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BOOK OF ABSTRACTS

Block C

C3 Sustainable soil management

Contents

Block C 4

C3 Sustainable soil management 4

Session Description 4

Abstracts of Oral Presentations 6

SCALE – Managing Sediment Connectivity in Agricultural Landscapes for reducing water Erosion impacts 6

Predicting soil carbon removal by erosion in hillslope environments by erosion-deposition modelling could improve C cycle assessment 8

Buffer Zone Efficiency under Ploughing, Direct Drilling and Grazing in Boreal Conditions 10

Collaborative Design of erosion and sediment transport control measures at watershed scale in agricultural landscapes: Insights from stakeholders 12

Soil management impacts on soil structural properties in ten European long-term experiments 14

Consequences of soil compaction on yield and the environment: a modelling study 16

Soil compaction risk under climate change: an analysis for different pedoclimatic zones in Europe 17

Potential for carbon sequestration on arable land under the limitations of the Flemish manure legislation 19

Towards enhanced adoption of soil improving management practices in Europe 21

Abstracts of Poster Presentations 22

The FAST method for visual assessment of soil aggregate stability 22

Effects of Long-Term Soil Compaction on Physical Parameters and Carbon Stocks under Pannonian Conditions 23

Linking soil resistance and earthworm abundance 25

Effect of Agricultural Management on Soil Properties of Two Different Soil Types in the Czech Republic 27

The use of computed tomography to study the effect of fertilization on soil structure during a long-term experiment 29

Soil properties and wheat yield in headlands: results from field scale experiments in *Cambisol* and *Retisol* in Lithuania. 30

A Review On Microplastics In European Soil: Occurrence, Sources, Analytical Methods, And Potential Ecological Risk 32

Carbon dioxide (CO_2) and Methane (CH_4) annual emissions from drained and undrained forest Terric Histosols 33

ClimateCropping: Climate Smart Management for Resilient European Cropping Systems 34

Teaching agricultural soil biology to support sustainable crop production under pending climate change conditions by semi-saline irrigation 36

The Impact of Ploidy on Daylily Plant Resilience in Drought Conditions 38

Block C

C3 Sustainable soil management

Session Description

Involved projects: SoilCompaC, SCALE, SoilX

Conveners: Lisbeth Johannsen, Olivier Heller, Alejamdro Romero

Sustainable soil management requires consideration of the multifunctionality of agricultural landscapes, where the need for efficient production of agricultural products may be in conflict with environmental and climate-related requirements. The multiple land uses place high demands on soil functions and the involvement of multiple stakeholders require an integrated approach between policy and practice to achieve sustainable soil management. The challenges presented by projected increases in the occurrence and severity of extreme events due to climate change add further complexity to achieving sustainable soil management.

Strategies for sustainable soil management that aim to prevent and mitigate soil compaction, improve soil water retention and infiltration capacity, as well as mitigate soil erosion, may be well known, but require further understanding to assess the possible gains and trade-offs with other sustainability targets.

Soil compaction is a major threat to soil productivity and ecological and hydrological soil functioning. Although adverse impacts of compaction on soil properties and functions are relatively well documented, estimates of the extent and severity of compaction in Europe remain elusive, we have limited knowledge on how compaction changes the carbon cycle, and we lack information on compaction risks for different pedo-climatic zones and cropping systems in Europe and how the risks evolve due to climate change. Especially, research results quantifying interactions between soil compaction and climate, and presenting information on how to assess, detect, recover and minimize soil compaction, thereby providing a basis for sustainable soil management in Europe, are urgently needed.

Soil management impacts the soils' structure and the soils' ability to infiltrate water during heavy precipitation events and to store plant available water for dry periods. With climate change, both drought and heavy precipitation are becoming more frequent and are threatening crop productivity and other vital ecosystem services. New evidence from field experiments, model simulation and farmer interviews identifies soil management strategies for climate change adaptation and approaches for their promotion.

The challenge of soil erosion, where on-site soil management of agricultural fields also has potential off-site impacts, is emphasized by connectivity and highlights the impact of landscape elements on the transport of water and sediment during hydrological events. Implementation of targeted mitigation measures and encouraging changes in land use practices can ensure sustainable soil protection. Improved modelling of soil erosion processes with focus on connectivity at different scales and ensuring empirical validation of erosion risk maps is essential for effective decision-making tailored to regional circumstances.

In the present session, focus is on evaluation and development of sustainable soil management, especially with regard to soil threats as soil erosion and soil compaction. We kindly invite interested parties to submit an abstract with results from their novel research dealing with any of the knowledge gaps mentioned above.

SCALE – Managing Sediment Connectivity in Agricultural Landscapes for reducing water Erosion impacts

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The SCALE project intends to improve the knowledge of sediment connectivity and how to model it at different scales and locations, to enhance our understanding of soil erosion by water, sediment transport and landscape connectivity. This will help to advance the efficient implementation of mitigation measures, which account for regional differences in erosion damages supported by erosion modelling at different scales. We present the results of the project, which contribute to an enhanced knowledge on soil erosion processes, connectivity modelling, the implementation of mitigation measures and policy adaptation across landscapes in Europe.

These results include an overview of the current implementation of connectivity elements and mitigation measures in specific soil erosion models, as well as how to improve their model representation for improved soil erosion risk assessment and mitigation planning. Further, we developed guidelines for model users on the practical use of the connectivity approach in modelling developed via several mitigation scenarios for various soil erosion models. Our work shows that integrating erosion mitigation measures and sediment connectivity elements into models suitable for landscape scale simulations enhances our understanding of erosion and sediment transport and its management. However, it also highlights the necessity for further developments to improve the incorporation of sediment connectivity in modelling. Further, we analysed the effect of different treatments of the input and output grid resolution of soil erosion risk maps and how this affects the zoning of non-tolerable soil erosion as a basis for areas to implement regulatory measures. The local costs of implementing erosion mitigation measures and the diverse perspectives of farmers and other stakeholders from focus group meetings reveal the need for targeted mitigation strategies which consider the different perceptions on soil erosion risk, farm system sustainability and the feasibility of mitigation measure implementation.

The outcomes of the project highlight the need for targeted erosion mitigation measures in areas of heightened risk of erosion, as well as more appropriate protocols including sediment connectivity modelling to improve accuracy in soil erosion risk assessment, particularly when employing soil erosion risk maps for policy or planning purposes.

Keywords: soil erosion, sediment connectivity, mitigation measures, sustainable soil management

Predicting soil carbon removal by erosion in hillslope environments by erosion-deposition modelling could improve C cycle assessment

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Enhanced erosion - and sediment transport - in consequence of wrong soil management practices represents one of the most important threats in all the European countries, declined in different ways according to landscape, land use, climatic and pedoclimatic patterns. The erosion of the first topsoil layer does not involve only the loss of the mineral fraction, but also the mechanical removal of the organic carbon (C) from the soil, and the fraction of microbial biomass contained in it, with a decline in soil fertility.

This process interacts with soil C sequestration by biochemical activity, negatively affecting the balance among humified substances, mineralization, and CO_2 emissions. Indeed, the problem of soil C removed by water erosion and deposited somewhere along the watershed is still a matter of discussion among the soil experts' scientific community. Understanding the processes governing soil organic C turnover is confounded by the fact that C feedback driven by soil erosion has not been fully explored at large scale, yet (Lugato et al., 2018).

The present study aimed to verify the weight of the different processes involved in soil C sequestration (physical-mechanical vs biochemical) and their importance in soil C stock balance in a watershed in Central Italy. Soil erosion rates - as yearly average – were predicted by applying the RUSLE model coupled with Unit Stream Power-based Erosion Deposition methodology, together with the sediment reallocation both in other agricultural parcels (on-site erosion) and out of the watershed (off-site erosion), with the final prediction of the quantity (mass/surface) of soil C losses by mechanical removal and deposition fate (on-site and off-site).

A final comparison with the balance of soil C stock via a process-based model (RothC) allowed to assess the ratio between erosion and deposition, and to evaluate the importance of soil organic C removal by erosion.

Keywords: soil C loss; water erosion; erosion-deposition models; soil C stock

Buffer Zone Efficiency under Ploughing, Direct Drilling and Grazing in Boreal Conditions

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Establishing buffer zones (BZ) under perennial plants between cultivated arable land and receiving waters is a supplementary way of reducing sediment and phosphorus (P) losses in surface runoff.

Buffer zones have several roles in minimizing water loading. They decrease the area of tilled and fertilized soil near water bodies, reduce soil erosion in slopes, and remove sediment and nutrients from runoff water. In Jokioinen, SW Finland, a six-plot experimental field was established in clay soil to study long-term changes in functioning of BZ and their retention capacity for total solids (TS), total (TP) and dissolved reactive P (DRP).

Ten-meter-wide BZ located in the slope (*c*. 10%), whereas 60-m-long upper source area was quite flat. Grassed BZ (GBZ) were harvested annually, whereas vegetated ones growing natural bushes, trees and plants (VBZ) were not managed. Two 70-m-long field areas were cultivated without BZ (control. NBZ). The source field and the slope of NBZ were under spring crop and they were ploughed in autumn (1991–2001). Following three years the source field was grazed by cattle (2003–2005) and after that it was under direct drilling (Sept. 2006–Sept 2021). In the end of September 2021, composted pulp mill sludge (30 t/ha) was spread on the field and tilled into depth of 10 cm. Surface runoff (0–30 cm) was collected from the lower end of the BZ and piped to an observation building where water volume was measured with a tipping bucket, and representative subsamples were taken for laboratory analyses. The loads of TS, TP and DRP from GBZ and VBZ were compared to ones collected from the control (NBZ).

In autumn ploughing, the GBZ and VBZ halved the annual load of TS (1 t/ha) in the surface runoff from the NBZ whereas the decrease of TP load of 1 kg/ha was 36% and 28%, respectively. The load of DRP, however, was 70% higher from the VBZ than from the other treatments being the highest in spring. During pasture years, erosion was small (0.3 t/ha) in NBZ, and TP load of 0.7 kg/ha was decreased by 13% and 21% in the GBZ and VBZ, respectively. During grazing years, the DRP load was higher in all treatments compared to cereal years.

Under direct drilling, annual TS load was 0.5 t/ha in the NBZ; the GBZ and VBZ decreasing the load by 24% and 31%, respectively. In direct drilling, the annual load of DRP (0.30 kg/ha) from the NBZ was

twice as high as in autumn ploughing (0.15 kg/ha). During last three months in 2021, the load of TS (0.6 t/ha) and TP (0.7 kg/ha) were high due to the increased erosion events after soil tillage.

When modelling the effectiveness of BZ in water protection, the management of both the source fields and the BZ need to be considered. Soil type, topography, cultivation managements, type of BZ and weather conditions have a strong influence on surface runoff and erosion. To decrease DRP losses from plants to spring runoff, annual harvest of BZ is recommended.

Keywords: buffer zones; erosion; phosphorus; cultivation managements

Collaborative Design of erosion and sediment transport control measures at watershed scale in agricultural landscapes: Insights from stakeholders

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The current wave of protests in the EU agricultural sector, extending all over Europe, underscores profitability problems and the administrative burden as key issues that should be addressed by the EU to facilitate the better sustainable management of farms. Therefore, the issue of erosion and connectivity cannot be addressed separately from this general context. There is a need for increased sector participation in the design and implementation of regulations and their technical specifications.

We present the results of focal group meetings conducted in representative catchments of the SCALE Project located in Austria, Belgium (Flanders), Denmark, Finland and Spain to identify and select mitigation measures considering the perspective of the stakeholders and evaluate the social and economic barriers hindering their implementation.

The meetings were attended by local stakeholders: farmers and public servants connected with the agricultural and environmental sectors. Participants were asked to assess the relevance and their perception of soil erosion risk and sediment transport, the usefulness of erosion models and maps to implement erosion control measures, and how to improve these tools. They were also inquired about the most suitable measures to be implemented and the actions needed to overcome the barriers for wider adoption.

Farmers expressed different perspectives about erosion risk. While there was a group of farmers in the Austrian, Flemish, and Spanish catchments who were aware of the impacts of erosion on soil quality, crop yield, and water quality, the farmers from Nordic countries do not perceive soil erosion as a significant threat. In general, farmers mistrust assessments based on erosion models and maps and would prefer to advocate for more intense field monitoring to obtain reliable and precise data.

The implementation of erosion control measures largely depends on farmers' experience and "tradition" and profitability analysis. Subsidies were considered as a promising tool to foster the

adoption of new voluntary measures, but improving subsidy schemes, particularly by streamlining the administrative process, was remarked as a priority by all participants.

The diverse perspectives among farmers and stakeholders emphasize the need for tailored mitigation strategies considering the different perceptions of the relationship between soil erosion, crop yield, and the sustainability of farm systems, and the feasibility of implementing measures.

Given that many of the EU policies and regulations are driven by scientists' concerns and warnings, we question how much these concerns align with and are shared by farmers. To explore this, new group discussions involving representatives from the scientific community and academia, aiming to compare their perspectives on soil erosion and sediment transport issues with those of farmers are in course.

Keywords: sustainable soil management; co-design approach, Common Agricultural Policy

Soil management impacts on soil structural properties in ten European long-term experiments

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Abstract

Soil structure plays a crucial role in determining functional soil properties essential for crop growth, including water infiltration, water retention, and mechanical resistance, which directly impact water availability to crops and accessibility of resources by roots. Soil management affects soil structure directly through loosening by tillage and traffic compaction, as well as indirectly, for example by influencing soil organic carbon (SOC) content, earthworm abundance and activity, and root growth.

In the SoilX project, we evaluated how soil hydraulic and mechanical properties respond to differences in soil management. Our assessments encompassed measurements of saturated and unsaturated

hydraulic conductivity, water retention, aggregate stability, and penetration resistance in the topsoil and in subsoil layers. In addition, we measured earthworm abundance and visually assessed the soil structural quality. Basic soil properties including texture and SOC were also measured. We sampled over 100 experimental plots across ten long-term field experiments (LTEs) in Europe. To compare soil management across LTEs, we calculated numerical soil management indicators.

Preliminary data analysis of the Swiss LTEs revealed that tillage intensity had a negative and soil cover a positive impact on earthworm biomass, and that saturated hydraulic conductivity was positively correlated with earthworm biomass. Higher carbon inputs were associated with increased SOC contents, higher unsaturated hydraulic conductivity, and slightly larger amounts of plant-available water. Comprehensive analyses of data from all ten LTEs are currently on-going.

The preliminary findings underscore the significant impact of soil management on soil structure and function. Quantitative relationships between soil management and soil structural properties derived in the SoilX project will help guide the development of sustainable soil management strategies aimed at enhancing soil health and resilience to climatic extremes.

Keywords: long-term experiments, soil structure, soil management, soil hydraulic properties, soil mechanical properties

Consequences of soil compaction on yield and the environment: a modelling study

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Soil compaction is an important environmental and agricultural hazard, affecting at least 68 Mha of agricultural lands in worldwide. Soil degradation by compaction is increasing due to agricultural intensification that relies on the usage of heavy machinery, under mechanically vulnerable soil conditions. This agricultural trafficking leads to a disruption of soil structure and concurrent change in soil hydraulic and mechanical properties. Such soil structure degradation may have negative consequences for soil functioning, affecting both agricultural production and key soil environmental functions such as carbon and nitrogen cycling, which are crucial in the context of climate change mitigation. While it is generally known that soil compaction will have adverse negative effects on crop yield, impacts on nitrogen leaching, nitrous oxide emissions and carbon storage are less well quantified. Understanding relationships between these quantities remains challenging, as this involves complex interactions between soil physical, chemical and biological processes controlling soil functioning, which are in turn affected by agricultural management and depend on pedoclimatic conditions. In this study, we used a soil-structure based modelling approach to systematically assess the consequences of soil compaction on agricultural production and environment services and disservices. We coupled a soil compaction model that simulates compaction-induced changes in soil bulk density, macroporosity, and saturated hydraulic conductivity for different levels of soil compaction (i.e., mimicking different tractor weights and passages), with an agroecosystem model to simulate agricultural soil functioning. The model was used to analyse how different levels of compaction influence crop yield, nitrogen leaching, nitrous oxide emissions and carbon storage. Simulations were performed for different (1) soil textures, (2) soil structure recovery rates, (3) crop types and (4) climate regimes. We compared our simulations with field observations found in the literature. Despite the limitations in the modelling approach, our study sheds lights on relevant soil processes and scenarios that could help informing agricultural managing strategies.

Keywords: agroecosystem modelling, nitrous oxide; carbon stocks, nitrate leaching

Soil compaction risk under climate change: an analysis for different pedoclimatic zones in Europe

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Climate change affects the agriculture in manifold ways. One important point is the change of the weather conditions, which results in variation of precipitation and temperature. Both, precipitation and temperature changes, will affect plant and root growth as well as the available water content in the soil. In addition to many other soil and plant processes, soil moisture has a major influence on soil strength. A change in soil moisture due to climate change will therefore have an impact on the trafficability of soils and the risk of soil compaction. However, it is currently not known to what extent and in what direction the trafficability and soil compaction risk may change as a result of climate change.

In this study, we used a modelling approach to analyse the behaviour of soil compaction risk in times of climate change. First, we collected soil, crop and weather data from 13 different pedo-climatic zones in Europe. Using a new version of the SaSCiA model (Spatially explicit Soil Compaction risk Assessment), we calculated the wheel load carrying capacity (WLCC) for the last two decades. To model the effects of climate change, we selected 10 different climatic models and 2 SSP-scenarios (SSP1-2.6 and SSP5-8.5). For each pedo-climatic zone, we calculated the WLCC for each climate model and each SSP-scenario from present to 2100 on a daily basis.

The results show that climate change will affect the WLCC and thus the soil compaction risk. Although the extent and direction of WLCC-change depend on the pedo-climatic zone, there are some overall trends. In summer, the WLCC will increase due to lower precipitation and higher temperature drying out the soil. In late summer and fall, the behaviour is different. In some pedo-climatic zones the WLCC increases, in others it decreases. As maize and sugar beet harvest takes place at this time and both processes are accompanied by high wheel loads, the soil compaction risk will increase here in future. Late winter and spring show almost no variation in WLCC. At this time soils are often at field capacity which is also expected to be reached in the future. Thus, the soil compactions risk remains high during this period.

In addition to the average long-term effects, the variation in the WLCC between years is significantly high. There is an irregular alternation of dry and wet years within certain periods. The effects of these dry or wet years exceed the long-term changes in WLCC caused by climate change. This is an important point, as the compaction of the subsoil lasts for a long time.

Keywords: soil compaction, modelling, climate change

Potential for carbon sequestration on arable land under the limitations of the Flemish manure legislation

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Several large-scale studies have indicated declining soil organic carbon (SOC) contents in intensively managed cropland soils in Northern Belgium during the last few decades (e.g., Sleutel et al., 2007). As SOC content is regarded as a major indicator for soil health, improved SOC management is required (D'Hose et al., 2014). Almost all soil and crop management practices have implications for SOC but the most obvious way for increasing the SOC content is by using organic fertilizers such as animal manures or compost or decreasing soil disturbance by applying reduced tillage. However, several EU regions have fertilizer regulations to comply with the Nitrates Directive, and these regulations limit the use of organic fertilizers as a source of N and P, and consequently may constrain the built-up of stable SOC. Farmers need to balance the carbon input by exogenous organic matter on the one hand, and the risk of N and P leaching on the other.

We studied the effect of a combination of several measures (i.e., slurry application, compost amendment and non-inversion tillage) on topsoil C content, nutrient leaching and soil quality in the multi-year field trial BOPACT (°2010). The sandy loam soil initially had a suboptimal C content (i.e. 0.81%). After a period of 12 years, the yearly addition of compost (2t C ha^{-1}) resulted in a significant ($p<0.01$) increase of the SOC content in the 0-30cm (+0.15 percentage point on average) compared to no compost, while the application of non-inversion tillage mainly altered the distribution of the carbon in the topsoil. This application of 22.4 Mg C ha^{-1} also buffered the soil pH-KCl (+0.2 units, $p<0.01$) and increased the overall plant available nutrient content (i.e. P, K, Mg & Ca). Further, our research demonstrates that farmers can use compost, for at least 12 years, on top of cattle or pig slurry application to soils with suboptimal C levels to increase C content in the top soil, without inducing a higher risk for N leaching (i.e., NO3-N content in the 0-90cm). However, the $PCaCl_2$ content, which is often used as a proxy for P leaching, was significantly increased ($p<0.01$). The absolute increase was rather limited though (+0.8 mg kg soil).

In the framework of the EJP SOIL - SoilX project, the BOPACT field trial was intensively sampled in the spring of 2023 for biological (earthworm population, PLFA) and physical soil properties (penetration resistance, bulk density, Ksat, plant-available water). At the moment, results are still coming in.

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Keywords: soil organic carbon, compost, non-inversion tillage, soil quality, nutrient leaching

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Towards enhanced adoption of soil improving management practices in Europe

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Sustainable agricultural soil management practices are key to restore, maintain and improve soil health. The European Joint Programme for SOIL (EJP SOIL) has identified twelve main soil challenges in Europe. To assess the potential and eventually increase the adoption of soil-improving management practices, it is necessary to know i) the current levels of adoption of the practices, ii) socio-technical barriers influencing their adoption, and iii) their bio-physical limits.

This study compiled an inventory of soil improving management practices relevant for European conditions, and used a survey among soil scientists to assess the levels of adoption of these practices in Europe. In total, 53 soil management practices were identified that address one or several of the soil challenges. The adoption of most practices was low or spatially heterogenous across Europe, highlighting region-specific limitations to sustainable soil management. Qualitative interviews were conducted to explore the importance of socio-technical aspects of adoption. Using conservation agriculture as example, factors that can hinder adoption included the availability of knowledge and adequate machinery, financial risks, and farming traditions. Through a modelling approach, 54% of arable land in Europe was found to be suitable for cover cropping, indicating that the adoption of soil management practices is frequently limited by climatic constraints.

We propose a region-specific approach that recognises the importance of identifying and overcoming socio-technical barriers, and by acknowledging bio-physical limits that may be expanded by innovation.

Keywords: conservation agriculture, cover crops, EJP SOIL, soil challenges, soil degradation, soil health, soil restoration, soil threats, sustainable soil management

The FAST method for visual assessment of soil aggregate stability

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The strength of the soil structure is a key parameter in determining the susceptibility of the soil to erosion and in allowing for proper water infiltration. One way to assess soil structural stability is to measure the stability of soil aggregates in water. Methods already exist, such as the ISO-certified standard by Le Bissonnais et al., but it is rather time-consuming and can introduce operator-related biases.

We present a rapid and cost-effective tool for assessing soil structural stability: the Fast Aggregate Stability Test (FAST). Originating from the work of Fajardo et al. in Sidney, the FAST principle involves visually monitoring the spread of slaking aggregates upon wetting, and has already been implemented in the SLAKES smartphone application (now renamed Moulder). Although attractive due to its minimal equipment requirements, this method could not easily sample enough individual aggregates to meet the statistical needs of soil research. The goal of our work was to develop a robust, adaptable, and sufficiently representative method that could be widely used in soil science laboratories.

The protocol has been modified to use a 3D-printed plate that allows the simultaneous immersion of up to 96 individual aggregates in water. This amount of soil used per test is similar to that used in the Le Bissonnais tests, ensuring representative results. The increase in projected area of the aggregates during slaking is tracked using image recognition software, ImageJ. The final stability index is determined based on this area increase. Soil structural stability can be assessed within one hour using a procedure that involves placing aggregates on a plate, filming and analyzing. This method provides an objective assessment of soil stability in a timely manner.

The FAST index shows the expected behavior of aggregate stability, as evidenced by its correlation with other soil characteristics and its ability to discriminate between soils that have undergone different tillage practices. An indicative classification of the FAST index into four categories of soil stability, similar to the Le Bissonnais tests, is proposed.

The FAST method is expected to facilitate a wider implementation of structural stability studies.

Keywords: aggregate stability; soil health monitoring; 3D-printing; image analysis; method development

Effects of Long-Term Soil Compaction on Physical Parameters and Carbon Stocks under Pannonian Conditions

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The majority of agricultural soils experience compaction due to numerous factors such as the use of heavy machinery, cultivation under inappropriate conditions, or repeated passage of machinery on headlands. This compaction alters mechanical and hydraulic soil properties, leading to changes in key soil functions such as water and air flow, as well as carbon and nitrogen stocks, ultimately impacting plant growth and yields. This study aims to investigate the effects of long-term compaction compared to less trafficked areas of a field. As part of the SoilCompaC project (EJP SOIL), a field with a history spanning several decades was selected for this experiment. Featuring a crop rotation predominantly comprised of grains, the field represents the agricultural landscape of eastern Austria under Pannonian climate conditions and Calcaric Chernozem of alluvial origin. Three sampling points were selected in the headland (HL) and in-field (IF), respectively.

Soil penetration resistance was measured four times, consistently revealing higher resistance levels on the headlands on each sampling date. Crop yield of spring durum wheat was determined by collecting one square meter of aboveground biomass from each sampling spot and separating it into grain and straw yields. We found higher yields in the headland. After harvest, six pits - each two meters deep - were excavated using a backhoe attached to a small excavator. Three pits were located on the HL while the remaining three were IF. Visual soil profile evaluations were conducted, followed by taking soil samples measurements of bulk density, total carbon and nitrogen content, total organic carbon and nitrogen content, calcium carbonate ($CaCO_3$) levels, p*H*, saturated hydraulic conductivity, and air permeability. Selected results show that the mean total organic C stock (0-100 cm) was 231 Mg ha^{-1} for IF and 162 Mg ha^{-1} for HL. The bulk density differed between IF (=reference) and HL: 0-10 cm: -4%, 10-20 cm: +1%, 20-30 cm: +1%, 30-40 cm: +7%, 40-50 cm: +5%, 50-70cm: 0%, 70-100 cm: +1%.

For understanding of the complex system in compacted soil, long-term field experiments are necessary.

Keywords: long-term soil compaction; headland; bulk density; Pannonian conditions; calcaric chernozem

Linking soil resistance and earthworm abundance

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Earthworms are considered ecosystem engineers and show a strong interaction with soil structure. In addition, earthworms and soil structure depend on soil tillage, and earthworm abundance usually decreases with soil tillage intensity. Thus, earthworm numbers are lowest under a ploughing regime and highest under no-till. Similar applies for soil bulk density and causes higher soil moisture and soil penetration resistance in no-till than for plough. Earthworms depend on soil moisture and burrow deeper under dry conditions and/or aestivate until soil moisture increases. Also, soil penetration resistance is affected by soil moisture with higher values under dry conditions across soil tillage systems. These complex interactions of tillage, soil moisture and resistance also affect earthworm abundance. We hypothesised that earthworm abundance decreases with increasing soil penetration resistance for ploughing, whilst abundance increases with decreasing soil penetration resistance for no-till, as a function of soil moisture.

The hypothesis was tested with preliminary data from Hollabrunn, Austria, a long-term experiment (LTE) in north east of Austria with chernozem soil of loamy silt texture (clay 217; silt 570; sand 213 g kg^{-1}, total organic carbon 23.5 g kg^{-1}). The LTE consists of plough (25 cm depth) and no-till (0 cm) for 18 years. We took earthworm (4 soil monoliths 20 × 20 × 20 cm) and soil resistance (15 points per plot)

samples in April 2022, 2023, 2024 and October 2023. Soil penetration values were measured by 1 cm, 1 N accuracy, with penetration speed of 2 cm s^{-1}, with a 1 cm^2 cone. Maximum soil penetration depth was -40 cm, partly restricted by dry soil. Soil moisture was measured gravimetrically at 0 - 20 cm.

For no-till, preliminary results showed a higher soil moisture content and lower soil penetration depth than plough. Earthworm numbers responded as hypothesised, showed higher abundance with increasing soil penetration depth for no-till, related to higher soil moisture than for ploughing. These preliminary results showed that earthworm abundance can be predicted by maximum soil penetration depth. This could become a novel approach for farmers to estimate earthworm abundance. We seek to broaden our simple earthworm estimation for different soil textures and include data sampled in the SoilX project. We further hypothesise that earthworm number and soil penetration depth are affected by soil clay content and climatic boundary conditions.

Keywords: soil penetration resistance, soil penetration depth, soil management, earthworm, soil moisture, soil texture, SoilX

Effect of Agricultural Management on Soil Properties of Two Different Soil Types in the Czech Republic

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The aim of this contribution is to present the results of soil properties obtained in the Czech Republic as part of the SoilX project. The main research questions of the SoilX project are: 1. How exactly has soil management altered soil hydraulic properties in long-term field experiments across Europe? 2. To what extent can soil structural improvements enhance the resilience of cropping systems to future precipitation extremes? 3. Which socio-economic factors enable soil management improvements? Contrasting soil management treatments in 12 long-term agricultural field experiments (LTE) across Europe are investigated. To fulfil the objectives of the project from the Czech side the field measurements and sampling were carried out in the spring of 2023 at two locations, Čáslav (Luvisol) and Lukavec (Cambisol). Two contrasting variants were investigated at both sites: control (no fertilizers and other enrichments) (MIN), and manure and N2PK fertilized soil (FYM). In the field, a penetration resistance, soil CO_2 efflux, field soil water content (SWC), earthworms' abundance, and unsaturated hydraulic conductivity for pressure head of –2 and –0.5 cm, respectively were measured. Grab soil samples were taken in the depth of 5, 30 and 50 cm to evaluate basic soil properties (e.g., soil pH, soil organic carbon content (SOC)) and stability of soil aggregates (WSA index). Intact 100-cm^3 soil samples were taken in the same depth to measure the hydraulic properties using the multistep outflow method, and the pressure plate apparatus. In laboratory, the minidisk tension infiltrometers were used to measure the unsaturated hydraulic conductivities for pressure head of –5 and –0.3 cm, respectively.

Results indicate apparent differences in most of the parameters measured for the different variants and soils. For example, the higher WSA index, SOC, or field SWC were found for FYM variant than for MIN variant in both sites. On the other hand, earthworm abundance or field soil CO_2 effluxes were higher in FYM variant in Čáslav and surprisingly higher in MIN variant in Lukavec. Used fertilisation decreased soil pH in Čáslav (however, it had no effect in the control variant of Lukavec, which is naturally more acid soil). Some soil properties were not affected using fertiliser, e.g., penetration

resistance, or the field unsaturated hydraulic conductivities. We can see from the achieved results that the effect of fertilization can have different effect on different soil type.

Data obtained within this project and data gained before during LTE will be used as inputs into selected biophysical models to estimate the benefits of soil structural improvements for mitigating the impacts of increasing precipitation extremes (i.e., drought and heavy precipitation) under climate change. Synthesized project results will improve the basis of knowledge and evidence to provide better soil and crop management advice for both farmers and policy makers at European and regional levels.

Acknowledgment

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Keywords: long term experiments; fertilisation; soil structure; soil management; SoilX

The use of computed tomography to study the effect of fertilization on soil structure during a long-term experiment

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The aim of this contribution is to present the results of soil properties (porosity) obtained in the Czech Republic as part of the SoilX project. The main research question of the SoilX project is: How exactly has soil management altered soil hydraulic properties in long-term field experiments across Europe? Contrasting soil management treatments in 12 long-term agricultural field experiments (LTE) across Europe are investigated. In order to fulfil the objectives of the project from the Czech side, field measurements and sampling were carried out in spring 2023 at two locations, Čáslav (Luvisol) and Lukavec (Cambisol). Two contrasting variants were studied at both sites: control (no fertiliser and other amendments) (MIN) and fertilised with manure and H+N3PK (FYM). Plastic columns with a diameter of 7 cm and a height of 12 cm were collected at a depth of 1-13 cm (Ap horizons) and 30-42 cm (Bw and Bt horizons in Lukavec and Čáslav, respectively). These samples were used for porosity measurements using computed tomography (CT) NIKON XTH 225 ST. In addition, set of three 100-cm^3 undisturbed soils samples were taken from each horizon to measure porosity and soil hydraulic properties using standard methods.

The results from the Lukavec site show that the porosity determined from the plastic column samples obtained by CT is higher in the Ap horizon in the control than that in the fertilized variant, while no effect of fertilization is observed in the Bw horizon. Whereas at the Čáslav site, the effect of fertilisation is evident. The fertilised variant showed higher porosity in the Ap horizon and lower porosity in the Bt horizon compared to the control. The results obtained on the 100-cm^3 correspond to the CT observations.

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Keywords: computed tomography, porosity, soil structure, image analysis, long-term experiments

Soil properties and wheat yield in headlands: results from field scale experiments in *Cambisol* and *Retisol* in Lithuania.

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Continuous usage of heavy machinery, especially when soil is wet, often results in soil compaction in headlands, which can lead to wors soil conditions and at the end the yield loss. Many studies have shown the yield decrease as affected by soil compaction, but still lack of data reported on soil carbon and nitrogen cycles due to enhanced soil bulk density in headlands. Investigations of compacted headlands are important not only to assess the magnitude of the problem, but also to find the solutions for the sustainable use of such areas and mitigation of soil compaction. The aim of this study was to evaluate soil parameters in compacted headland and cultivated field down to 1m depth as well as their influence on wheat yields in two soil regions in Lithuania in 2022–2023. Experiments were located in Akademija, Kėdainiai distr. (Central part), in winter wheat (55°23'15.5"N 23°52'16.7"E in 2022) and spring wheat (55°24'38.4"N 23°51'00.1"E in 2023) fields and in Vėžaičiai, Klaipėda distr. (Western part) in winter wheat fields (55°43'26.1"N 21°30'15.8"E and 55°41'16.7"N 21°34'20.3"E in 2022 and 2023 respectively). According to WRB the soil in Central Lithuania was classified as *Endocalcari-Epihypogleyic Cambisol* and in the Western Lithuania as *Bathygleyic Dystric Glossic Retisol*. Soil texture in both experiments was indicated as a loam soil. SubVESS, soil texture, pH, total C (organic and inorganic), total N, bulk density (BD), total porosity, soil water retention curve, hydraulic conductivity (Ksat, constant head), aggregate stability (water stable aggregates) were measured down to 30 cm (0–10, 10–20, 20–30 cm) in 2022 and to100 cm in 2023 (0–10, 10–20, 20–30, 30–40, 50–70, 70–100 cm depth), penetration resistance down to 80 cm (every 1 cm), soil biological activity, root length, diameter and density per cm^3 were assessed in a top soil (0–20 cm), above ground biomass (wheat and spontaneous flora), wheat grain yield and quality were also evaluated. Greenhouse gas fluxes of N_2O, CO_2 and CH_4 were measured in both experimental sites in 2022 during winter wheat development in spring at stem elongation, at wheat flowering and before the harvest. All data were collected from headland and normal field from 5 replications in 2022 and 3

replications in 2023 (10 and 9 plots respectively) in two regions – soil types (*Cambisol* and *Retisol*). Gross area of each experimental plot was 25 m^2 in Akademija and 36 m^2 in Vėžaičiai. The results obtained in both experiments and in both years showed that the values of the soil physical and chemical parameters describing the soil condition were essentially worse within the soil profile in the headland than in the mid-field. Soil BD in the headlands exceeded the critical limit of 1.65 Mgm^{-3} within the whole profile, while in the cultivated field it was below the limits down to 50 cm in *Cambisol* and to 40 cm in *Retisol*. Soil organic C and total N tended to decrease in headland compared to normal field in both locations, while C/N in *Retisol* was significantly lower in 20–50 cm soil layer. Such conditions affected the wheat grain yield, which decreased by 9% (spring wheat) and 12% (winter wheat) in *Cambisol* and by 13% to 31% (in 2022 and 2023 respectively) in Retisol, when compared grain yield in compacted headland to non-compacted field.

Keywords: soil compaction, bulk density, organic carbon, total nitrogen, grain yield.

A Review On Microplastics In European Soil: Occurrence, Sources, Analytical Methods, And Potential Ecological Risk

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In North Europe, microplastics are a pervasive issue, as in the rest world. Microplastics in North Europe have raised concerns due to their potential environmental and health impacts. Efforts to address microplastic pollution in North Europe include research initiatives to understand its sources, distribution, and potential ecological risk.

We systematically compare last decade's studies on microplastic pollution in different Baltic Sea region countries (Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Poland, and Germany).

The focus is identifying the recent knowledge level and status quo of the mentioned research, mapping potential pollution sources, and identifying hotspots to get a wider view of possible ecological risks in the future of the Baltic Sea region.

A review of scientific papers was performed by Google Scholar and Scopus databases. Research terms were entered to identify relevant scientific papers: microplastic, soil, and selected country. Only the country of the first author was considered. A total of 66 publications in English were considered relevant to the objectives of this review. More than 89% of the articles were published in the last 5 years.

After performing the analysis, we observed a lack of information on the regional release of microplastics to agricultural soils, no clear classification of factors affecting the concentration of microplastics in soil, and no observations of possible effects on the environment in the target regions.

Keywords: microplastic, soil, pollution, Baltic Sea region, Europe

Carbon dioxide (CO_2) and Methane (CH_4) annual emissions from drained and undrained forest Terric Histosols

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In Lithuania, Histosols cover about 8–10% of the terrestrial territory, and the largest part, 513 kha (about 78%), is occupied by nutrient-rich organic soils classified as Terric Histosols (WRB, 2014 [2015]). Greenhouse gas (GHG) emissions from drained Histosols contribute more than 25% of emissions from the Land Use, Land Use Change and Forestry (LULUCF) sector. In this study we measured heterotrophic CO_2-C, and CH_4-C emissions from drained and undrained forest nutrient-rich organic soil (Terric Histosols) in 2021-2023. The study was conducted in the stands of native tree species as silver birch (*Betula pendula* Roth), black alder (*Alnus glutinosa* (L.) Gaertn.), and Norway spruce (*Picea abies* (L.) H. Karst.).

Three subplots (area of each subplot were 500 m^2) were established for gas measurements at studied forest stands, and the distance was 30 m between subplots. Gas samples were collected using 65 L non-transparent chambers. Sampling frequency was 2-3 times per month during the growing period and once per month during the cold season. The collected samples were analysed by gas chromatography in the laboratory of the University of Tartu (Estonia). Heterotrophic respiration was estimated as a proportion and accounted for 65% of soil total CO_2-C.

In drained forest Terric Histosols, the total annual heterotrophic CO_2-C emissions ranged from 2.9 to 4.6 t $ha^{-1}yr^{-1}$, while the total annual CH_4-C emissions were negative and varied from -1 to -5 kg ha^{-1} yr^{-1}. In undrained Terric Histosols the annual heterotrophic CO_2-C emissions were lower and varied from 2.7 to 2.8 t ha^{-1} yr^{-1}, meanwhile the total annual CH_4-C emissions were positive and reached 40 kg ha^{-1} yr^{-1}.

Keywords: Forest land, Terric Histosols, GHG, emissions.

ClimateCropping: Climate Smart Management for Resilient European Cropping Systems

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The large-scale adoption of sustainable soil management practices (SMPs) potentially mitigating GHGs still include substantial uncertainties in soil carbon (C), nitrogen (N) and phosphorus (P) balances, economic profitability and farmers' willingness to adopt new SMPs, particularly under climate change. ClimateCropping aims to provide scientific evidence, mainly based on long term experiments (LTEs), on how management of agricultural soils can contribute to climate change adaptation and mitigation, better cycling of nutrients and other associated co-benefits in European (EU) cropping systems and pedo-climatic conditions. This project is implementing an interdisciplinary approach that includes meta-analysis of historical LTE data, field observations, life cycle assessment, ecosystem modelling, agro-economic assessment and stakeholder engagement to evaluate the contribution of alternative SMPs such as 1) reduced tillage, 2) cover cropping, 3) organic fertilisation and 4) crop residue retention, to climate change mitigation and adaptation in cropping systems along a North-South climate gradient across Europe. Historical data will be complemented with new measurements and modelling of LTEs in seven EU countries (Austria, France, Germany, Ireland, Spain, Switzerland and the

UK). The focus will be on studying soil C stock, soil C sequestration potential, effects on N and P cycling, GHG mitigation, C footprint and potential trade-offs with yield at local to regional scales. Additionally, a selection of soil C decision support models will be evaluated for the above SMPs. The soil assessment will be complemented with an evaluation of economic and social sustainability including practical feasibility, and socio-cultural factors on farmers' willingness to accept a single or a combination of SMPs. Specific objectives are the following:

Determine soil C sequestration potential for alternative SMPs considering C, N and P inputs and inherent soil properties;

Evaluate the influence of climate change on soil C sequestration, N and P cycling under conventional and alternative SMPs;

Quantify climate change mitigation at field, farm and regional scale associated with alternative SMPs using ecosystem and LCA modelling;

Assess the climate change adaptive capacity and economic profitability associated with alternative SMPs;

Identify socio-cultural structural factors that enable or disable the adoption of alternative SMPs and policies that could accelerate the adoption of these SMPs in the EU.

Research is underway to prepare for activities of the project including collation and processing of data from 13 LTEs to feed forward to soil C stock assessment, ecosystem modelling, LCA and socio-economic analysis. Profiling and validating of decision support tools for soil C assessment is in progress. Literature review of LCA methodologies for use in cropping systems and on farmers' willingness to adopt alternative SMPs have been conducted. The first farmer interviews have been completed in Spain incorporating SMPs in olive production systems.

This project will develop holistic understanding of the GHG mitigation impacts of selected SMPs, alone and in combination, in main cropping systems across relevant climate regions and enable their uptake in EU agriculture. Results will contribute to the achievement of the national and international climate goals and will be highly relevant for European and national scale climate change policies.

Keywords: Sustainable soil management; Long term experiments, Life Cycle Assessment, Ecosystem modelling, Socio-economic assessment

Teaching agricultural soil biology to support sustainable crop production under pending climate change conditions by semi-saline irrigation

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Saltwater contamination is a major contributor to agricultural soil degradation. With rising sea levels and increasing summer droughts due to climate change, ground water and soils in temperate coastal areas are increasing in salinity. This is compounded as growers are forced to use the increasingly saline ground water to irrigate crops in summer. In arid areas, saltwater contamination has been reported to decrease crop yields, but the short- and long-term effects of soil saltwater contamination in temperate areas has not yet been thoroughly investigated, and especially little is known of the effects of increased salinity on soil microbial communities. Here we developed a 3-year experiment to study the effects of different levels of semi-saline irrigation on crops and soil microorganisms and test the hypothesis that deliberate semi-saline irrigation across the growing season applies a selection pressure and serves to pre-adapt soil organisms to increased soil salinity. The aim is to determine if we can we pre-prepare soils for future climate change conditions. After the first year the data show that irrigation with higher levels of semi-saline water (6 dS/m) had a negative impact on potato and spinach yield, but that irrigation with medium levels of salinity (3 dS/m) had no negative impact on crop yield compared to the control using ninety 30-liter mesocosms. Our results also show that increased salinity levels had an impact on the structure of soil bacterial and fungal communities from metabarcode DNA sequencing, as well as the function of soil microbes via gene expression from RNA sequencing. The lack of effect on crops at 3 dS/m part-saline irrigation but the change in microbial community structure and function suggests the selection pressure imposed by this part-saline irrigation level across the growing season has driven the soil biology community change to a state where it is better adapted to the increased salinity, and this supports crop yield. This is in line with the hypothesis that soils can be taught to be more tolerant of future climate change conditions. The outcome of this work will provide evidence to support growers' decisions on the levels of semi-saline

irrigation that can be used safely to irrigate crops to sustainably rescue yields in increasingly dry summers. More generally, as far as we are aware, this is the first proof in principle of the concept of pre-adapting soils to future conditions: this presents a method of mitigating the effects of climate change to ensure sustainable food production and soil health for future generations.

Keywords: soil, microorganism, crop, salinity gradient, climate change

The Impact of Ploidy on Daylily Plant Resilience in Drought Conditions

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The correlation between soil moisture levels and water availability significantly impacts how plants respond to environmental stress, especially during drought conditions. This study analysed the complex correlation between soil moisture content and morpho-physiological traits of daylily plants with different ploidy levels. The study examined various morphological and physiological parameters like relative water content (RWC), dry weight, plant height, leaf characteristics, accumulation of reactive oxygen species (ROS), chlorophyll and flavonoid levels, and nitrogen balance indices. The research findings show how diploid and tetraploid daylilies adapt to limited water resources.

The study observed the daylily plants' response to water deficit stress under abnormally dry conditions where soil moisture was 25%. Diploid and tetraploid varieties showed reductions in RWC, an essential indicator of their water status. However, the extent of RWC decline differed between the two ploidy levels, suggesting the potential for future research to explore the role of genetic factors in regulating water retention mechanisms. This finding underlines the complexity of the topic and the exciting avenues for further investigation.

As soil moisture levels dropped to 10% under severe drought conditions, the impact on the daylily plants became more pronounced. Diploid and tetraploid plants experienced significant decreases in RWC, with tetraploid varieties exhibiting slightly higher resilience to water scarcity. Notably, specific genotypes within each ploidy group displayed remarkable water retention capabilities, maintaining higher RWC percentages even under severe drought conditions. This variability underscores the genetic diversity in daylily populations and the potential for practical application of the research in selecting drought-tolerant cultivars through breeding programs.

The study highlights the crucial role of understanding soil-water dynamics in shaping plant responses to drought stress, with significant implications for horticultural practices. The findings provide valuable insights into enhancing crop resilience to water scarcity and optimizing water management strategies by unravelling the physiological mechanisms governing water use efficiency in daylilies. This knowledge empowers breeders and researchers to target critical traits associated with drought

tolerance, paving the way for developing water-efficient plant varieties capable of thriving in changing environmental conditions.

In conclusion, this study provides a foundation for advancing sustainable agriculture practices and fostering resilience in greenery cultivation amidst escalating water scarcity challenges.

Keywords: Tetraploid Plants; Plant Physiology; Water Deficit; Adaptation Strategies; Morphological changes