Budapest Soil Health Forum

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Budapest Soil Health Forum

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Budapest Soil Health Forum

Artificial Intelligence for Soil Health

International Conference

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Session 1

Soil health indicators, monitoring and spatial modeling

Developing a robust soil health indicator framework for Europe

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Soils play a crucial role in supporting various ecosystem services, from food production to climate regulation and waste recycling. Global soils face varying degrees of anthropogenic management and degradation, making the protection of soil health vital for maintaining soil functions critical for supporting all life on Earth. Soil indicators can help effectively communicate information from monitoring programs to policymakers, describing the state and changes in soil systems as well as helping to develop, guide, and provide feedback for a range of stakeholders. Given the vast number of indicators used to assess soils, a selection framework is required to select the most appropriate. The proposed framework for soil health indicator selection synthesizes information from current environmental frameworks to help provide a set of criteria for indicator selection, allowing candidate soil indicators to be assessed. Selected indicators can be communicated through templates which explain the environmental function and policy questions they address. This procedure can be demonstrated using the twelve descriptors presented in the EU soil monitoring law. Thus, the criteria form the basis of a robust indicator selection framework to communicate scientific findings to policymakers regarding soil health.

From the Ground Up: A Comprehensive Review of Soil Health Indicators in South Africa

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Soil health is a crucial factor in agricultural productivity, ecosystem stability, and climate resilience. In South Africa, mapping soil health indicators is particularly important due to the country's diverse landscapes, climate zones, and increasing land-use changes. The review utilized the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to systematically identify and assess relevant literature on soil health indicators mapping in South Africa. Initially, a comprehensive search across multiple databases was conducted, yielding a total of 858 articles related to soil health, mapping methodologies, and indicators within the South African context. The PRISMA process then applied several inclusion and exclusion criteria to filter these articles. Inclusion criteria focused on studies that specifically dealt with the assessment and mapping of physical, chemical, and biological soil health indicators relevant to the South African landscape. This process led to a substantial reduction in the number of studies; from the initial 858 articles, only 123 met the stringent criteria set by the PRISMA framework, ensuring that the final selection represented the most relevant and high-quality studies for this review. Additionally, studies employing both traditional and modern techniques, such as remote sensing and GIS, were prioritized. Exclusion criteria ruled out studies that were not directly applicable to South African soil conditions, lacked adequate methodological detail, or focused primarily on other regions or countries.

The review identifies several key indicators for soil health in South Africa, including SOC, erosion susceptibility, and nutrient availability. Physical indicators like soil texture and bulk density provide important data on water retention and structure, while chemical indicators, such as pH and nutrient availability, are crucial for assessing soil fertility. Biological indicators, such as microbial biomass, are increasingly used to understand soil's role in nutrient cycling and carbon sequestration. South African research is progressively incorporating advanced technologies such as remote sensing and geographic information systems (GIS) to monitor these indicators. While these technologies hold significant promise, issues with data accessibility and technical expertise remain barriers to widespread adoption. Traditional soil health assessments in South Africa have relied heavily on field-based surveys, soil sampling, and laboratory analysis. Although these methods provide reliable results, they are often limited in terms of spatial coverage and temporal resolution. Recent advancements in digital soil mapping (DSM) and remote sensing technologies have allowed researchers to assess soil properties over larger areas more efficiently. These tools, when paired with predictive modelling and machine learning techniques, enable spatial estimation of soil health indicators at multiple scales. However, inconsistencies in data collection protocols, short-term datasets, and a lack of standardized mapping methods continue to hinder efforts to establish a national soil health database.

Several challenges have impeded the effective mapping of soil health indicators in South Africa. A significant issue is the lack of centralized, harmonized datasets, as soil health data are often scattered across different institutions and agencies. This fragmentation complicates the creation of comprehensive mapping initiatives. Technical capacity is another challenge; many areas, especially rural regions, lack the expertise to implement advanced soil monitoring tools such as remote sensing and GIS. Additionally, the cost of implementing these technologies, including sampling and laboratory

analysis, is prohibitive for many farmers and researchers. Finally, the variability of soil types and land-use practices across the country further complicates the standardization of soil health mapping techniques, as different regions require tailored approaches.

Despite these challenges, there are several emerging opportunities for improving soil health mapping in South Africa. Increasing integration of Earth observation data with field-based measurements offers a promising route to more accurate and cost-effective soil health assessments. Platforms like Google Earth Engine (GEE) provide scalable solutions that can be utilized across different landscapes and timeframes. Furthermore, participatory approaches that involve local communities and farmers in soil health monitoring can foster data collection and knowledge transfer while encouraging sustainable land management practices. These collaborative efforts are essential for addressing local soil degradation issues and adapting soil health strategies to regional needs.

The review suggests that developing a national framework for standardizing soil health indicators and mapping methodologies would be a critical step forward. Such a framework would allow for greater collaboration and data sharing among government agencies, research institutions, and private organizations. It would also require increased investment in training programs and infrastructure, particularly in under-resourced areas, to enhance the technical capacity for soil health monitoring. By addressing these issues, South Africa can build a comprehensive soil health monitoring system that supports agricultural productivity, biodiversity conservation, and climate resilience.

Integrating Artificial Intelligence with Spectral Analysis for Precision Soil Organic Carbon Estimation as Soil Health Assessment

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Accurate soil organic carbon (SOC) assessment is crucial for evaluating soil health, particularly in croplands where organic matter influences soil fertility and carbon sequestration. Traditional methods, such as the Munsell Colour Chart, have limitations in standardization, leading to unreliable SOC assessments. In contrast, reflectance spectroscopy (RS), especially in the visible-near infrared (Vis-NIR) range, offers a more reliable approach for SOC prediction. This study explores the application of AI-driven multivariate models, including Random Forest, Cubist, and Support Vector Machine Regression (SVMR), combined with advanced spectral preprocessing techniques to improve SOC estimation accuracy. Using 165 soil samples from the University of Manitoba research farm, we derived 15 VIS-based colour parameters and 12 additional colour indices for SOC estimation. The VIS-based colour method resulted in an R^2 of 0.45 while incorporating colour index parameters with the VIS-based colour method increased the R^2 to 0.47, and using Vis-NIR data produced an R^2 of 0.72. The results demonstrate that utilizing the full Vis-NIR spectrum, rather than relying solely on the VIS range, provides a more comprehensive dataset, leading to better SOC estimates. This research highlights the potential of integrating AI with spectral data for enhanced soil health monitoring, offering a scalable, cost-effective tool for agricultural soil management. Our study underscores the importance of spectral pretreatment and variable importance selection, paving the way for improved soil organic carbon monitoring and sustainable soil management practices using AI and integrating other remote sensing datasets such as Landsat, Sentinel and MODIS satellite images for regional soil health assessment, and using UAVs with hyperspectral optical sensors for higher spatial and spectral resolutions.

Leveraging Large Language Models (LLMs) for automated soil health data extraction from ecological research papers

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The vast and growing ecological literature is an invaluable resource for improving our understanding of soil health and related environmental issues. However, accessing and extracting key information, such as the availability of datasets and associated code, remains a labour-intensive task that limits the scalability of research synthesis and meta-analysis. In response to this challenge, we are developing a novel AI-powered tool that uses Large Language Models (LLMs) to automate the extraction of key metadata from published ecological research papers.

Our system includes several important features:

1. Literature search: the tool performs targeted literature searches based on keywords, author names, topics or predefined lists of Digital Object Identifiers (DOIs), simplifying the identification of relevant ecological studies.

2. Automatic retrieval of articles: Research papers are automatically downloaded for further processing.

3. Extraction of data and code availability: Using the fine-tuned LLM, the system "reads" the papers and extracts whether the associated research data and/or code has been provided by the authors. This extraction process focuses on identifying explicit statements in the text of the paper, in supplementary materials or in associated repositories.

4. Tabular output: The extracted information is stored in a structured, tabular format that allows for easy analysis, comparison and integration into broader research workflows.

5. Automatic data download: When available, the system automatically retrieves the datasets and code and stores them for further analysis or replication studies.

We have developed and tested this package in the context of ecological and soil health research, focussing in particular on studies investigating the effects of environmental pollutants and land use on soil ecosystems. Initial tests of the tool have shown promising results in identifying publicly available datasets and codes and have significantly improved the efficiency of data extraction and synthesis compared to manual approaches. The application of this system in ecology holds significant potential to advance soil health assessment by enabling researchers to more easily access and utilise existing data for meta-analyses, machine learning model development and evidence-based decision-making.
Further development will focus on refining the LLM-based extraction methodology, improving the accuracy of data and code identification, and expanding the tool's capabilities to process additional metadata types. This tool provides a scalable and efficient solution to overcome the bottlenecks associated with manual data extraction and represents a valuable contribution to the ecological research community.

Soil monitoring system at Pan-European scale for soil health assessment across space and time

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The European Union aims to achieve healthy soils by 2050. To support this goal, a soil monitoring system that facilitates both local soil management and political decision-making must be considered across space and time. Here, we introduce a Pan-EU soil monitoring system that combines local soil observations with updated maps of soil health indicators. First, we developed Soil Monitoring Units (SMUs) based on similar pedoclimatic conditions (climate and soil types) across the EU. These SMUs provide the spatial framework for comparing and analysing soil health indicators, enabling farmers to assess their soil conditions relative to peers who share the same natural conditions. This step is crucial for generating local information, thresholds, and targets for soil health evaluation and future management. Second, we integrated the threshold values for each soil health indicator within SMU into existing soil health indicator maps, spatially highlighting areas that fall outside the typical value ranges. This approach can inform policy decisions at the EU, national, and regional levels by identifying areas where soil health indicators deviate from the norm and where corrective measures should be taken. These initial steps aim to establish a baseline and provide valuable insights for setting thresholds and targets, which can be compared with future soil monitoring campaigns. This is especially important in the absence of reference values, as relative changes can indicate the direction of soil health development. Furthermore, identifying areas with more significant problems can guide EU soil sampling efforts to prioritize regions experiencing high soil degradation or risk. The feedback loop in this monitoring system across space and time with identification of risk zones, target soil sampling and measures to improve soil conditions will help achieve the goal of healthy soils by 2050.

Session 2

Novel in-situ and laboratory techniques to assess soil health

A compositional (CoDa) for soil organic carbon VISNIR measurement method preventing moisture interference

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Soil organic matter content (SOM) has an important role in modulating atmospheric CO2, while soil organic carbon (SOC) is the best marker of SOM. Soil components are interdependent, thus they carry only relative information, belonging to the type of data so-called 'compositional data' (CoDa). VisNIRS modelling with soil reference data needs therefore specific CoDa methods. Soil moisture (SM) changes supposes an important difficulty to VisNIRS measurement of SOC. The CoDa methods integrate SOC prediction along with the other soil parts considered, including SM. Here are presented the final results from different soil compositional approaches carried out within ProbeField Project https://ejpsoil.eu/soil-research/probefield, (EJP-Soil programme), focused on proximal sensing techniques for SOC measurement.

Different approaches for 6, 5, 4, 3, and 2 soil parts were assessed. The soil components cosidered were SOM, SM, soil inorganic carbon (SIOC), the textural fractions clay (C) and silt (S), and the sand content which was considered in all the approaches together the rest of soil mass (Other).

The results provided correlation coefficients between SOM predictions and the corresponding reference values oscillating from r = 0.7s with the traditional PLS calibration to predict SOM to r = 0.87 with the 4-Part 'Clay' CoDa approach, which was the best . Therefore, this method to estimate SOM could be satisfactory. More research is ongoing to verify this approach within the frame of the ProbeField Project.

Novel, laboratory-independent device to measure extracellular enzymatic activity in soils

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Biological indicators play a critical role in assessing soil functions and overall soil health, yet they remain underrepresented compared to chemical and physical indicators. Soil health is deeply influenced by the biological activity within, which is essential for nutrient cycling, organic matter decomposition, and overall ecosystem productivity. Extracellular enzymatic activities (EEA), in particular, provide valuable insights into how soil biological activity responds to external factors such as management practices, climatic changes, or pollutants. However, traditional methods for measuring EEA typically require complex laboratory setups, which limits their application in real-time field assessments.

In this study, we introduce a novel, laboratory-independent soil enzyme activity reader (SEAR). SEAR utilizes an approach where soil enzymes react with fluorogenic substrates embedded in a transparent gel. Upon contact, the enzymes catalyze a reaction, producing fluorescent products that are detected on the opposite side of the gel. This enables a rapid and efficient assessment of multiple enzymatic activities, with the potential for analytical replicates and controls through the use of reaction plates with multiple gel compartments.

We validated SEAR by spiking sand samples with varying concentrations of different enzymes, thereby establishing operational limits for rate detection, precision, and substrate concentration ranges. Our results demonstrate that SEAR performs reliably across a wide range of soil types, including sandy to silty clay loam soils, acid forest soils (pH < 4), carbonate-containing agricultural soils, and soils with up to 18% organic carbon content. Furthermore, the device was tested under various environmental conditions, including soil moistures ranging from 2% to 173% of water holding capacity and temperatures from 6°C to 50°C, successfully demonstrating its versatility for field applications. With SEAR, soil EEA measurements can be conducted quickly in the field, eliminating the need for laboratory access, sample storage, or pretreatment, which can alter results. The use of industrially manufactured reaction plates with strict specifications, combined with an automated data analysis pipeline, ensures standardized measurements without requiring specialized laboratory skills.

In conclusion, SEAR represents a significant advancement in soil biological assessment by enabling fast, accurate, and field-ready measurements of EEA. Its potential for standardization and ease of use positions it as a powerful tool for soil scientists and environmental managers to assess soil health and functionality in real time across diverse landscapes and conditions. SEAR will also enable ongoing monitoring of soil biological activity, supporting long-term studies and adaptive management practices for sustainable land use.

A sound approach to monitoring soil health

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Soil health is increasingly recognized as playing a vital role in maintaining or restoring functional ecosystems. An important aspect of soil health is faunal diversity – yet this can be difficult to monitor, requiring invasive techniques and a high-level of expertise. The use of ecoacoustic techniques (recording and analysing sound characteristics) provides a potential solution to this problem, with soil ecoacoustics being a new but rapidly developing field.

Recent studies have demonstrated the effectiveness of soil acoustic methods at detecting soil biodiversity, and Baker Consultants is developing a range of analytical techniques, including AI, to apply ecoacoustics to soil health monitoring in the UK and Europe. This project is funded by the UK Government (Defra) and is focussed on the agricultural sector, but with potential applications in a variety of other contexts.

Many of the soil functions that concern landowners, and in particular farmers, are generated by earthworms – which make a range of sounds that enable acoustic monitoring of their activities. In addition, a range of beetle larvae and other macro and meso-fauna generate sounds that can be recorded in the field. In this talk, we will present results from pilot studies showing how these soil fauna can be monitored using emerging ecoacoustic techniques. We will also discuss a study published in Restoration Ecology journal that demonstrates the detectable differences in soil soundscapes between soils in forest restoration sites and deforested areas. Finally, we will summarise the future applications for soil acoustics, the uses of AI in this setting, and the potential contexts for this exciting new technology, which could provide vital insights for agricultural management, rewilding, Biodiversity Net Gain and habitat restoration projects.

Application of AI-driven system for monitoring earthworm behavior in ecotoxicological soil health assessments

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The behaviour of earthworms is an important indicator for ecological and ecotoxicological studies, providing information on the organisms' responses to environmental stressors such as pollutants and changes in soil composition. However, conventional methods for monitoring soil organisms are problematic due to the opaque nature of the soil matrix. In this study, we present an innovative AI-based system for continuous real-time monitoring of earthworm behaviour in soil environments.
The developed system integrates a 2D terrarium experimental setup with a deep convolutional neural network (CNN) to automatically track and analyse earthworm movements. By recording and processing image sequences, the system quantifies key behavioural endpoints such as total tunnel length, re-exploration rate and total distance travelled, providing valuable metrics for understanding earthworm responses. In addition, new parameters relating to movement patterns and tunnelling efficiency have been introduced to further enrich the dataset.
To test the performance of the system, we conducted three different experiments. First, a modified avoidance test was performed with H3BO3 as reference contaminant to evaluate the system's ability to detect behavioural responses under proven conditions. In the second series of experiments, we tested the effects of various commonly used pesticide formulations, including organophosphates, carbamates and triazoles, mixed uniformly into the soil. Finally, we investigated the performance of the system in different soil compositions by varying the ratio of quartz sand, kaolin clay and Sphagnum peat to simulate different environmental conditions. In all three experiments, the AI-based monitoring system showed consistent accuracy, reliability and improved precision compared to conventional methods.
The proposed AI-based monitoring approach represents a breakthrough in soil health studies. It provides a cost-effective, rapid and objective tool to assess the ecological impact of contaminants on soil organisms. By continuously and unobtrusively monitoring the behaviour of earthworms, this system provides a robust platform for ecological monitoring and pesticide risk assessment and advances soil health research.

New methods for in-situ soil health surveillance

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Soils are formed by mineral debris, organic detritus, water and living organisms. The soil ecosystem takes millennia to form and is sustained by a web of interplay both within the soil and with the vegetation ecosystem it harbors. Alongside the introduction and increased use of chemical fertilizers, soil health became synonymous with the soil chemical and physical properties. The present paradigm of cumbersome soil sampling and physico-chemical laboratory analysis, is expensive, slow and narrow. To capture the integrative function of soils, or soil health, methods that capture and describe soils as ecosystems including also living organisms, water regulation and nutrient recycling, and that do so in near real time to allow operational management, are required. General developments in information technology and communication (ICT), microelectronics and Artificial Intelligence (AI), combined with more specific technological advancement in for instance light and microwave sensing technology have paved the way for a range of new, often miniaturized, sensors that have also evolved into new tools for soil characterization. But like in medicine, old school palpation is in-escapable also for screening soil health. As part of the EU funded project AI4SoilHealth (https://ai4soilhealth.eu) a range of novel in-situ methods are being tested at pilot sites across Europe, including: soil spectroscopy, soil penetrometers, Ion Selective Electrodes (ISE), macrofauna observation, environmental DNA (eDNA), enzymatic activity, soil aggregate stability and water infiltration. Standardizing these methods, and using the EU-wide Land Use and Coverage Area frame Survey (LUCAS) physico-chemical analysis schema as reference methods, AI is applied for developing a smart-phone operated rapid assessment framework for soil health metrics. Here we present an overview of new methods to use for in-situ soil monitoring, methods that mostly give an instant answer or can be analyzed in a home environment within a few hours.

Session 4

From degradation assessment to smart farming

Bayesian Networks for soil degradation risk assessment using multivariate data

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Soil degradation is a complex process that includes erosion, salinisation, acidification, compaction, loss of organic matter and pollution. Identifying degradation risks is crucial for sustainable land management and ecosystem productivity. Bayesian networks integrate multiple data sources and uncertainties and provide probabilistic modelling to aid decision-making. Bayesian networks are graphical models that represent relationships between variables and calculate the probability of outcomes such as soil degradation. Variables in this context include climate data (e.g. precipitation, temperature), soil properties (e.g. texture, organic matter), topography and human activities (e.g. agriculture, deforestation). Bayesian networks use Bayes' theorem to calculate the probability of soil degradation based on the available data.

The first step in creating a Bayesian network to assess soil degradation is to identify the most important risk factors. These factors range from climatic conditions such as precipitation and temperature to soil properties such as texture, organic matter and pH. Topographical features such as slope and altitude also play a role. Human activities such as agricultural practises and land development have a significant impact on degradation risks.

Once these factors are identified, the network is structured by linking the variables together in such a way that their causal relationships are expressed. The nodes stand for the variables, the edges for the connections between them. For example, extreme rainfall can have a direct impact on erosion, while soil acidification could be linked to the use of fertilisers. This structure illustrates how risk factors interact and contribute to soil degradation.

Next, the network is populated with conditional probabilities based on data. For example, the precipitation and erosion data indicate how often certain amounts of precipitation lead to erosion. These conditional probabilities allow the Bayesian network to calculate the overall risk of soil degradation. One of the biggest advantages of Bayesian networks is their ability to update predictions as new data becomes available. For example, if new measurements of soil organic matter are available, the network can refine its predictions about the probability of degradation.

In practical applications, Bayesian networks can predict the risks of soil degradation in real time using multivariate data such as climate models, satellite images and soil sensors. These networks enable predictive modelling of processes such as erosion or changes in soil fertility due to changes in agricultural practises. Their results help decision-makers, such as land managers and farmers, to make informed decisions about sustainable land management. The risk assessments produced by the network can support decisions on the adaptation of agricultural techniques, the implementation of erosion control measures or the reduction of irrigation intensity. By integrating Bayesian networks with geographic information systems (GIS), spatial maps of land degradation risks can also be created, helping to visualise areas at risk and enable more targeted interventions.

However, the application of Bayesian networks is associated with challenges, particularly in terms of data quality. The accuracy of predictions depends on the availability of reliable and complete data.

Inaccurate or incomplete data can lead to erroneous conclusions. To mitigate this, the combination of different data sources — such as satellite images, field measurements and historical records — is crucial. Another challenge is scaling these models as the volume of environmental data grows. Combining Bayesian networks with other AI techniques, such as deep learning, could improve their performance. In addition, the development of systems that automatically update the network with new data is a promising area for future development.

To summarize, Bayesian networks are a valuable tool for land degradation risk assessment based on multivariate data. Their ability to integrate different data sources, account for uncertainties and update predictions in real time makes them particularly well suited for sustainable land management. As climate change and human activities increasingly affect soil health, Bayesian networks enable predictive analyses and informed decision-making, contributing to global efforts to preserve ecosystems and soil fertility.

Assessment of the Impact of Climate and Land Cover Changes on Land Degradation

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Soil degradation could be influenced by climate and climate extremes, affecting soil health and ecosystem stability by altering environmental conditions. This study evaluates the impact of climate change on soil degradation across Europe using a newly developed Soil Vulnerability Index (SVI). We employed outputs from 25 climate models and land use scenarios under two Shared Socioeconomic Pathways (SSP2-4.5 and SSP5-8.5) within a random forest model of controlling factors to estimate SVI values for near (2031–2060) and far (2071–2100) climate future. Results indicate significant changes in SVI values (defined as a difference greater than ±0.05) in the range of 24% to 34% of the observation points depending on the scenario and time period. These SVI changes suggest that among landcover types, forests are at the greatest risk of soil degradation, with 17% to 33% of the forested areas are projected to experience increased SVI values (indicating decreased soil health). Additionally, we identified temperature rise and the presence of perennial and nitrogen-fixing crops as the most important variables in predicting soil vulnerability to degradation. Our findings highlight the need to develop target soil management strategies for mitigating negative impacts of climate and land cover changes on soil health under future climate projection scenarios.

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Vulnerability of viticulture to climate change by means of satellite remote sensing techniques in the DO Ribera del Duero

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The increasing impacts of climate change present significant challenges for agriculture, particularly for vineyards, which are highly sensitive to changes in temperature and water availability. This study focuses on using remote sensing techniques to monitor the health of vineyards in Peñafiel, Valladolid, Spain, within the Ribera del Duero region. Over the years 2020, 2021 and 2022, Sentinel-2 satellite imagery was employed, and vegetation indices such as NDVI, GNDVI, and NDWI were calculated to evaluate key parameters like photosynthetic activity, chlorophyll content, and water stress in the vineyard. This approach provided critical insights into the conditions affecting grape production, enabling better-informed decision-making in terms of water management and soil conservation.

The analysis revealed a consistent decline in NDVI and GNDVI values, especially in 2022, which was strongly correlated with water stress conditions as identified by the NDWI index. This trend suggests that the vineyards are increasingly vulnerable to the effects of climate change, highlighting the necessity for improved irrigation practices and other adaptive measures to enhance vineyard resilience. The ability to detect early signs of stress enables vineyard managers to adjust practices such as irrigation schedules, improving the overall sustainability of production.

While this research primarily utilizes remote sensing and GIS tools to process satellite data and generate thematic maps, future work could integrate artificial intelligence (AI) to enhance analysis. Machine learning algorithms could be applied to historical data on vegetation, climate, and soil conditions, enabling predictive models that forecast vineyard health under various climate scenarios. Such models would support automated decision-making systems that optimize water use and resource management in real time, based on evolving environmental conditions.

The potential for AI integration in this context could significantly increase the effectiveness of precision agriculture. By automating responses to indicators of stress or predicting future impacts of climate change, vineyard managers would have the ability to make more proactive adjustments. These measures would not only mitigate immediate risks but also improve the long-term sustainability of grape production in the face of ongoing climatic shifts.

This research underscores the importance of using cutting-edge technology to maintain the sustainability and productivity of vineyards in regions like Ribera del Duero, where changing environmental conditions increasingly affect crop viability. By combining remote sensing with future AI-driven models, the sector could improve its ability to respond swiftly and efficiently to the challenges posed by climate change.

GenAI-based recommender system for monitoring and control of urban gardens

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This paper presents the development of a platform based on the Internet of Things (IoT) to monitor urban gardens as a strategy to mitigate hunger, promote food sovereignty, and foster a circular economy in areas with food shortages. The platform includes an IoT architecture with a social design layer that facilitates knowledge transfer to communities and a recommendation system based on evolutionary computation to optimize the productivity of urban gardens. Additionally, a recommendation system powered by generative AI (GenAI) is employed to monitor soil conditions based on environmental variables. According to the FAO, climate change is exponentially affecting global agricultural production, with food prices expected to increase by up to 90% by 2030, and hunger and malnutrition rates rising by 2050. To validate the AI and evolutionary computation models, three experiments were conducted in urban gardens, utilizing models such as multiple linear regression, genetic algorithms, ant colony algorithms, and spatial estimation algorithms like the Kriging algorithm, achieving a productivity increase of 25% to 45% in urban lettuce gardens. This approach contributes to the 2030 Agenda for Sustainable Development Goals (SDGs).

Paving the Way towards Digitalisation Enabling Agroecology for European Farming Systems (PATH2DEA)

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PATH2DEA – Paving the Way towards Digitalisation Enabling Agroecology for European Farming Systems, stefan.pfeiffer@ait.ac.at

The potential of agroecological farming systems to master many of today's challenges to the environment, economy, health, and society can be significantly promoted by coupling with digital tools and technologies. The Horizon Europe project PATH2DEA (Grant Agreement Nr: 101060789 (EU) & 22.00535 (SERI)) is committed to unlocking digitalisation's catalysing power to foster European agriculture's transition towards enhanced sustainability. It will build on farmers' competences and views and match them with the rich repertoire of digital solutions already available for agriculture, aimed at tailoring digital technologies to users' needs and fostering wide-range adoption of digital agroecological farming in the EU and associated countries. Strategic engagement by multiple actors includes early adopters of digital agroecological farming represented by six Showcase farms located in different pedo-climatic regions, with hands-on experience for solid consensus validation of the project's conclusions. PATH2DEA is deeply rooted in the European Agroecology Innovation Ecosystem and will establish itself amidst key players and proven instruments to mediate and connect among disciplines and sectors with a clear ethical-societal perspective. Via interactive discussion rounds, specific situations regarding digital technology uptake and use will be explored and brought to consideration by actors and stakeholders for increasing awareness and understanding. PATH2DEA will deliver a robust knowledge base in the frame of an Open Source Repository of digital tools and technologies in agroecology with decision support functionalities and a well-aligned R&I Roadmap for guiding digital agroecology transition. Finally, PATH2DEA will use its results for bridging towards the upcoming European Agroecology Partnership.

Abstracts of poster presenations

Microbial Community Prediction in Plant-Soil Systems Using Machine Learning

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The integration of machine learning (ML) into microbiome research has opened new frontiers for analyzing microbial community data, and only recently it was applied to better understand soil-plant interactions. Statistical analysis of amplicon and shotgun metagenomic sequencing data has long favored tree-based algorithms due to their ability to handle compositional, sparse, and high-dimensional data, even when sample sizes are limited. However, the application of deep learning, though often reserved for large datasets, can also be advantageous in soil and plant microbial ecology if the risk of overfitting is properly managed.

In this study, we used ML tools to investigate the extent to which different soil environments influence the composition of endophytic bacterial communities in Setaria viridis, a model species for C4 grasses. Seeds from two distinct locations in Austria were grown in both native and non-native soils, and microbial communities from various plant compartments were analyzed using 16S rRNA sequencing. The results show that soil plays a significant role in shaping these communities, with distinct microbial shifts observed when plants were grown in non-native soil. Nevertheless, a core set of seedborne bacteria persisted.

By using ML algorithms to analyze Amplicon Sequence Variants (ASVs), we generated predictive models supporting the hypothesis that soil exerts a driving influence on plant-associated microbiota while retaining some transmitted endophytes. By employing a variety of algorithms—from tree-based models to neural networks—we determined that certain soils drive more significant shifts in the microbial composition than others, offering valuable insights into the soil's role in shaping plant microbiomes under varying environmental conditions.

Advanced Physics-Informed Machine Learning for Estimating Key Soil Properties Linked to Fundamental Soil Health: Particle Size Distribution and Water Retention Curves

Sarem Norouzi[1], Mogens H. Greve[1], Charles Pesch[1], Cecilie Hermansen[1], Per Moldrup[2], Emmanuel Arthur[1], Trine Norgaard[1], Marzieh Zaresourmanabad[1], Lucas C. Gomez[1] and Lis W. de Jonge[1]

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Over the past two decades, machine learning (ML) methods have been widely applied in soil science to estimate various soil properties. Despite its successes, traditional ML methods encounter several limitations, such as high data requirements, poor generalization to new scenarios, and challenges in ensuring physically consistent predictions beyond the range of their training data. To overcome these limitations, we propose the use of physics-informed machine learning (PIML) methods, which integrate physical laws directly into the learning process to enhance model robustness and generalizability, particularly in data-limited scenarios. We demonstrate the capabilities of PIML by developing two PIML models for the estimation of two fundamental soil properties related to soil health, soil particle size distribution (PSD) and soil water retention curves (SWRC), using measured spectral reflectance data (400–2500 nm). Unlike conventional approaches, these PIML models are designed to learn non-specific forms of SWRC and PSD by effectively incorporating both observational data and physical laws during training. This novel approach offers capabilities beyond those achievable with traditional methods. Specifically, the PIML model for PSD can seamlessly integrate both complete and incomplete measurements from diverse soil classification systems without requiring harmonization through interpolation of inputs, and is able to make predictions in any soil classification system. This makes the proposed approach particularly suitable for modeling PSD across datasets collected from various countries with different soil classification systems, such as at a pan-European scale. Additionally, The PIML model for SWRC can effectively handle samples with sparse or incomplete measurements, making it well-suited for SWRC datasets that often contain missing sections of the curve or limited data points. The proposed PIML approach provides a fast and cost-efficient method for monitoring fundamental soil properties to evaluate key soil health indicators. It can also be adapted for proximal sensing and digital mapping of other soil health-related properties.

Mapping the WRB 2022 soil types of Europe at 30 m resolution

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Knowing the soil types of Europe can be fairly useful in the high spatial detail because soil types reflect vertical soil stratification and diagnostic features/soil properties that can be used for a soil health assessment. The study introduces the European maps of predicted soil types at 30 m resolution based on the WRB 2022 classification using legacy point data. The main resources for training data are national legacy point datasets of the member states and WOSIS supplemented by simulated points from the European Soil Database v2 Raster Library 1kmx1km (5 % of points in total). The national datasets using older WRB versions or national classification systems were correlated to WRB 2022 using original metadata including conversion tables and literature. When the correlation was unclear, we used two most probable WRB soil types. Predictions are based on ensemble machine learning models combining Light Gradient Boosting Machine and Random Forest. We applied a multi-label classification following the hierarchical structure of the WRB 2022 system. We used a conformal prediction to provide the relevant reference soil groups and principal qualifiers for every pixel. It resulted in the dynamic legend reflecting the uncertainty and the quality of the national training datasets. This approach allows a more realistic overview of the soil types to the users with respect to the complexity and natural overlaps between soil types. The results are compared with national soil type maps such as UKSO, bodemdata.nl. This dataset is one of the key building blocks of the Soil Health Data Cube and can be used both for direct analysis, stratification and forming soil districts, in the context of the European Soil Health law and, as valuable inputs for crop-yield modeling, land use management planning.

Polynomial Regression Ensembles for Predicting Crop Yield and Soil Quality Indicators: Towards a Future Soil Health Forecasting Service

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Crop models are generally the tool of choice for providing biophysically informed answers for a wide variety of questions regarding the production of crops and associated externalities such as soil organic carbon (SOC) dynamics, water consumption, soil degradation, nutrient pollution, etc. Vitally, they provide reliable insights into how future climate projections drive changes in crop systems - A feat that cannot be achieved with data-driven methods alone, as this would require extrapolation from historic training data. Modern crop growth simulators orchestrate many different mechanistic models that describe crop growth, nutrient cycling, harvest, and other processes. They commonly operate on a daily time step where the effects of weather, soil, site, and management variables are taken into account to compute changes in biomass over time periods spanning several years or decades. This inherent complexity results in computational time that scales poorly with the number of years or locations simulated as well as considerable effort in parametrizing the model, as many parameters are location and crop specific.

To address these issues and facilitate predictions on a large or even global scale, we propose a data-driven approach to emulate crop model simulations for biomass production and changes in SOC depending on management practices. The emulator proposed in this work is based on the EPIC-IIASA crop modelling framework. Initially, appropriate pan-European training data is generated by EPIC-IIASA with a wide range of different parametrizations that capture adequate variability in climate and soil properties as well as a combination of management practices, i.e., amount of fertilizer used, and fraction of residues left on the field after harvest. An aggregated version of the data that also includes the simulated response constitutes the training set for a series of third-order polynomial regression models that predict different soil and crop properties. These models are trained on 20-year averages of the data to mimic the long-term response of EPIC-IIASA. Some of the regression models compute intermediary quantities that are passed to other models to estimate the final response, resulting in more accurate predictions overall compared to fitting a single, data-driven emulator. For example, while a single model predicting SOC directly from the inputs would result in a R^2 of around 0.7 on the holdout set, the decomposition into submodels yields an R^2 above 0.9 across all crops and levels of management. The model network first predicts the long-term biomass response, decomposes it into root weight and yield, accounts for the carbon contained in residues left on the field based on farming practices and passes these predictions to a final module that estimates organic carbon in plow depth, i.e., the carbon sequestration potential of the field in question. This breakdown of the biomass and carbon simulation problem emulates the behavior of EPIC-IIASA accurately using readily available climate, soil, and management variables. Furthermore, the polynomial regression modelling approach results in some advantageous mathematical and computational properties. 1.) Efficient vectorization enables large-scale, pan-European yield predictions by performing a single matrix multiplication, returning results in real-time. 2.) Uncertainty intervals around predictions are well-defined and can be propagated through the model chain. 3.) Models are inherently explainable, as the relationships between covariates and response as well as their interaction and higher order effects are

quantified as coefficients. The accuracy of the models is reported as an overall predictive R^2, RMSE and MAE on a holdout dataset not used for model training. To show prediction accuracy for specific locations we also provide distributional statistics for these values when evaluated across all locations in Europe.

Two use cases are presented to highlight the applicability of the approach: A Farmer's Advice app that informs the user about the long-term effects on their field as a consequence of management practices as well as an extended application of the models to locations within a 1 by 1 km grid across Europe. Our results highlight that emulating crop models, or parts of them, with data-driven counterparts constitutes a viable approach to drastically reduce the computational and operational effort for predicting crop and soil properties. Furthermore, the reduced set of parameters required to generate predictions opens up a wide range of potential applications, such as citizen science initiatives or the integration of crop models into larger model ensembles.

Spatiotemporal prediction, uncertainty estimation and their assessment of soil organic carbon density (2000-2022) at 30~m resolution for Europe

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We developed a comprehensive modeling framework for Soil Organic Carbon Density (SOCD) mapping across Europe, producing high-resolution (30 m) SOCD maps for every four years interval from 2000 to 2022, at four depth intervals (0–20 cm, 20–50 cm, 50–100 cm, and 100–200 cm), with accompanied pixel-based 95% prediction interval. This framework, utilizing Random Forest (RF) and Quantile Random Forest (QRF), emphasizes both model performance and computational efficiency. The SOCD prediction model demonstrated strong performance in both 5-fold spatial cross-validation (MAE = 8.66, MedAE = 4.3, and MAPE = 0.54) and independent testing (MAE = 7.81, MedAE = 3.59, and MAPE = 0.45), with R2 values exceeding 0.7 and concordance correlation coefficients (CCC) above 0.8. Validation of the PI estimation confirmed that PIs effectively capture uncertainty intervals, though with reduced accuracy for higher SOCD values. Our temporal uncertainty analysis highlights challenges in detecting SOCD changes over time, with PI overlap indicating limitations within the current timeframe. Exploratory analysis using Shapley values identified soil depth as the most important feature, with vegetation and long-term bio-climate features as the two major contributing feature groups. All data and code used in this study are publicly available at https://gitlab.com/AI4SoilHealth.

Predicting Soil Salinity Using Sensor Data and Machine Learning in a Hydromeliorated River Delta

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Sea-level rise (SLR) and the intensification of seawater intrusion (SWI), exacerbated by climate change, represent significant threats to both surface and groundwater resources in coastal regions. The Mediterranean, including the Adriatic Sea, is recognized as a critical hotspot for these phenomena, particularly affecting low-lying coastal areas such as estuaries and deltaic plains. One of the key consequences of these processes is the salinization of water resources, which in turn leads to soil salinization, a major factor limiting agricultural productivity in coastal regions, especially in river deltas. Globally, over 830 million hectares (Mha) of land are classified as salt-affected. Traditional soil salinity monitoring methods, including field sampling and laboratory analysis, are precise but are often costly, time-consuming, and lack the real-time data necessary for timely decision-making. Recent advances in soil sensor technology have enabled the use of indirect methods for assessing soil salinity, such as the measurement of apparent electrical conductivity (ECa), which has become widely adopted in both research and agricultural practices. In particular, ECa measurement is frequently used in irrigated soils to estimate salinity levels. Accurate, real-time data on soil and irrigation water quality can inform predictive models, facilitating improved water and soil management by farmers. This study was conducted in the Luke polder of the Neretva River Delta (NRD) on the eastern Adriatic coast (43°1'37"N, 17°33'39"E) during the cabbage (Brassica oleracea var. capitata) irrigation season from March to June 2022. The objective was to develop, test, and evaluate the performance of various machine learning (ML) models, including multiple linear regression (MLR), regression tree (RT), random forest (RF), support vector machine (SVM), and extreme gradient boosting (XGB), for short-term prediction of ECa in the soil profile down to a depth of 1 meter. The daily ECa values in the study area were strongly influenced by saline groundwater and saline surface water from drainage canals used for irrigation. The ML models incorporated five input variables to predict daily ECa values: water depth and electrical conductivity (ECw) in drainage canals and in shallow piezometers, and the volume of irrigation water applied. Model performance was evaluated using the Akaike Information Criterion (AIC), mean absolute error (MAE), and root mean square error (RMSE). The dataset, consisting of 92 daily observations of the input variables, was divided into training and validation sets (80:20). Results indicated that the RF model exhibited the highest predictive accuracy, with an MAE of 0.198 dS m^{-1} and an RMSE of 0.226 dS m^{-1}, followed closely by the XGB model with an MAE of 0.204 dS m^{-1} and an RMSE of 0.248 dS m^{-1}. Despite the relatively small dataset, the findings demonstrated that accumulation of salts in the soil profile up to 1 meter, represented by ECa, can be effectively predicted using input variables such as water depth, ECw, and irrigation volumes. This research provides valuable insights for agricultural producers and policymakers in coastal regions, particularly in river delta areas, by supporting the optimization of irrigation practices and mitigating the detrimental effects of soil salinization.

The work presented here was co-funded by the project "Advanced agroecosystem monitoring system at risk of salinization and contamination" (K.K.05.1.1.02.0011) financed by the European Regional Development Fund, and by the European Union Horizon Europe - Research and Innovation Programme under grant agreement No. 101086179 (AI4SoilHealth).

Optimizing Soil Block Division to Minimize Erosion: A Comprehensive Simulation Approach Using Agent-Based Modeling

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The Czech Republic faces the challenge of extensive soil blocks, remnants of collectivization, which significantly contribute to soil erosion. Current legislation requires the division of blocks larger than 30 hectares; however, commonly used division methods may not be optimal for erosion prevention. This study presents an innovative methodology for optimal soil block division aimed at minimizing erosion. We employ agent-based modeling in the NetLogo environment to simulate soil particle flow on both virtual and real 500x500 meter soil blocks. On virtual blocks, we model various surface topographies (convex, concave, flat) and flow directions (divergent, convergent, parallel). We implement Quinn's multi-directional flow model and test various configurations of alternating crop strips with different widths and orientations. To more accurately simulate strip cropping, we modified the calculation of potential water erosion to account for crop diversity in the contributing area, which standard methods overlook. This adjustment allows for a more realistic assessment of erosion processes in complex agricultural systems. Our results challenge the common assumption that contour-aligned division is always the most effective for erosion prevention. We found that a key factor is placing the less erosion-prone crop at the lowest part of the slope. In some cases, contour arrangement may lead to higher erosion than other division angles, with effectiveness depending on specific topography and runoff characteristics. This study provides a comprehensive view of the soil block division issue and offers potential for developing more sophisticated land management strategies. Although we do not directly use artificial intelligence, our approach based on detailed simulations paves the way for future AI applications in land use optimization and erosion prevention across diverse terrain conditions.

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Towards use of AI-Powered Hybrid Soil Health Assessment to Design Nature-Based Solutions for Restoration of Degraded Soils in Sub-Saharan Africa

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Soil is the basis for almost all of the food we produce on this planet. In total, more than 95% of the food we produce is rooted in the soil, making soil of critical importance for today's food security. Ecosystem services, such as food production, biodiversity conservation or climate regulation, are tightly coupled with soil functions, e.g. organic matter cycling, and threats to soil, e.g. erosion. Despite this strong link, around 75% of the Earth's soil has been degraded due to human activities, especially in climatically vulnerable regions with sensitive soils, as found in many places in Sub-Saharan Africa (SSA). This high level of soil degradation not only results in declining food production but could also lead to lower farm income and household well-being. Given the importance of soils in maintaining ecosystem services, it is essential that measures are taken to improve soil health. This requires accurate assessment of the impact of different management measures such as nature-based solutions, and their efficacy in different sites. In this work, we propose a novel hybrid modelling solution, combining: 1) the explanatory potential of modelling approaches based on biophysical processes; 2) the power of Artificial Intelligence (AI) models built on vast amounts of data; and 3) the unique experience of different stakeholders, such as farmers, through knowledge-based modelling. This hybrid solution, integrated into a data processing pipeline, will not only employ in-situ field data from chemical, biological and physical soil health indicators, but also satellite imagery. In an extensive benchmarking process, we will compare different types of models as well as fusion types to obtain most accurate assessments of the impact of nature-based solutions on soil health in SSA. Ultimately, this comprehensive solution could not only enable more precise soil health assessments for any type of stakeholder, but also uncover hidden insights into approaches that could be used to improve soil health.

Budapest Soil Health Forum

Improving Soil Health: Amendments, Monitoring, and Modeling

International Conference

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Abstracts of oral presentations - Improving Soil Health: Amendments, Monitoring, and Modeling

Mapping of bundles of soil-based ecosystem services in the European Union and their evolution by 2050

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Soil health can be assessed by the extent in which the soil is able to provide various ecosystem services. Ecosystem services are the direct and indirect contributions of an ecosystem to human well-being. The ecosystem services provided by soils or related to soils are known as soil-based ecosystem services (SESs). SESs are directly and quantifiably controlled by soil chemical, physical and biological properties, processes and functions. SESs do not occur separately in the environment, but simultaneously. They should thus be evaluated together as SESs bundles. In addition, these services are threatened by global changes, such as climate change and changes in land use, which will affect their provision. This work aims to define SESs bundles at the European Union (EU) level, and to evaluate the effect of climate and land use changes on their evolution by 2050. The SESs assessed include hydrological control (HC), soil erosion control (SEC), greenhouse gas and climate regulation (GHG), and primary biomass production (PBP). To assess HC, the digital soil mapping approach was used. SEC was quantified through the Revised Universal Soil Loss Equation (RUSLE). For GHG and PBP, dynamic global vegetation models (DGVMs) produced by UK Earth System Models (UKESM) were exploited. The impacts of climate change were assessed using two Shared Socioeconomic Pathways (SSP1-2.6: sustainable scenario, and SSP5-8.5: high-emission scenario with significant climate impacts). Concerning land use change, we used the projections provided by the LUISA (Land Use-based Integrated Sustainability Assessment) modelling platform. The assessment offers a comprehensive analysis of the spatial distribution and projections for the SESs bundles in the current state and by 2050. Clustering methods, specifically k-means, were employed to identify SESs bundles at EU scale. The proposed approach allowed us to identify hotspots with high or low provisions of SESs and how they will be evolved by 2050 under the pressure of climate and land use change. Moreover, it could provide guidance for sustainable agriculture in the framework of the EU Green Deal and the Soil Strategy for 2050.

Session 1

Monitoring and assessing soil health

The impact of erosion processes on soil properties and crop yields in the chernozem region

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In this presentation, we address the impact of soil erosion on crop yields in erosion-prone chernozem areas of South Moravia. In these areas, we conducted long-term research on erosion processes and changes in physical, chemical, and biological properties in different parts of slopes (erosion, transitional, and accumulation zones), with the most significant changes to be presented in this contribution. This research was also important for studying changes in crop yields. We studied the impact of erosion on yields in areas with winter wheat, which is one of the most widespread crops in the region. During the research, we tested various indices; the Enhanced Vegetation Index (EVI), cited in literature as one of the best correlates of yield, was ultimately used to provide indirect information about yield. Erosion areas on chernozems are often visible in orthophoto images, but the necessary images are not always available. Therefore, we proposed a method for identifying areas affected by erosion based on the use of Sentinel 2 satellite images and NDVI or NBR2 indices. The relationship between yield and erosion was then expressed using Pearson's correlation on a sample of randomly selected pixels. The obtained results showed a statistically significant linear decrease in yield depending on the level of degradation. All plots were further reclassified according to the degree of degradation into categories of high, medium, or low degradation status. Subsequently, EVI values were calculated, resulting in wheat yields on non-degraded areas being on average 16% higher than on erosion-affected sites. We verified these results in pot experiments with similar yield changes between erosion and deposition parts of slopes. Research on the impact of erosion processes on soil properties was important not only for planning anti-erosion measures (e.g., strip cropping) but also for discussions with farmers and soil protection policymakers.

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Soil health in urban areas: knowledge, assessment and measures for protection and improvement

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Urban soils are primary components of cities and main supports and suppliers of a large range of ecosystem services. Maintaining and enhancing soil health can be particularly challenging in cities, where soils are exposed to many degradation processes and can be deeply disturbed by anthropic activities and contamination. In this communication we will discuss some of the main challenges for soil health protection and improvement in urban areas. First, knowledge of urban soils is still insufficient compared to soils in non-urban areas. The availability of a thorough knowledge of soil morphology and properties is a very valuable tool for soil health assessment in the cities. Second, development of sound, widely accepted methodology for soil health assessment is necessary. Soil health assessment is an essential part of policies for soil and environmental management and protection, but many difficulties exist for developing methodology, so we are currently far from having widely accepted methods for assessment. Finally, the reuse of waste streams as a tool for improving soil health in urban areas with multiple benefits for soil protection and circularity will be examined. Examples from recent studies undertaken in the city of Santiago de Compostela, in northwestern Spain, will be presented for discussion of all these aspects.

Hybrid monitoring and modelling of soil moisture in a Nordic wheat field

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Soil moisture content determines many decisions in agricultural land use. It determines what kind of crops can be cultivated, when operations can be planned and how the yield will turn out. It also is a pivotal factor in the generation of overland flow and its dynamics are a driver for flooding. Knowledge of soil moisture is important for many stakeholders in the agro-hydrological landscape. The required spatial resolution and accuracy of this knowledge varies with the intended use and the associated stakeholders. For flood prediction, regional estimates of soil moisture content for major land use groups are often sufficient for the parameterisation of large, basin, scale runoff models. At the other end of the spectrum, irrigation needs may vary from one plot or tree to the next. In northern Europe, the timing of harvesting and tillage operations in early autumn depends highly on soils' trafficability. While methodologies for small scale (regional) soil water content estimation have an established history and adequate performance, large scale (sub-field) estimates are still error prone.

Methods for the estimation of soil water content can broadly be divided into those based on measurement and those based on simulation. Measurement of soil moisture has been restricted to the point level while it consisted of taking and weighing samples or installing and reading a sensor. The advantages of the accuracy of point measurements are often outweighed by the uncertainty about their representativeness and the costs of operating a continuous scheme for a whole field. Soils, even agricultural soils, are notoriously heterogeneous in their physical and chemical properties. This implies that there is a hard limit to the combination of representativeness and accuracy. Simulation models, on the other hand, are not restricted to the point level. Their representativeness is limited to the availability of the geodata that is required to parameterise the model and to evaluate its performance.

Remote sensing may provide new ways to come to new estimates of soil moisture content in the topsoil, or to better integrate modelling and measuring approaches. Satellite and UAV (drone) imagery capture the soil surface reflection in different EM-bands. While imagery in the visible part of the spectrum can provide useful insight into the development of vegetation, crops or other above-ground processes, different wave lengths are required for a deeper look. In this study, the potential of a two-pronged approach to the estimation of superficial soil moisture content is explored. It was hypothesised that the combination of satellite imagery and soil moisture modelling would result in better estimates than the respective individual methods.

A 0.27 km² wheat field in southeastern Norway was monitored intensively for a growing season in 2017 (May - September). Superficial soil moisture was measured manually (handheld TDR) once per one or two weeks at 30 to 50 locations. In addition, crop growth was monitored by recording crop height and (vertical) vegetation cover. Two series of satellite imagery were recorded. Sentinel-2 imagery was processed to get the Normalised Difference Vegetation Index (NDVI) for crop coverage. Synthetic Aperture Radar (SAR) imagery was processed and tested for its suitability to detect spatiotemporal differences in moisture content in the topsoil. Drone imagery was taken at several moments during the monitoring and the consecutive year.

The Hydrus-1D soil hydrological model was calibrated for clay and sandy loam soils (of the monitored field. The soil texture-specific spatial averages of the soil water content measurements were used as

reference data. The simulated soil water balance elements were evaluated and compared with those derived from ground and remote measurements.

The results of the research indicate that SAR imagery gives reasonably reliable soil moisture estimates at the sub-field level. When the estimates were aggregated by texture group in the study area, the results were satisfying. The study also shows that hybrid monitoring of water balance elements combined with inverse modelling can be successfully used for developing spatially representative soil hydraulic functions. These functions can further be used for predicting soil water content at field scale under changing conditions.

Assessing the effects of soil and crop management practices on soil quality and health indicators in the rice-wheat cropping system under semi-arid climate

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Assessment and monitoring of soil health and its links with sustainability and food security has gained paramount significance on global scale. The rice-wheat cropping system (RWCS) is backbone of agriculture and food security in South Asia including Pakistan. We analyzed 95 soil samples from the rice-wheat belt in Pakistan for physico-chemical and biochemical properties and tested the effects of soil and crop management practices on these soil quality indicators. Crop management practices included rice (direct-seeded vs puddled conditions sowing) and wheat (zero tillage vs seed-bed sowing) whereas soil management practices were organic amendments (no amendment vs animal manure), irrigation sources (tube well vs canal plus tube well mixed), rice residue management (burning, removal, incorporation and zero tillage), and wheat residue management (removal vs incorporated). Soil pH, bulk density (BD; g cm-3), soil basal respiration (mg CO_2-C g-1 24 h^{-1}) and total organic carbon (TOC; g kg-1) ranged from 7.31-8.84, 0.79-1.65 g cm^{-3}, 0.21-3.10 mg CO_2-C g^{-1} 24 h^{-1} and 0.66-11.5 g kg^{-1}, respectively. Application of manure and mixing tube well and canal water reduced soil pH. Crop residue retention and zero tillage resulted in lower soil pH than removing or burning the residues. Application of mixed irrigation significantly reduced soil BD compared to tube well irrigation. Incorporation of both rice and wheat residues and zero tillage practices reduced soil BD than burning and removing the crop residues. Soil basal respiration was nearly two-fold higher under mixed water irrigation compared to the tube well irrigation. We also found that incorporation of rice and wheat residues significantly enhanced soil basal respiration and values were two-times higher compared to burning, removing and retaining crop residues under zero tillage practices. Soil basal respiration was significantly higher under puddled nursery sowing than the direct-seeded rice. Addition of animal manure and mixed irrigation practices increased TOC contents. Moreover, rice and wheat residue incorporation enhanced TOC contents when compared with residue removal and burning. Data was also assessed in terms of chronosequence of adaptation of RWCS i.e. <10, 10-30, 30-60 and >60 years and the data revealed that soil pH did not change much, BD decreased over the years and was the lowest after >60 years of adopting RWCS, soil basal respiration was the highest at <10 years chronosequence and was the lowest at >60 years chronosequence and TOC contents increased with increasing duration of adopting RWCS. Our study demonstrated that BD, soil basal respiration and TOC were influenced more by the crop and soil management practices than soil pH and, hence, were more sensitive indicators of soil quality. Data also suggested that these soil quality indicators strongly reflect the long-term changes in productivity and soil health of RWCS. Application of animal manure, retaining crop residue, mixing tube well and canal water, adopting zero tillage practices and continuity of these practices on long-term basis could enhance the sustainability of the RWCS under semi-arid climate and ensure local and regional food security.

The impact of high ratio in forests on the Baltic urban planning: the cases of Tallinn, Riga, Tartu, Kaunas, Vilnius

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The Baltic Countries (Estonia, Latvia, Lithuania) are extremely rich in forests: the ratio is 40-60%, and the highest is in Estonia. Their cultural heritage reflects the forests, too: let us consider the iconic piece of Lithuanian folk literature, Eglė of the Queen Snakes, which has been elaborated in dramatic and poetic pieces of fiction, too, and trees play an iconic role in other pieces of the folk culture and fiction, too. Estonia's richness in forests impacted the modern Estonian identity linked to the trees, too, and nowadays Estonians visit some "saint" trees and celebrate their ritual events, expressing their Estonian identity linked to the earth and trees. In this paper, the three capitals, Tallinn, Riga, and Vilnius, and the two emblematic university towns, Tartu and Kaunas are chosen for cases-studies, how the green area in modern urban architecture reflects the high ratio of forests and the cultural heritage in modern urban planning.

The investigated problem is, how the identification of the Baltic peoples is reflected in their urban culture, in recent and former capitals. Considered aspects: – impacts made by the Soviet immigration on urbanization, which ruined all that was green and traditional; – how and to what extent the local special heritage is preserved in the urban architecture. Latvia and Estonia belong to the "Baltic" region in a narrower sense: former Hansa towns with merchant architecture: stores under the roofs of old houses from the Middle Ages, together already with the postmodern, too. In Tallinn, the "globalized" shopping complex around the Soviet-style Hotel Viru in the downtown may symbolize how the postmodern urban architecture solved the problem of closeness to nature in traditional cultural heritage, as well.

Latvia and Estonia belong to the "Baltic" region in a narrower sense: former Hansa towns with merchant architecture: stores under the roofs of old houses from the Middle Ages, especially in Riga, which is the largest capital city, and already postmodern, too. In Tallinn, the "globalized" shopping complex around the Soviet-style Hotel Viru in the downtown may symbolize the postmodern character of the Estonians, as well.

Vilnius stands out with its baroque heritage (unlike medieval Tallinn and Riga), and its special couleur locale, too: the old and new quarters are built cyclically, as an onion, not combining. Thus, modern architecture is built around the downtown, while in Tallinn it is almost imposed in the downtown. Kaunas, after being a former Tsarist military garrison city, became the capital of independent Lithuania in 1920-30-ies; then, in Soviet-occupied Lithuania, Kaunas played the role of the "very, real" Lithuanian city, in contrast to Vilnius; all this has also been reflected in its external appearance, too. Consequently, in all three Baltic countries, the trend towards Nordic cultures is undoubtedly, also in Lithuania, a rather Central-European country, which nowadays strives to be Nordic. At the same time, all three Baltic countries take special care of their national heritage in the urban culture, too, in particular in wood matter and green areas, as well.

The author continues his earlier presentations, such as that in Naples, Italy on September 14-15, 2023, at the 3rd International Architectural Sciences and Applications Symposium, about the cultural heritage in the three Baltic Capitals; then in Diyarbakır, Türkiye, on July 8-9, 2024, at the International

Symposium on Architecture, Engineering, and Design, about the design in the above mentioned Baltic cities. However, only abstracts were published there, and, considering all aspects of the topic, the full-paper will be given here.

The archetype of these studies was a lecture at the "ReThinking Europe in Scandinavia and the Baltic Sea Region" - The 11th Annual International Symposium of the Association of Nordic and Baltic Studies of Romania (of which the author is an elected member of the executive committee), on 28th May 2020; that presentation with the full text as well as references is accessible in the profile of the author: https://www.academia.edu/43189616/Baltic_Urban_identity… –thus, that longer and completed paper must be considered, too, while evaluating this new proposal. Differing from the former lectures, in this paper, the author focuses on the role of wood in urban architecture and the role of trees in the urban area, how the special Baltic cultural heritage of forests and trees is reflected in contemporary postmodern urbanization.

Session 2

Models and prediction tools in the soil-water-atmosphere systems

Towards an Open Soil-Plant Digital Twin Based on STEMMUS-SCOPE model Following Open Science

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Climate extremes (e.g., droughts and heatwaves) jeopardize terrestrial ecosystem carbon sequestration. The development of an open digital twin of the soil-plant system can help monitor and predict the impact of extreme events on ecosystem functioning. A soil-plant digital twin has three main components: a process-based soil-plant model, physics-informed machine learning, and data assimilation. We illustrate how our recently developed STEMMUS-SCOPE model contributes to such a soil-plant digital twin, linking soil-plant processes to novel satellite observables (e.g. solar-induced chlorophyll fluorescence). The digital twin approach allows a mechanistic window for tracking above- and below-ground ecophysiological processes with remote sensing techniques. This "open" soil-plant digital twin is created following Open Science and FAIR principles for data and research software. In this context, we explain how our recently developed STEMMUS-SCOPE model contributes to an open digital twin of the soil-plant system. In addition, we illustrate how we improved the FAIRness of the existing STEMMUS-SCOPE software. We showcase the building blocks of a soil-plant digital twin, and emphasize the importance of FAIR-enabling digital technologies, which translate research needs and developments into reproducible and reusable software, data and knowledge.

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Integrated management of small water retention and soil erosion prevention measure in agricultural catchments, Example from Slovenia

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The objective of the research was to examine the environmental and economic sustainability of agricultural soil water management (abundance, scarcity) and soil management (erosion), using small measures to retain water and prevent soil erosion in fields under conventional and conservational minimal tillage.

When analysing the impact of soil water deficit in all observed catchments, we did not observe significant differences in the monthly mean values of matric soil water potential during the growing season. During the driest period of the measurements, both conventionally and conservatively cultivated fields were in a dry state since the soil does not provide plants with access to water for a large part of the growing season. Erosion measurements on a corn field in 2021 showed the total annual amount of eroded soil in arable land (39.13 t/ha), which is 39-48 times more than direct sowing (no-till) (0.808 - 1.09 t/ha) and five times more than conservation minimum tillage (7.74 t/ha). The costs of long-term loss of eroded soil on arable land are estimated to be 1500 EUR/ha or 38 EUR/t of land. The long-term cost for local communities, which have to remove this soil from roads and watercourses, is 600 EUR/ha or 15 EUR/t of land. In terms of yield, the cultivation methods are comparable, with virtually identical yields achieved by conservation minimal tillage (40.64 t/ha) and direct sowing (no-till) (39.89 t/ha). Modelling with the SWAT model showed that by choosing effective measures, we can reduce erosion and at least partially increase water retention so that farms can effectively deal with the consequences of expected climate change. The optimisation results showed that the most economically efficient measure in all cases is conservation tillage. When introducing conservation treatment, it is still necessary to be aware that the purchase of the necessary machinery represents a relatively high cost. The effects of alternative scenarios from the point of view of the economy can be considerable (up to a few 10 %) and from the environmental efficiency minimal (a few %) or vice versa. Based on the analyses carried out, the farmers' overall highest rating for the probability of implementation was given to the measure "inclusion of greening", followed by "conservation tillage". The lowest ranked measure at the overall level is "field buffer strips on steep slopes", followed by the measure "change of ploughing direction from vertical to transverse".

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Analysing the effectiveness of Natural/Small Water Retention Measures in the Pannonian biogeographic region

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An integrated model-based evaluation of the effectiveness of Natural/Small Water Retention Measures (NSWRMs) was conducted in two Hungarian case studies (Felső-Válicka and Tetves) using the Soil Water Assessment Tool (SWAT+) model. The Felső-Válicka case study covers 124 km², while Tetves covers 72 km². Both areas are hilly, located within the Lake Balaton catchment area, and are part of the Pannonian biogeographic region.

We applied the R workflow developed in the OPTAIN project (Optimal strategies to retain and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe) to facilitate input data preparation, model setup, calibration, and scenario simulations. In our model configuration, individual fields or parcels can transfer surface runoff and lateral flow to neighbouring objects (using the contiguous object connectivity approach), allowing us to assess the site-specific effectiveness of NSWRMs within the catchment. The performance of different NSWRMs was evaluated based on changes in hydrological indicators (water quality and quantity in the watercourses), as well as soil hydrological and nutrient indicators, and crop yields. In the Tetves case study, the following NSWRMs were assessed: 1) riparian forest buffers, 2) forested buffer strips between agricultural parcels, 3) no-till management combined with cover crops, and 4) land use change from cropland to meadow. In the Felső-Válicka case study, we analysed 1) riparian forest buffers, 2) forested buffer strips between agricultural fields, and 3) no-till management combined with cover crops. Results indicate that no-till management with cover crops has the highest projected impact on all analysed indicators, showing positive effects on water and nutrient retention without significant loss of arable land and crop yields. Other NSWRMs demonstrated less impacts on water and nutrient retention in our case studies but all measures positively contributed to the catchment's water management.

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Mapping and classifying soil hydraulic properties in Hungary using statistical clustering and expert insights

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The knowledge of soil water management properties is of outstanding importance for agricultural, hydrological, and other environmental modelling and analysis. To support the description of soil hydraulic processes, we derived a new 3D soil hydraulic map for Hungary at 100 m resolution, covering six soil layers up to a depth of 2 m (HU-SoilHydroGrids). In addition to this dataset, which contains continuous values of the computed soil hydraulic parameters, there is a need to aggregate the map information to enable its application in large-scale hydrological models with high computational demands. In Hungary, the Várallyay soil water management categories map provides an opportunity for the hydrological classification of soils. The map, with nationwide coverage, was designed to support the planning and implementation of agricultural water management interventions. Its nine soil water management categories and seventeen variants were created based on expert rules, taking into account field capacity, wilting point, available water content, infiltration rate, saturated hydraulic conductivity, and the vertical variations in soil texture. The newly available quantitative 3D soil hydraulic maps offer the opportunity for statistical classification of soil hydraulic properties. In this research, we performed the hydrological classification of Hungarian soils, based on both Hungarian and international studies. As the first step in our methodology, we performed clustering using the k-means method on the 100 m resolution HU-SoilHydroGrids database. In our analysis, we considered eight soil hydraulic parameters across six soil depths (van Genuchten parameters, water content at saturation, field capacity, and wilting point, as well as available water content, and hydraulic conductivity), which allowed us to statistically identify twelve classes. The soil groups created through statistical analysis provide a solid foundation for the numerical delineation of soil hydrological groups in Hungary. However, expert review of the clusters are necessary to ensure that underrepresented groups, which differ significantly from a soil water management perspective, are also included. As a result, we further subdivided the twelve groups based on soil profile depth, genetic soil type, electrical conductivity, and exchangeable sodium content. Using the statistical method supplemented by expert rules, we created 68 categories. A key consideration in the development of the soil hydrological groups was ensuring their applicability in environmental modelling.

The preparation of the HU-SoilHydroGrids dataset was carried out within the framework of the Széchenyi Plan Plus program with the support of the RRF 2.3.1 21 2022 00008 project. The derivation of the soil hydrological groups was funded by the Sustainable Development and Technologies National Programme of the Hungarian Academy of Sciences (FFT NP FTA). The statistical computations were performed in the HUN-REN Cloud (https://science-cloud.hu/) e-infrastructure.

A rapid assessment of soil organic carbon stocks of whole Pakistan by using IPCC tool and ARC GIS

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Robust and accurate estimation of soil carbon (C) stocks are needed to implement future research and policies targeting the improvement of soil health, reduction of emissions of greenhouse gases as carbon dioxide (CO_2), especially from the agriculture sector. The situation of countries like Pakistan, where current knowledge on soil C is scarce, requires particular attention. The Intergovernmental Panel on Climate Change (IPCC), through general guidelines proposed a methodology for predicting soil organic carbon (SOC) stocks and changes – the IPCC Tool. In this work, the IPCC Tool was used in combination with geographic information systems (GIS) to obtain a map of high resolution (1 km^2) for the SOC stocks (0–30 cm depth) in Pakistan. The study used wide IPCC-based soil, climate, land use, land cover and land management information specifically developed for Pakistan. Average SOC stock levels (0–30 cm depth) per district ranged between 4.7 and 68.4 Mg C/ha soil, with a contrasted distribution North-South. IPCC-estimated SOC stock values (0–30 cm depth) showed a weak but significant correlation with those SOC values obtained from the Global Soil Information system (SoilGrids; www.soilgrids.org; current available country-level source for Pakistan; $R^2 = 0.515$, $P < 0.001$, $n = 141$). Hence, the IPCC-estimated SOC stock down to 30 cm for whole Pakistan was approximately 2.9 Gt C, lower than that obtained from SoilGrids (approximately 3.1 Gt C) for the same area. The SOC digital map and SOC database developed in this study provide vital background information for country-level up-to-date assessment of soil C stocks, which will encourage future development in this area. Especially it was much needed study for the country for the better policy making to improve the overall soil health. Present work can be easily replicate for any country and give the similar benefits to soil scientists, researchers and policy makers.

Session 3

Improving soil health: new technologies and land management

The standard and protocol scheme for soil spectral reflectance in both laboratory and field

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For over 30 years, various research groups worldwide have been active in the soil spectroscopy realm. These groups measure soil reflectance across the VIS–NIR–SWIR (0.4–2.5 μm) region in the laboratory, mainly for chemometric purposes. As a result, many soil spectral libraries (SSLs) have been generated with local to continental coverage, each making use of different sensors and protocols. As soil is a dynamic and complex system affected by a plethora of different variables, small changes to its state might induce significant changes to soil's VIS–NIR–SWIR reflectance. To this end, measuring reflectance spectroscopy of soils must be very accurate since it is a procedure very sensitive to measurement geometry, illumination status, sensor output, sample preparation, and more, and thus, merging or comparing SSLs remains a problematic issue. In addition, since hyperspectral remote sensing (HSR) technology is entering a new and promising era (from both air and space domains), the utilization of SSLs is becoming more and more attractive to users for the direct implementation of SSL models on HSR data, for which consolidated harmonized SSLs at a global scale would be a must . Measuring soil reflectance by agreed standards and protocols should thus also be aligned with HSR technology. In this context, a group of highly motivated soil spectroscopy and HSR scientists joined together since 2020 under the umbrella of the IEEE-Standard Association Working Group P4005 "Standards and Protocols for Soil Spectroscopy." This activity is connected with the GLOSOLAN-SPEC working group aims to build a globally representative soil spectral calibration library (database) based on VNIR-SWIR-MIR spectra and the accompanying soil property reference data recorded in one gold-standard reference lab. The idea is to study how the wide range of protocols, sensors, and measurement methods can be practically assessed and treated to enable SSLs harmonization. The project lasts 48 months, where currently the P4005 WG provided a draft protocol version #8 for laboratory VNIR-SWIR measurements while the next protocols for field measurement and extension of the spectral range to the LWIR spectral region are in progress. We also examined ways to facilitate standard measurement within and between laboratories. In this presentation, we will describe the VNIR-SWIR protocol, the harmonization processes developed, and report on the first activities towards exploiting the SSLs that originated from disturbed (in the laboratory) soil surface to undisturbed soil (in the field) that is the interface between the airborne- and orbital- HSR sensor, and the SSLs.

First steps towards the computation of a multifactorial soil quality index (SQI) for vineyard soils: a multidisciplinary approach

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The assessment of soil quality is essential to guarantee food production and safety. On a global scale, the increasing and unstoppable soil consumption and degradation make both the protection and the preservation of soil health mandatory, along with the development of suitable and sustainable restoration strategies.

In this study, conceived within and funded by the Agritech National Research Centre (CN00000022), the soil quality of three Apulian vineyards (i.e. two located in the district of Bari, one in the district of Taranto) is under investigation. All vineyards produce the Allison seedless table grape variety, are trained by tendone trellis system and fertigated, but show different productivity.

Seeking a link between soil quality and grape production, multiple soil characteristics have been taken into account, including chemical, physical, biological and phytosanitary parameters. In particular, all vineyard soils are investigated for: pH, OC, total N, CEC, available P, carbonates, CO_2 e N_2O emission (chemical indicators); bulk density, texture, hydraulic conductivity, electrical conductivity, temperature, humidity (physical indicators); enzyme and microbial activity, and QBS-ar, this latter based on the abundance of micro-arthropods in soil (biological indicators). Phytopathogens are also constantly monitored. Both traditional analytical methods and innovative technologies are used, including ad hoc developed equipment for in field measurements (e.g., photoacoustic sensors and robotic systems).

Furthermore, in one of the vineyards (Turi, BA), which locally showed slightly different soil characteristics and productivity, an extensive investigation has been set up in order to assess the spatial variability of a selected number of soil properties in relation to grape production. This will provide a sufficiently large dataset for multivariate statistical analysis, with the aim of computing a multifactorial soil quality index (SQI) able to monitor and evaluate the quality of vineyard soils.

After the first soil sampling in fall '23, other samplings are scheduled (June '24 and fall '24) to appreciate possible variations in soil indicators over time or with seasonality, especially for biological indicators. The completion of soil sampling and analysis by the end of the year, along with the acquisition of productivity data will allow to comprehensively assess the quality of the soils under investigation, thus posing the bases to propose sustainable strategies for soil quality improvement.

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Biological solutions to phosphorus deficiency: promoting maize growth with phosphate-solubilizing bacteria

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The agricultural sector is grappling with numerous challenges, including the effects of climate change and the decline in soil fertility, which are significantly hindering the production of essential food crops. To address the growing global food demand and compensate for nutrient-depleted soils, farmers often apply large quantities of chemical fertilizers. Unfortunately, this approach raises environmental and health concerns and fails to address the low bioavailability of certain nutrients, particularly phosphorus (P). Furthermore, natural P reserves are limited, making it crucial to mobilize P from every possible source. Soil microorganisms, particularly phosphate-solubilizing bacteria (PSB), can convert insoluble forms of P into plant-available forms, thereby enhancing crop growth in P-deficient conditions. This work explores innovative strategies to enhance P availability and promote sustainable agricultural practices using phosphate-solubilizing bacteria (PSB). The research is focused on three main objectives: (i) evaluating the effects of PSB inoculation on the growth of maize in a P-deficient soil; ii) assessing the ability of PSB to solubilize calcium phosphate from by-products; and (iii) devising new formulations of PSB using by-products-derived carriers.

Three PSB strains, Rhodococcus sp. EC35 (B1), Pseudomonas sp. EAV (B2), and Arthrobacter nicotinovorans EAPAA (B3) were tested individually and in combination (BM) on maize grown in a P-deficient soil. The soil received three different P treatments: control (no P fertilizer), soluble P (KH_2PO_4), and sparingly soluble P (tricalcium phosphate; TCP). Overall, PSB inoculation enhanced maize growth across all treatments. In the absence of P fertilization, bacterial inoculation increased P accumulation in both roots and shoots, as well as dry biomass by approximately 20%. Strain B2 exhibited the best results in soils with soluble P, boosting root and shoot biomass by 102% and 63%, respectively. In TCP-amended soils, PSB inoculation, particularly with strain B3 and the mixed inoculants (BM), also promoted maize biomass and P uptake.

In addition, the research includes efforts to develop new formulations of PSB using carriers derived from by-products. Indeed, several strains showed ability to solubilize hydroxyapatite obtained from fish by-products, suggesting that by-product of the fishing industry, could serve as an alternative P source when combined with PSB. These advances will enable to create more efficient and sustainable biofertilizers, further contributing to environmentally friendly agricultural practices.

Exopolymer of *Paenibacillus polymyxa* adsorbs heavy metals from soil and water

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Microbial exopolymer (EPS) have gained significant attention as promising tools in bioremediation due to their non-toxic properties and capacity to interact with various heavy metals. Here, we have demonstrated the adsorption capacity of EPS, produced by a strain of *Paenibacillus polymyxa*, for multiple heavy metals, including Cr, Co, Cu, and Zn. The EPS was prepared by ethanolic precipitation from the culture broth of P. polymyxa. Cr was quantified by colorimetric method with 1,5-diphenylcarbazide, while the concentrations of Co, Cu, and Zn were determined using ICP-OES. *P. polymyxa* produced a maximum of 64 g/L of EPS when cultivated in an EPS-inducing medium for 72 hours at 28 ºC. In soil, the EPS showed adsorption capacities of 34.15 mg/g for Cr (67.20%), 8.80 mg/g for Co (38.63%), 38.63 mg/g for Cu (26.88%), and 7.67 mg/g for Zn (24.63%). Furthermore, we showed that Cr adsorption capacity of EPS in aqueous solution was determined to be 84.8 mg/g, following the Langmuir adsorption model. Our findings demonstrate the adsorption capacities the EPS produced by *P. polymyxa* for Cr, Co, Cu, Zn, and Pb, suggesting its potential application in the bioremediation of metal-contaminated soils and water. Future research will focus on elucidating the molecular structure and monosaccharide composition of EPS to further understand its binding mechanisms and optimize its bioremediation efficacy.

The importance of biological soil crust forming microalgal cultures on soil in croplands and vineyards vulnerable to erosion

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Land degradation and desertification driven by climate change are threatening nearly half of the EU member states. In Hungary, around 2.3 million hectares of land are affected by wind and water erosion. Consequently, preserving and enhancing our soils are essential for the agriculture. Biological soil crusts can be found on the top layer of the soil and include various microorganisms such as algae, cyanobacteria, lichens, and mosses. Even though their biomass in the environment is relatively low, their influence is on soil is significant. These crusts perform multiple roles in the ecosystem, including improving soil structure and hydrological properties, promoting microbial communication and increasing resistance to erosion, which helps the establishment of higher vegetation. During our research, we assessed the effects of BSC forming Klebsormidium bilatum microalgal cultures in sloping farmland and vineyards. The microalgal culture tested in the experiments was developed by Albitech Biotechnological Ltd. Our tests included measurements of soil moisture, aggregate stability, porosity as well as determining soil loss from artificial rainfall simulations. Following the re-isolation of the utilized microalgal culture, we can confirm that the algae successfully developed colonies on the top layer of the soil. Further results demonstrated that algal inoculation improved soil properties, leading to increased aggregate stability and porosity, while also reducing soil loss due to water erosion. These results highlight the potential benefits of microalgae inoculation in agricultural applications. The project was supported by MKI-2018-00034 grant and the National Multidisciplinary Laboratory project NKFIH-872 of the National Research, Development and Innovation Office, Hungary.

Abstracts of poster presentations

Landslide changes the soil characteristics in Leyte, Philippines

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Little information is available on the effects of landslides on soil properties. Such information is crucial for the rehabilitation of landslide-affected areas. Thus, the study was conducted to evaluate the changes in the morphological, physical, and chemical properties of volcanic soils due to landslides, compare the degree of changes between young and old volcanic soils, and evaluate the contribution of the soil properties to the occurrence of landslides. Soil profile examination and sampling were done in the landslide sites in Brgy. Bunga (old volcanic soil) and Brgy. Mailhi (young volcanic soil) in Baybay City, Leyte. The two catastrophic landslides were triggered by the tropical storm Megi (Agaton) in April 2022. Soil morphological properties were evaluated from soil pits while soil physical and chemical properties were determined from composite soil samples collected from representative soil profiles. Results revealed that the two sites differ in terms of morphological characteristics (soil color, texture, consistence, horizons and rock fragments). Landslide caused mixing (reworking) of soil profiles resulting in the change of soil horizons in both sites and considerable changes in the morphological, physical, and chemical soil properties. The study revealed that the characteristics of the original soils particularly color, structure, and texture greatly influenced the physical characteristics of the reworked soils. Landslides caused more severe changes in the young volcanic soil than in the old volcanic soil. It also greatly affected the chemical properties and nutrient status of the soils. High porosity, low bulk density, nature of parent materials (fragmented and unstable) of the soils as well as steep slopes triggered by severe rainfall contributed to the occurrence of landslides. Lastly, the study revealed that the kind of vegetation cover appeared to have no influence on the occurrence of the two deep landslides.

Changes in suspended sediment amounts in a small stream as a function of varying environmental conditions

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Assessing stream water quality in agricultural catchments is important to understanding the impact of agricultural practices on both soil and water ecosystems. Total suspended solids (TSS) entering small streams can pose great threats to the aquatic environment from agricultural areas. Therefore, the aim of the present study was to investigate how nearby agricultural and semi-natural land use types affect stream turbidity under varying environmental conditions. The study was conducted on a small (21 km^2) agriculturally dominated catchment, where at the outlet the Csorsza stream enters Lake Balaton, Hungary. The area is dominated by a Continental climate, with high Mediterranean influences. The summer seasons are hot and dry, and cold winters with higher precipitation amounts are typical. We analyzed a three-year-long (2021-2023) data on water turbidity, chemistry, meteorological information, and soil water content (SWC) and temperature from a nearby cropland site. Water samples were collected daily from the same collection point, and bi-weekly to monthly along the stream from the spring to the outlet, whenever water flow was present. We measured stream water turbidity (FNU), total dissolved inorganic nitrogen (as NO3+NO2 and NH4; TDIN) content, water pH, and specific conductance (SPS). Meteorological data was collected from the catchment outlet. SWC measurements were collected using 5TM sensors (Decagon Devices) at 10-minute intervals at 15 cm depth.

Our results showed a weak correlation between FNU and precipitation ($r=0.16$, $p=0.21$), due to high FNU values from low water levels. This mainly occurred during drought conditions. Weak negative connections were observed between SPS and FNU values ($r=-0.17$, $p=0.18$), showing that high precipitation lowers water conductivities. The FNU values of the groundwater spring-fed sampling point significantly differed from the other sampling points ($p < 0.05$). The results of the cluster analysis showed that three main clusters can be distinguished based on the daily sample data, which divided our dataset into three groups of daily precipitation amounts of i) precipitation sums below 4.8 mm, ii) averaging 6.3 mm, and iii) averaging 23.7 mm. The three clusters, especially the extreme events are most significantly separated along precipitation and FNU values.

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Effects of selected nature based solutions (NBS) on soil quality

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Nature-based solutions (NBS) are defines as actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. NBS use ecosystems and the services they provide to address societal challenges such as climate change, food security or natural disasters. The NBSOIL project will gather existing knowledge regarding nature-based solutions (NBS) for soils and how these can be beneficial for society.

In order to demonstrate, document and evaluate nature-based solutions on agriculturally used soils in Poland, 4 experimental farms belonging to IUNG were selected, three of which are located in the eastern part of the country and one in the western part.

The farms are characterised by varying soil and climatic conditions. The farms are characterised by a high proportion of sandy soils exposed to loss of organic matter, acidification and drought. The farms carry out multidirectional crop production with cereals as the main branch. Cereals (winter and spring wheat, winter and spring triticale, winter and spring barley, winter rye, oats), grain maize, winter and spring rape are grown. The share of cereals in the sown area ranges from 50% to 70% depending on the farm. This is a typical share of cereals in the sowing structure in Poland. Of the other crops, the following are grown: sunflower, legumes, sorghum, hops, fruit trees. Some of the farms also have animal production, dairy and meat cattle. On the farms where livestock production is carried out, in addition to arable land, there are also permanent meadows and pastures and temporary grassland. Silvopasteur is also carried out.

The main reason for using reducing tillage, applying natural organic fertilization including manure, growing cover crops, and converting arable land into permanent and temporary grassland on farms is the need to take care of the proper level of organic matter, the supply of which is low due to the sandy nature of most soils. In addition, soil cover with plants plays a key role in reducing wind erosion phenomena and nutrient losses. The use of cover crops is not feasible in the late harvest of corn for grain. In this case, crop residues are left in the field.

The research was financed as part of the NBSOIL project

Linking soil microbial extracellular polymeric substances (EPSs) with soil quality in natural soils across a precipitation gradient

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Soil microbial extracellular substances (EPSs) are considered important for soil quality provided their beneficial effects on soil biological, chemical, and physical properties. However, no clear link exists between EPSs concentration and soil quality indicators in various natural soils. Soil microbes supposedly produce EPSs to protect themselves from environmental stressors, such as drought. However, EPSs production requires significant energy and resources. There is a lack of integrated understanding of how microbial EPSs production is regulated in natural soils with varying levels of historic precipitation and resource availability. To address this gap, we conducted a large-scale survey to examine the relationships between EPS components and soil quality indicators, including several soil biological, chemical, and physical properties, along a gradient of MAP, ranging from 44 to 353 mm. We found that concentrations of EPS-polysaccharide (EPS-PS), EPS-protein (EPS-PN), and organic matter types (SOM, POXC, and WAEP) increased with MAP. Similar patterns were observed between EPSs production efficiency and MAP. Soil properties strongly associated with EPS components included soil microbial richness, diversity, N and P-cycling enzyme activities, water-holding capacity, bulk density, SOM, and soil total nitrogen. Redundancy analysis showed that MAP was the largest contributor to variations of EPS components, but its effect was largely mediated by SOM and soil biological properties. In addition to MAP, MAT had both direct and indirect influences on EPS variations. Furthermore, we calculated the soil quality index (SQI) using a minimum dataset derived from PCA of 21 variables representing soil biological, chemical, and physical properties. The relationships between EPS components and SQI were mostly indirect and similar to those between SOM and SQI; suggesting that while EPS components are significantly associated with soil quality, they are not superior indicators to SOM. This may be because EPSs represent a transient part of SOM and are subject to biodegradation. Overall, the strong relationship between EPSs production and SOM across the precipitation gradient suggests that microbial EPSs production in soils is primarily regulated by resource availability, with climate playing a smaller but significant role.

Carbon stocks and nutrient status of soils under intensive vegetable production in Ormoc, Leyte, Philippines

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The increasing demand for agricultural productivity has led to a significant shift towards intensive vegetable production in the Central Highlands of Leyte, converting forested areas into agricultural land, which raises concerns about its impact on soil carbon stocks and nutrient status. Despite this, there is a notable lack of research on the carbon stocks and nutrient status of Andisols in Ormoc, which is essential for understanding their response to intensive agricultural practices and promoting sustainable agricultural strategies. The study evaluates the chemical changes in Andisol properties resulting from the conversion of forests to intensive vegetable cultivation in Ormoc City, Leyte. Twenty (20) farmlands under intensive vegetable cultivation and one reference forest site were selected for comparison, all having closely related pedogeomorphological characteristics. Each site was divided into five (5) plots and considered pseudo-replicates. Soil samples were collected using soil auger at a depth of 0-20 cm. A total of 105 composite soil samples were analyzed for chemical properties.

The results revealed significant differences in soil pH, organic carbon content, and nutrient stocks across different sites. Soil pH ranged from acidic to strongly acidic, with intensive vegetable production sites exhibiting a wider pH range. Soil organic carbon was lower in cultivated sites compared to the reference forest site. However, SOC stocks varied significantly across sites, ranging from 34.35 to 83.01 Mg ha-1, reflecting Andisols' high carbon storage potential due to substantial Al and Fe content. Available phosphorus, exchangeable potassium, calcium, and magnesium levels were higher in intensively cultivated sites, while available nitrogen levels varied.

Long-term effects of organic and mineral fertilization on the functional and genetic diversity of soil fungi

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Fungi play an essential role in ecosystems, which cannot be provided by other species. Functionally, soil fungi can be pathogens, decomposers and symbionts which interact beneficially with their host plants. Very few data are available on soil fungal communities in agroecosystems.

In a long-term fertilization experiment performed in chernozem soil near Martonvásár (Hungary), the composition of free-living and root-associated soil fungal communities were investigated. Plots of a maize-wheat bicultural experiment, treated for 60 years with mineral (N, P, NPK), organic (manure) or combined fertilizers, were investigated. Soil samples were collected in 2022 from the rhizosphere of winter wheat at flowering phenophase. Indicators describing fungal community abundance and diversity were investigated by ITS-amplicon-based metagenomic analysis of soil samples.

Quantitative parameters of soil-dwelling fungi increased in response to both organic and nitrogen fertilization. Manure affected mainly Ascomycota species while nitrogen fertilization affected mostly Basidiomycota fungi. Any nitrogen fertilization of simple, complex (NPK) and organic treatments reduced the diversity of the fungal community. The abundance of functional groups that promote plant growth was mainly determined by the presence of N fertilizer or organic manure. The abundance and diversity of arbuscular mycorrhizal fungi in the soils and in the plant roots were drastically reduced by fertilization, and their presence is marginal under nutrient supply conditions ideal for the plant.

In the soils of agroecosystems, the extents of C, N and P supply have major importance not only for the nutrient supply of the cultivated plants, but also for the quantitative and qualitative development of the fungal communities that support, inhibit or degrade plant growth.

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Applying the SWAP model for evaluating the effectiveness of natural soil water retention measures – case studies from three European biogeographical regions

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Within the EU Horizon project OPTAIN (OPtimal strategies to reTAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe, optain.eu) project, the effects of Natural/Small Water Retention Measures (NSWRMs) on water regime, soil erosion and nutrient transport are evaluated at both, catchment- and field-scales for present and future climate conditions. Our goals were to assess the effectiveness of NSWRMs at field scale and cross-validated these results from those obtained from the catchment-scale SWAT+ model. The field-scale assessment is based on the adaptation of the SWAP mathematical model to seven pilot sites across three European biogeographical regions and on combined NSWRM – projected climate scenario analyses. For the catchment-scale assessment, the harmonized SWAT+ modelling workflow was used, developed within the OPTAIN project. This advanced approach accounts for the connectivity within the catchment and has several new features, allowing more precise evaluation of the water transport at field and catchment scales. We present the harmonized SWAP modelling workflow and the combined scenario analyses, including the implementation of various in-field measures in the SWAP model. Further, we give highlights from the first results of the comparison of the water balance elements, simulated by the SWAP and SWAT+ models at field scale.

Applying the SWAT+ model to evaluate the effectiveness of natural/small water retention measures in a boreal catchment

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Diffuse nutrient losses to Nordic waterways pose a significant challenge for agriculture. The bioeconomy transition and climate change further complicate freshwater ecosystem management, necessitating adaptive strategies to ensure both food security and environmental protection. In his study we evaluated the effectiveness of selected Natural Soil Water Retention Measures (NSWRMs) on soil erosion and loads of nitrogen to surface water bodies using the SWAT+ hydro-biochemical model. We used discharge and water quality data from a monitored catchment as reference data for model calibration. The new object-based approach, developed within the EU H2020 project OPTAIN was used to set up the SWAT+ model and to simulate the NSWRMs as hydrological objects instead of using their standard parametric representations. We evaluated the effectiveness of reduced tillage, grassed water ways, sedimentation ponds established in the forested areas and buffers on water retention and nutrient loads.

Our simulation results indicated that conservation tillage, maintaining winter stubble cover, contributes to substantial reduction of soil and nutrient losses. Grassed waterways, implemented in existing gullies can improve water and nutrient retention within the landscape. The implemented measures did not increase early spring soil moisture, which is favorable for spring cereal planting and soil trafficability. Further investigation is needed to optimize the location and type of NSWRMs within the catchment and to assess their long-term effectiveness under changing climate conditions.

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Impact of inter-row management on soil moisture variability in vineyards

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Vineyards are among the oldest agricultural lands but suffer from severe soil degradation due to erosion, poor organic matter, and intensive tillage. The main objective of this study is to investigate soil–plant–water interactions based on field measurements of soil water content (SWC) and soil temperature in different inter-row managed sloping vineyards. The following management methods were applied: no tillage (NT), tillage (T), and cover cropping (CC). The soils are Calcaric Cambisol, Loamic (WRB). We conducted field measurements in May and September 2023 (representing the flowering and harvest phenological stages), focusing on soil water content (SWC; HydroSense II), soil temperature, and carbon dioxide emissions at seven points of each slope per management system. Concurrently, continuous soil moisture monitoring (data were collected at 10 minute intervals) was carried out with sensors installed at 15 and 40 cm depths (5TM and Teros 12, Meter Group) at the bottom and top portion of each study slopes.

Soil moisture values from the continuous monitoring were generally higher at the upper slope positions than the lower ones. No significant differences in soil temperature were observed between the two positions ($p>0.05$; Wilcoxon test). The highest average SWC was recorded in the tilled vineyard during the flowering period (24.3% v/v). A strong correlation ($r=0.96$, $p<0.05$; Pearson correlation) was observed between the NT and CC systems, suggesting that these management practices had similar effects on soil moisture. Significantly higher SWC and soil temperature were recorded during the flowering period compared to data collected after harvest ($p<0.05$), which findings were highly related to meteorological conditions. The highest soil temperature was observed for CC (24.08℃) and the lowest for T (19.97℃). Regarding Soil fluxes, we found 40.8 and 35.3% higher CO_2 emissions for CC and NT compared to T, respectively. We found substantially higher average CO_2 emissions (0.84 $mgCO_2/m^2/s$) after harvest compared to the flowering stage. The findings of SWC among inter-row management suggest that both grassland and cover crop systems can contribute similarly to soil moisture balance, offering potential benefits for sustainable vineyard management.

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Study of heavy metal and nitrate pollution and mobility in Debrecen soils in model column experiments

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Monitoring and regularly assessing urban soils is crucial due to their frequent contamination with various pollutants, particularly heavy metals like zinc (Zn) and copper (Cu) from industrial activities, as well as easily soluble nitrates resulting from agricultural practices. These contaminants accumulate in soils, presenting significant environmental and health risks. Heavy metals, for instance, can be absorbed by plants and enter the food chain, posing toxic threats to both humans and animals. While small amounts of zinc and copper are essential for plant and animal growth, their elevated concentrations can lead to toxicity.

Debrecen plays a unique role in the Eastern Hungary region, sitting at the intersection of modern economic investments and traditional agricultural activities. This duality results in a mix of heavy metal pollution from industrial development and easily soluble, mobile compounds, such as nitrates, from agricultural practices. As a result, the soils in Debrecen are particularly susceptible to contamination from these sources, making it an important focus for our study.

To explore these potential contaminants, we conducted model experiments investigating the migration of these pollutants in three different soil samples from the Debrecen area. The soils tested included a loamy sandy soil and two types of sandy loam soils. Experiment was set up at three soils with similar organic carbon content (between 0.8 and 1.1%) and pH (7.90 and 7.25) but different texture (78-54% sand and 22-46% of silt+clay, respectively). In our soil column leaching experiments, designed to simulate pollution, we used a pollutant solution with copper and zinc concentrations of 1 mg/L, 10 mg/L, and 100 mg/L and 1g/L, 5g/L, 10g/L for nitrate. Soil columns were prepared in triplicate, and the irrigation pattern simulated the average rainfall distribution of a typical summer month. The concentrations of copper and zinc in the soils were then measured using the ICP-OES method. Our findings revealed that the vertical migration of these pollutants within the soil columns varied significantly depending on the soil type and the concentration of contaminants applied. Specifically, it was observed that heavy metals, such as copper and zinc, introduced at the surface, began appearing in the deeper soil layers approximately one month later. This suggests that heavy metals applied at the surface can gradually percolate through the soil, posing a potential long-term risk to urban soils and possibly contributing to environmental degradation in urban settings.

Soils were then analyzed at different depths and vertical concentration profiles were plotted. Overall, highest concentrations were measured in the upper layers for contaminants in the soil column with higher clay content (C), whereas vertical profiles were more uniform in that with lower clay content (S).

The results of laboratory column experiments were used to validate solute transport models built-up in HYDRUS modeling environment. Based on the validated models, different scenarios had been considered with variable initial nitrogen concentration to predict the vertical nitrogen distribution in the investigated soil profiles.

In conclusion, the study underscores the need for continuous monitoring of urban soils to mitigate the environmental and health risks posed by both industrial and agricultural contaminants.

Evaluation of soil conservational tillage practices for soil health and greenhouse gas emissions

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Conservational agriculture is becoming increasingly prevalent in many parts of the world. It offers benefits for soil health in certain soil types, increased soil carbon storage, in some cases, reduced greenhouse gas (GHG) emissions.

We conducted a study to assess the long-term impact of conventional ploughing and conservational shallow cultivation and no-tillage practices on the soil physico-chemical parameters and the GHG emissions of a chernozem soil. The study was carried out in the Józsefmajor Experimental and Training Farm's long-term tillage experiment (Hungarian University of Agriculture and Life Sciences). The results showed that the average GHG emissions were higher in the conservational treatments, which also resulted in higher carbon sequestration in the topsoil. The ratio of yield to GHG emissions was most favourable in the conservational shallow cultivation treatment.

Usage of an innovative water and nutrient retention technique in horticultural practice

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Drought and the continuous decline of soil organic matter are increasingly becoming global issues. It can now be confidently stated that these are the most significant yield-limiting factors in agriculture. In recent decades, drought-related crop failures have led to substantial financial losses for farmers. As a result, researchers face the pressing challenge of developing innovative solutions to reduce these losses and ensure their practical application in agriculture.

Our objective was to repurpose chicken manure from large-scale poultry farms, typically considered hazardous waste, by transforming it into composite products through the addition of materials that enhance soil organic matter and positively influence mineralization processes.

An experiment was set up to study the effects of composites made from superabsorbent polymers and organic manure in an apple (Malus domestica Borkh. 'Pinova') orchard at the experimental site of the University of Debrecen in Pallag (47°25'28" N, 21°38'31" E). The trees were planted in 2011 on M9 rootstock, with a row spacing of 4 m and a tree spacing of 1 m, trained to a 3.5 m tall slender spindle.

In our experiments, we added superabsorbent polymers into the fermented chicken manure at two different dosages (S1 and S2) and evaluated their impact on soil parameters. The findings were compared against a control group (K) and treatments using only chicken manure (KNEX). Soil tests were conducted every six weeks to monitor the effects of the applied treatments. The results demonstrated that the composite products effectively increased soil organic matter content in comparison to the control.

Our findings indicate that these composite products also enhanced soil organic nitrogen content over time and had a beneficial impact on mineralization. In brown forest soils, which have low nutrient retention and a sandy texture, we observed nitrate levels of 140-170 mg/kg in the topsoil following treatment.

These results support the notion that these composite products can significantly improve mineralization and boost water retention, particularly in soils with limited nutrient resources and low organic matter content.

Moreover it is necessary to develop an integrated water and nutrient management system that incorporates water-saving irrigation and nutrient management techniques with an increasing emphasis on optimized organic matter replenishment.

Enhancing soil water retention and optimizing nutrient supply in maize cultivation

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The extreme weather conditions caused by climate change and increasingly frequent drought periods pose significant challenges for agriculture. Enhancing the soil's water retention capacity has become crucial for successful adaptation in crop production. In our experiments, we investigated the effects of two water-retaining additives, Water Retainer (VízŐr®) and polyethylene glycol (PEG), on the growth and development of maize grown on humic sandy soil. Our aim was to investigate how these additives affect the amount of water in the soil, plant water uptake and growth parameters under different water capacity levels and nutrient supply conditions.

The experiments were conducted at two water capacity levels, 70% and 90% of the soil's minimal water capacity (VKmin). The lower water capacity (VKmin70%) modeled drier soil conditions, while the higher water capacity (VKmin90%) represented wetter soil conditions. To evaluate the efficiency of the additives, we examined several parameters: plant water uptake, growth parameters (stem height, leaf number), chlorophyll and carotenoid content, and plant stress tolerance (Fv/Fm parameter). Our results indicated that the two water-retaining additives had different effects on the plants and the soil water balance. Under VKmin70% conditions, plants treated with PEG showed significantly lower water uptake, suggesting that PEG effectively reduced water consumption in drier soil conditions. This reduced water usage also positively influenced the plants' water retention capacity, maintaining their physiological functions under dry conditions. In VKmin90% water capacity, representing wetter soil conditions, PEG continued to be effective in water retention, although plant water uptake was higher, meeting the increased growth demands of the plants.

The application of Water Retainer primarily had a positive impact on plant growth and development. Its use contributed to an increase in stem height and leaf number across both water capacity levels, along with an improvement in stress tolerance. At VKmin70% water capacity, plants treated with Water Retainer had higher water uptake than those treated with PEG or in the control group, indicating that it aids in water uptake even under drier conditions. Under VKmin90% water capacity, Water Retainer further improved growth parameters, chlorophyll and carotenoid content, and Fv/Fm values, which reflect the physiological status and photosynthetic activity of the plants. Overall, the experiments highlighted that water-retaining additives significantly influence plant water balance and growth dynamics. While PEG proved to be effective primarily in terms of water conservation, Water Retainer played a more prominent role in enhancing plant growth parameters and stress tolerance. The study of the effects of these additives, particularly concerning soil water capacity and nutrient supply, is of paramount importance for adapting to water-deficient conditions and developing sustainable crop production practices. Based on our research, further studies are recommended to determine the optimal use of water-retaining additives and to enhance plant stress tolerance.

Investigation of water infiltration and penetration resistance inside the elevation zones of a sodic landscape

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Proper functioning of soils is provided by harmonious cooperative activity of soil components. Optimum soil health is based on best functioning of the soil, but different soils have distinct composition, physical and chemical processes, therefore inherently different soil health. One extreme soil type, the sodic soils are characterized by several outstanding ranges of soil physical, chemical and biological properties, nevertheless maintain valuable natural vegetation cover. We focused on the interrelationship of field determined soil physical properties and soil chemical characteristics in the Hortobágy steppe. We hypothesed that different plant associations have different water infiltration values and penetration resistance, since soils' sodium content and elevation determined mainly the vegetation. Eleven study sites were selected, from lowest to highest elevation zones Salt marsh, Salt meadow, Annual salt pioneer swards of steppes and lakes, Bare spot, Artemisia steppe, Achillea steppe, Clearing of forested spot, Forested spot, Closed steppes on loess, Alfalfa field, Tumulus. We used a minidisc infiltrometer and a pocket push-cone penetrometer. Soil electrical conductivity and pH were also measured from 1:2.5 soil:water suspension in the field. We found that the Alfalfa field has the highest infiltration rate, while the lowest value was found in salt meadow. Soil hardness was the highest in Annual salt pioneer swards of steppes and lakes, and Salt marsh had the lowest. At low salt concentrations, and most of Hortobágy saline soils in the surface layers are like this, the higher the sodicity of the soil, the lower is the infiltration rate and the higher the penetration resistance.

Optimizing eucalyptus biomass and nutrient management in Riau: a comparative study of genotypic variations

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Biomass calculation is essential for understanding plantation development, managing stand and nutrition, and assessing carbon stock. Eucalyptus, a fast-growing species used in the pulp and paper industry, is extensively planted in Riau, Indonesia. However, nutrient limitations and low soil pH necessitate advanced silviculture and intensive management. This study compares the nutrient content of biomass in two Eucalyptus genotypes to inform future management strategy. The study was conducted on Typic Kandiudults-Fine Loamy soils, the dominant type in the plantation. Five-year-old trees from each clone were sampled and analyze for biomass and nutrient content across components such as foliage, branches, bark, stem wood, and roots. Results showed that leaves are the most metabolically active component, with significant differences in Mg content between clones. Branches play a critical role in nutrient translocation, with clone 2 showing higher nutrient accumulation. Nutrient loss through harvested trunks highlights the need for N and K fertilization to maintain soil nutrient sustainability. Additionally, clone 2 demonstrated better N translocation through roots, crucial for early growth. This study emphasizes efficient nutrient management in forest plantations and suggests that understanding genotypic variations can lead to improved management practices and sustainable biomass production.

Effects of a permanent bed, compost mulch, no tillage production system on soil fertility and soil properties. A soil focus case study of the Seed's Valley Ecological Farm, Hungary

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The Seed's Valley Ecological Farm situated in Nógrád county, 85 km north to Budapest in Cserhát mountain range. The farm is a small scale mixed organic operation producing over 40 vegetable species year round on a 6.000m^2 area. Production was started in 2015 on eroded brown forest soils with 2% SOM.

Used production practices
Applied low artificial input, minimal emission, ecology focused methods

- no-tillage methods, compost serves as mulch and prepared seedbed
- plant protection - according to organic regulations
- nutrient supply - in the form of plans based compost and pelleted poultry manure
- water management: drip irrigation and micro sprinklers controlled water and energy saving technology
- plants based compost serves as mulch, nutrient source and improves soil structure
- 90% of compost sourced from regional compost facility
- 10 % of compost originates from on-farm compost based on residual biomass

Results

- soil organic matter content tripled in 10 years
- high vegetable yields and productivity
- favorable changes of soil physical properties (low compaction, high soil microbial activity, high plant available nutrients)

SWOT Analysis of the soil related topics of the Seeds' Valley Ecological Farm

STRENGHTS	WEAKNESSES
- selective, effective technology - built micro irrigation systems - high doses of organic nutrient supply - farm terrain is a miniature watershed unit	- unfavorable agro-ecological conditions - shallow fertile topsoil - shortage of ready-to-use organic matter
OPPORTUNITIES	THREATS
- development of on-farm and local compost management system - development of 100 % self sufficient energy and water supply	- lack of highly motivated/skilled physical labor - challenges of further infrastructural developments because of high capital investment requirements

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