with soil depth increment. The highest performance (RMSE and R2) for prediction of EC in two depths were achieved using the RF model. More specifically, the R2 of prediction was up to 3% and 12% better in comparison to Cubist and SVM, respectively. Moreover, our results showed that an improvement was obtained in the prediction accuracy of models with using Boruta algorithm to select the most relevant covariates. As a result, Boruta-based Random Forest model was recommended for mapping soil salinity using environmental covariates derived from DEM and satellite in other semi-arid regions.

Chao Zhang and Guobin Liu

Soil bacterial community dynamics reflect changes in plant community and soil properties during the secondary succession of abandoned farmland in the Loess Plateau

The effects of natural succession on plant communities and soil variables have been established, but changes in microbial communities and their response to plants and soils have not been well characterized in secondary succession. We investigated the changes in soil properties and plant and soil microbial communities during the secondary succession on abandoned cropland in the Loess Plateau of China using high-throughput sequencing of the 16S rRNA gene. The study analyzed a chronosequence of farmland undergoing spontaneous succession after being abandoned for 0 (farmland), 5, 10, 15, 20 and 30 years(y). Plant community metrics including percent cover, and above/belowground biomass, first decreased in the initial stage (<10 y) and then increased during the succession. Proteobacteria, Acidobacteria, and Actinobacteria were the dominant phyla of soil bacteria across all succession. Bacterial communities transitioned from Acidobacteria-dominant to Proteobacteria-dominant communities during the 30 years of succession. Levels of soil organic carbon (C), total nitrogen (N), nitrate N and bacterial diversity were lower soon (< 5 years) after abandonment compared to the farmland, but they could recover to farmland levels after 15-20 years and were much improved after continued succession. Plant and bacterial community diversities (Shannon index and species richness) changed along successional time, but they showed different patterns, suggesting an incongruous process between plant and microbial succession. Organic C, total N, available N, and available P contents were significantly correlated with the abundance of most bacterial groups and the Shannon index, indicating the dependence of bacterial community diversity on soil nutrient supply.

Huimin Zhang, Qaswar Muhammad and Jing Huang

Long-term different green manure rotations improve soil biochemical properties, yield sustainability in paddy soil under double rice cropping system

Sustainable crop production especially under intensive cropping system is most important for food security and agriculture sustainability. We investigated yield sustainability, nutrient stocks, balance and enzyme activities affected by long-term different

green manure (GM) rotations in marginal acidic ferralic cambisol under double rice cropping system. The treatments including rice-rice-winter fallow (R-R-F) (control), rice-rice-Milkvetch (R-R-M), rice-rice-rapeseed (R-R-R) and rice-rice-ryegrass (R-R-G) have been setup since 1982 in this field experiment. Results showed that different GM rotation increased grain yield and sustainability yield index compared with control. Compared with R-R-F, the increase of average grain yield of early rice in R-R-M, R-RR and R-R-G were by 45, 29 and 27% respectively and that of late rice were by 46, 28 and 26% respectively. Positive yield trends were observed for both season rice yield in GM treatments. GM also improved soil chemical properties as compared to control. Over the years, in all treatments soil pH showed declining trends, while soil SOM, total N and total P contents and stocks of C, N and P showed increasing trends. Furthermore, GM significantly increased phosphatase and urease activities, and decreased apparent N and P balance compared with winter fallow. Multivariate analysis revealed that soil properties, mean annual precipitation and cultivation year were main factors influencing grain yield over the years. Hence, GM rotation is beneficial to sustain high crop yield by improving soil biochemical properties and to reduce nutrient losses in acidic ferralic cambisol under double rice cropping system.

Tianyu Zhang and Xiao Han

Estimation and evaluation of soil erodibility of northeast China

[Background] The northeast (NE) China is the grain base of the nation and is suffering from serious soil erosion problem. It covers an area of 1.24 million km2. Soil erodibility (K) is an important index to evaluate the sensitivity of soils to erosion. [Purpose] This study aims to: 1) to find out the soil erodibility (Knomo) of each soil specie of NE China; 2) To estimate the soil erodibility (Kplot) with the Knomo and local runoff plot data; 3) To evaluate the K of NE China by comparing it to other regions. [Method] The soil species datasets of all four provinces in NE China were collected. Totally, information of 473 soil species from 5 soil orders and 16 soil groups were extracted, including area, soil organic matter content and soil particle size content. The Knomo was calculated with these information and the USLE nomograph. The Kplot, which was measured with runoff plots, of NE China, other regions of China and other regions with same latitudes in the world were clollected and compared. [Results] The results indicated that: 1) The mean Knomo and Kplot of NE China is 0.028 and 00.032, respectively; 2) Compared to other regions with similar latitudes in the world, the Knomo and Kplot of NE China are both smaller. This is mainly due to the relatively lower content of silt and higher content of soil organic matters in NE China's soils. However, the rainfall factors may not be blamed for this.

Weijian Zhang, Yu Jiang and Kees Jan van Groenigen

Acclimation of methane emissions from rice paddy fields to straw incorporation

Straw incorporation is a common long-term practice to improve soil fertility and increase crop yields in agricultural systems worldwide. However, straw incorporation often increases methane (CH4) emission from rice paddies, one of the main sources of anthropogenic CH4. Intergovernmental Panel on Climate Change (IPCC) methodologies to estimate CH4 emissions from rice agriculture assume that the effect of straw incorporation remains constant over time, i.e., that CH4 emissions are unaffected by the duration of management practices. Here we show through a series of experiments and meta-analysis that these CH4 emissions acclimate. Effects of long-term (> 5 years) straw incorporation on CH4 emissions were on average 48% lower than IPCC estimates. Long-term straw incorporation increased soil methanotrophic abundance and rice root size, suggesting an increase in CH4 oxidation rates through improved O2 transport into the rhizosphere. Our results suggest that recent model projections may have overestimated CH4 emissions from rice agriculture, and CH4 emission estimates can be improved by considering the duration of straw incorporation and other management practices.

Zhuodong Zhang, Jingwen Rao, Lin Li and Chenxi Liu

Mapping soil organic carbon in the agro-pastoral transitional landscape system of Bashang area in North China

Soil organic carbon (SOC) is critical for soil fertility and of great importance to global change. The SOC in the agro-pastoral transitional zone (APTZ) in North China is sensitive to human disturbance and climate change. In this study, an area of 165 km2 were chosen in the APTZ of Bahsang area in Hebei province, and the SOC contents at two depths, surface layer 0-5 cm and subsurface layer 35-40 cm, were determined by field sampling, laboratory measurement, and modelling based on Random Forest (RF). Environmental factors such as parent material, topography, hydrology, land use, etc. were included in the RF modelling. Results show that the surface SOC content ranges from 0.88% to 8.42% with a mean of 4.62%, and the subsurface SOC content ranges from 0.60% to 5.29% with a mean of 2.84%. Elevation, vegetation, land use and slope gradient are the major controlling factors that influence SOC content. The SOC distribution has strong spatial variability in the agro-pastoral transitional landscape in Bashang area. The surface SOC content is higher than that of the subsurface, and the difference between the two layers is more obvious in the hilly area than in the flat area. Digital soil mapping based on RF is efficient and reliable to obtain high spatial

resolution SOC distribution at landscape scale, and such result is important and helpful for better soil resource management which is applicable to individual pieces of lands.

Marie Zwetsloot, Jeroen van Leeuwen, Marijn Van de Broek, Marko Debeljak, Henk Martens, Michiel Rutgers, Taru Sandén, Jaap Schröder, Aneta Trajanov, David Wall and Rachel Creamer

Synergies and trade-offs in functional soil management

Agricultural land provides a multitude of soil functions to society. In the LANDMARK project, we defined five soil functions: primary productivity, water regulation and purification, climate regulation and carbon sequestration, soil biodiversity and habitat provision and nutrient cycling. While all soils can perform all functions, we expect some soils to be better at supplying certain functions than others, dependent on environment, soil characteristics and management. With the increasing cross-scale demands for food security and environmental sustainability on land, the questions arise to what extent synergies and trade-offs exist between soil functions and how can they be quantified across Europe. To address this challenge, we visited 94 farm sites spread out over thirteen European countries covering five climatic zones and two land use types (cropland versus grassland). Soils were sampled for 18 soil properties and farmers were interviewed about their management practices and farm information. This dataset was analyzed by the Soil Navigator, a decision support system developed to assess and improve the supply of soil functions simultaneously. The Soil Navigator scores the performance of each soil function within each site as a “low”, “medium” or “high”. The majority of the 94 sites scored high on two to three soil functions, demonstrating that managing for multi-functionality in soil is possible, but that trade-offs do exist. We also found that synergies and trade-offs between soil functions vary among climatic zones and land-cover types. These results highlight the importance of considering local and regional scales in developing a functional land management monitoring schema.

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A slow path towards measuring root exudate effects on rhizosphere functioning and soil biogeochemical cycles

Plant roots create biological hotspots in soil with direct consequences for soil functions such as climate regulation and nutrient cycling. Many studies conclude that root exudation must be one of the main drivers of rhizosphere biogeochemical processes. However, very few studies manage to provide evidence for this statement due to the methodological challenges associated with rhizosphere research. To change this, the aim of our study was to test the poorly established link between root exudate diversity and soil functioning – specifically carbon cycling – using and modifying a variety of methods including high-performance liquid chromatography, stable-isotope tracing, enzyme analysis and microbial sequencing in the greenhouse and lab. We found that root phenolics have contrasting effects on soil microbial respiration, enzyme activity and soil organic matter decomposition. Moreover, root phenolics induced greater shifts in soil microbial communities than glucose often used as a proxy for root exudation in soil incubation studies. Besides presenting our findings on the connections between root exudates and soil functioning, we will elaborate on the failures and successes in our search for suitable methodologies to measure root exudate diversity and rhizosphere processes. In conclusion, we will discuss our thoughts on innovation in this research field.
