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BOOK OF ABSTRACTS

Block B

Session B3

Indicators for soil ecosystem services

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B3 Indicators for soil ecosystem sesrvices

Session Description

Involved projects: SERENA, MINOTAUR, ARTEMIS

Conveners: Klaus Jarosch (Agroscope), Costanza Calzolari (CREA), Stefano Mocali

Agricultural soils have the potential to convey ecosystem services (ES) mainly linked to provision of food, regulation of water regime, and climate mitigation by carbon sequestration. Agricultural intensification negatively affected the environment through soil degradation, loss of biodiversity and increased both greenhouse gas (GHG) emissions and nutrient leaching. Concurrently, a high soil quality status is required for ensuring 75% of soils are healthy by 2030 for food, people, nature and climate. In this context, the promotion of agro-ecological practices is crucial to re-design agricultural systems by increasing ecosystem resilience to mitigate climate change effects. This session aims to present and discuss different methodological approaches in collecting soil quality and crop productivity data for monitoring, modelling, and mapping European agro-ecological systems. Particularly, the definition and evaluation of indicators able to catch ES status at all scales and target values for healthy soils and sustainable agroecological systems are particularly welcome.

Abstracts of Oral Presentations

Abstracts of Poster Presentations

Soil threats and soil ecosystem services indicators for policy implementation: a proposed review

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Protecting, restoring, and using soils in a sustainable way are goals of European policies. The vision and targets of the EU Soil Strategy 2030 foresee the achievement of healthy soils by 2050. Key EU actions to protect, restore and sustainably use soils include the European Soil Strategy 2030 and the Soil Health Law 2023. It is therefore necessary to define soil health/quality and corresponding indicators to qualify soil degradation and assess its improvement. The aim of this review is to provide a framework based on existing policies to identify soil threats and soil ecosystem services indicators that meet the needs of current soil policies. The specific objective of this report is to analyse selected soil-related policies documents to assess the relevance of the indicators selected in the SERENA project in current policies. The analysis was carried out to identify which TS, SESs or indicators have already been addressed by policy measures and what gaps, if any, have emerged. This study was conducted in two phases: a first part of a desk study of the current soil-related agricultural policy and a second phase of stakeholder consultation on a list of proposed indicators for future policy implementation. It describes the results of the first phase, which mainly focused on the analysis of documents at European and international level. The analysis was based on the methodology developed by Jacob et al. (2021) and was carried out in three stages: I) identification/selection of soil related policy documents; II) selection of a set of indicators for documents screening; and III) analysis of collected documents in the terms of indictors proposed by SERENA project. It emerged from the detailed document analysis carried out in this report that in most documents, ST/SES indicators are mentioned in very general terms. The indicators mentioned in more than 30% of the documents were: SOC stock, SOC concentration, soil loss by wind/water erosion, earthworms occurrence, biodiversity indices, microbial biomass (characterizing soil ST); concentration of pollutants, GHG emissions, potential C sequestration, diversity/richness and soil erosion rates (characterizing SESs). In conclusion,

the proper implementation of soil policy objectives requires the above-mentioned ST/SES indicators. In the policy analysis process, the next pre-determined step will be stakeholder consultation to agree on a list of suggested indicators for policy implementation.

References

Jacob, M. et al., 2021. Report on identified regional, national and European aspirations on soil services and soil functions. EJP SOIL Deliverable 2.5. https://ejpsoil.eu/knowledge-sharing-platform/deliverables.

Keywords: soil indicators; soil threats; soil ecosystem services; soil policy

Carbon sequestration and climate change mitigation in soils – definitions and their implications

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As climate science redoubles its focus on CO_2 mitigation strategies in response to the global climate crisis, the term “carbon (C) sequestration” has become not only a buzz word with an increasingly broad definition, but something of a siren's call to scientific communicators and media outlets. Removing C from the atmosphere and sequestering it in the soil (also termed “negative emissions”), has the potential to partially compensate for anthropogenic greenhouse gas emissions, and is therefore an important piece of the global climate stabilisation puzzle. However, the term “carbon sequestration” is often used misleadingly, and although it is likely unintentional, the result is the perpetuation of biased conclusions and exaggerated expectations of the efficacy of climate change mitigation efforts.

As the earth’s largest terrestrial carbon pool, soil has an incredible potential to take-up additional C, however, this potential is challenged by human activities and soil warming; both of which dramatically alter soil C dynamics. In many cases, these changes to natural soil systems result in continuous C loss to the atmosphere. The result is that measures to build up soil C may only serve to reduce C losses (C loss mitigation) or transfer C inputs from one site to another (lateral transfer), but likely do not serve to increase net C uptake, the condition for true C sequestration. The fundamental vocabulary, in this context “C sequestration”, “climate change mitigation”, “negative emissions” and “soil organic carbon (SOC) storage”, needs to be correctly used and understood to allow for accurate interpretation and understanding of the effects of agricultural measures to increase SOC.

While checking 100 recent papers we found that only 4% correctly used the term C sequestration according to its definition. In addition, 13% used C sequestration as an equivalent to C stock. We believe that the proper use and understanding of language surrounding C sequestration in soils is important to reducing overinterpretation of results, and to the broader discussion surrounding climate change mitigation efforts. Herein, we rigorously discuss the implications of the misuse of the term “C

sequestration" and call for its concise use going forward concluding with suggestions on how to avoid miscommunication amongst different stakeholder groups.

Keywords: SOC sequestration, negative emission, carbon storage, climate change mitigation

Various approaches to agricultural soil data collecting and their use as indicators for soil-based ecosystem services in the Czech Republic

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In the Czech Republic, there are two basic approaches to the evaluation of the qualitative parameters of agricultural soils. The first of them is based on an extensive survey of agricultural land, unique in the European scale, which took place already in the 1960s. Its results became the basis for the creation of a system for land evaluation. The agricultural land is divided into the Valuated Soil-Ecological Units containing information about soil physical and chemical parameters and about relief and climate. Based on these units for example the risk of soil erosion is evaluated, and rules are set for the soil sealing or partially for soil contamination. The second derived system is systematic monitoring of soil chemical parameters. It is focused on soil nutrient status and together with yield evaluation it provides farmers an information on appropriate fertilization. As part of this monitoring, data of soil pH, the content of available nutrients and microelements are determined. Monitoring has been ongoing since the 1960s and thus provides data on, for example, the level of acidification of agricultural soils. This monitoring also includes information on land use. It differentiates arable land, permanent grassland, orchards, vineyards and hop gardens. However, the actual collection of soil samples is carried out according to a different scheme in each of these landuse categories. Analytical methods have changed several times. It is therefore rather difficult to harmonize this data with other databases. The comparability of the results and methodological approaches of this monitoring with the European LUCAS project is the subject of investigation by the EJP SOIL project, respectively its part WP6 - Soil data & Reporting. Main goals of this work package are to develop a prototype distributed system to integrate agricultural soil information across Europe and streamline the data flow to ESDAC, to provide thematic databases and maps of agricultural soil indicators, properties, and maps of agricultural soil properties and management systems, to set target values of agricultural SOC, agricultural soil degradation and fertility, and to develop methods to account, monitor and map agricultural soil carbon, fertility and degradation. Compatible thematic databases and maps of agricultural soil indicators and properties should provide the required data for soil-based ecosystem services evaluation.

In this contribution, we will present not only the approaches to soil evaluation in the Czech Republic, but also the results of a study comparing selected soil parameters found within the framework of

national monitoring and European LUCAS monitoring, considering different types of agricultural land use.

Keywords: soil monitoring; soil properties, land use, LUCAS

Statistical assessment of the usability of SOC sequestration indicators

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In the latest releases of EU reports on soil health and protection, soil organic carbon is mentioned as one of the major soil health, quality, and fertility indicators. Preventing soil organic carbon (SOC) loss is a requirement to be met by European Union member states (European Commission, 2021). One of the issues related to soil degradation is that after decades of inappropriate organic soil management, tons of carbon were released from soils into the atmosphere. As one of the greenhouse gases, CO_2 increase significantly changes the climate condition. Therefore, modern agriculture and land management must solve the challenge of implementing policies to protect soils from carbon losses and opportunities to increase soil carbon stocks and the potential of carbon sequestration. Hence our studies aimed to propose a method for the assessment of which indicators are the most suitable for the analysis of SOC sequestration potential and the method to indicate the most and the least favourable areas considering this soil ecosystem service.

To achieve this goal, a few steps were taken. To assess whether the data are statistically significant and to measure the variability of calculated metrics, two-way ANOVA was applied with the Kruskal–Wallis test for equal medians and Dunn's post-hoc analysis. The next step of the assessment is to simultaneously analyse the results of Spearman's rank correlation and PCA (Pindral et al. 2022). The purpose of these calculations is to exclude SOC sequestration indicators that are highly correlated with each other and thus redundant. Performing PCA analysis allows the selection of the determinant indicator of the spatial distribution of SES and therefore the most relevant indicators. According to the results of PCA, selected indicators were chosen to assess the potential for carbon sequestration in agriculturally used soils at the NUTS-5 level (Poland). For this purpose, three thresholds were defined for each indicator: good, neutral, and poor conditions. The chosen indicators were included in spatial structure and correlation analyses. For this purpose, a multi-spatial relationship index and a dependency index based on entropy analysis were calculated (Pietrzak, 1989). For the final result, the point bonitation method was used to identify the most and least favourable areas considering SOC sequestration (Pindral et al. 2022).

The applied method allows for a combination of the most suitable indicators for the assessment of SOC sequestration potential in agricultural soils and identifies areas requiring special soil conservation and carbon management practices. In the light of presented findings and the results obtained, it

should be concluded that the proposed method has a high application value and can be used for the assessment of other soil ecosystem services indicators and the analysis of the soilscapes' spatial structure.

Pietrzak M., 1989. Problemy i metody badania struktury geokompleksu. Wydawnictwo Naukowe UAM, Poznań (in Polish).

Pindral S., Kot R., Hulisz P., 2022. The influence of city development on urban pedodiversity, Scientific Reports. 12, 6009, https://doi.org/10.1038/s41598-022-09903-5.

Keywords: SOC cycle; regulating soil ecosystem services, digital soil mapping, multivariate statistical analysis

Questioning about the harmonization of soil health indicators between contiguous regional territories: the case of marginal soils in Tuscan-Emilian Apennines pedo-landscapes

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The existing administrative boundaries often do not accord with environmental ones and this can be observed at different pedo-landscape scales. This fact leads to the long-standing problem of harmonization among different outputs elaborated with different techniques, according to the requirements of the specific competent authorities and data availability. The harmonization of the available data within the same pedo-landscapes across borders, is a fundamental step in an upscaling process, and it could result particularly important in order to allow policy-makers to carry out a coordinated environmental governance of areas with the same problems, dynamics, and potential soil ecosystem services provision.

The present work presents a method to quantitatively investigate the difficulty of harmonizing soil health indicators elaborated in contiguous areas belonging to the same pedo-landscapes at regional scale, but with soil information elaborated with different approaches. This method is based on the use of standardized values of the indicators, in order to make them comparable between the two regions sharing the same pedo-landscapes. The investigated area is the Tuscan-Emilian Apennines soil region, with several marginal soils included in wooded areas, as well as agricultural soils mainly under permanent meadows, vineyards and fruit orchards.

Keywords: soil ecosystem services; harmonization; upscaling; marginal soils;

Soil health assessment is more than designing frameworks and defining indicators: the complicated landscape of soil health assessments in the Netherlands

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There is a lot of scientific debate on soil health assessments of agricultural soils. Soil health assessments are instrumental to quantify soil health status, soil threats and the contribution of soils to important ecosystem services. However, soil health assessments are difficult because of the complex nature of soils, the various uses and functions of soils and the difficulty of retrieving reliable data on all aspects.

In EJP SOIL, the work on this topic is mainly done in WP6 and in the projects SIREN, SERENA and MINOTAUR. So far, the discussion is focused on the frameworks for soil health assessments, definitions of terminology within the frameworks, development of indicators, data availability and data harmonization.

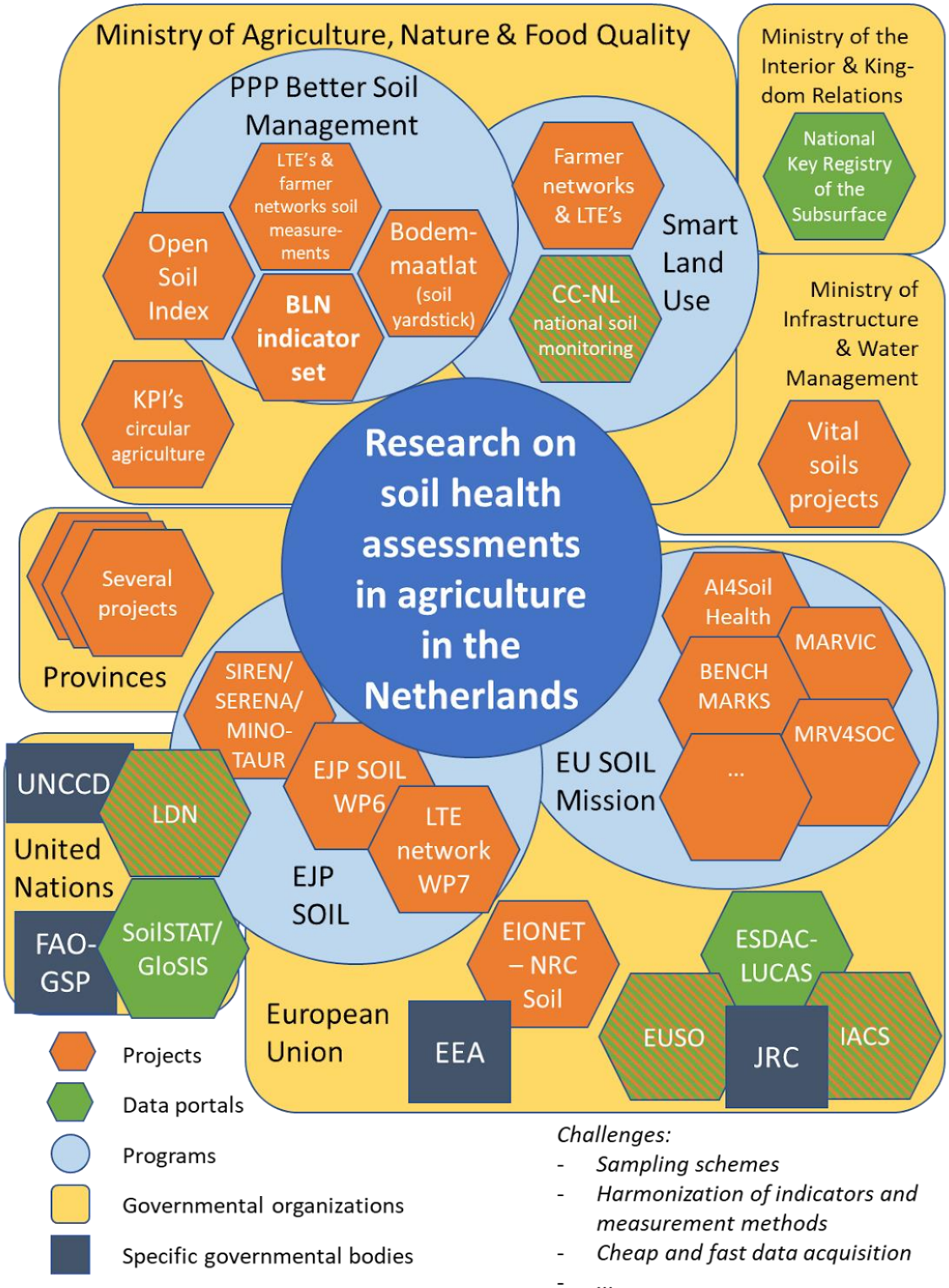
Apart from within the EJP SOIL community, this debate takes place in the wider international research community: e.g. other EU-projects (BENCHMARKS, AI4SoilHealth) and within the FAO-GSP of the United Nations. And besides research, across a large range of policy levels around the EU Soil Health Law development, in European organizations as the EEA and JRC and on national and regional level in the member states.

This paper describes the landscape of organizations, programs and projects around soil health assessments in the Netherlands (see figure). Alignment on soil health assessments for agricultural soils has been made between the government and the agricultural sector within the National Program on Agricultural Soils (NPL). Within the NPL program, a broad range of stakeholders, including the national parliament, have agreed that the BLN soil indicator set version 1.0 (de Haan et al. 2021) is the national standard for soil health assessments. In several projects, the BLN soil indicator set is used and tested. Further development of the framework on soil health assessment in a BLN 2.0 is ongoing to better assess the contributions of soils on ecosystem services and to better assess physical and biological soil aspects. However, other soil and ecosystem assessment initiatives on national level are possibly running in parallel as well e.g., the soil biological indicator network (BOBI) and projects on Key Performance Indicators for Circular Agriculture.

Alignment of Dutch initiatives with European initiatives on soil health assessment is still in its infancy. This situation with multiple indicator sets for agricultural soils and challenges in alignments is not unique for the Netherlands and it will take a tremendous effort to also create alignment between current monitoring systems in other member states as well. Yet having different monitoring approaches with different outcomes risks confusion, reduced trust among stakeholders and high cost of monitoring. We do however acknowledge the large need for different systems of soil health assessment and soil monitoring, as the objectives of assessments can differ in scale, soil type and land use. Still, harmonization of measurement methods, interpretation and presentation and methods for data exchange are needed to increase the quality, cost efficiency, mutual use and uniformity on conclusions from soil health assessments.

Keywords: soil health assessment; soil indicator, soil monitoring

Landscape on soil health assessments in the Netherlands



Challenges:

- *Sampling schemes*
- *Harmonization of indicators and measurement methods*
- *Cheap and fast data acquisition*
- *...*

Assessment of temporal dynamics of soil microbial diversity on archived soils: preliminary results of MINOTAUR project

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Soil microbes play fundamental roles in ecosystem functioning. It is of primary importance to assess the temporal dynamics of the soil microbial community, as long-term microbial responses to environmental changes substantially differ from short-term responses. Soil microbes are usually studied using cryopreserved fresh soils, while almost all archived soils are air-dried and stored at room temperature. Interestingly, several authors have recently reported that air-drying and long-time preserving exerts an almost negligible impact on soil microbial community profiles, laying the foundation for utilizing worldwide archived soils.

This study is part of the MINOTAUR EJP Soil internal project's activities and aims to determine the microbial community dynamics in both air-dried and frozen long-time preserved soils, to assess their vulnerability to climate change and sensitivity for management practices. Time series have been selected depending on the availability of samples and on the period covered by the archives. For this preliminary study, soils samples from 3 archived soil chronosequences available within the project Consortium (Italy, Slovenia, The Netherlands) were selected, from 2 sampling times (2011, 2022). Data obtained by DNA extraction and bacterial 16S rRNA gene sequencing will be compared to assess the eventual bias resulting from the different storage conditions, and possible correlations between i) the microbial communities and ii) the climate conditions and management of the collected soils will be investigated. Moreover, depending on the availability of taxonomical data, a specific focus might be placed on functional genes (N cycling).

On the basis of the data obtained in this preliminary study, in order to assess soil microbial biodiversity sensitivity to climate and agricultural management performed over time, a wider archived air-dried soil series will be selected and investigated. Archived soil series offer promising opportunities to characterize microbial temporal dynamics over decades to hundreds of years, and results obtained from this research might represent an important

starting point for the study of the effect of long-term environmental changes on microbial biodiversity and, potentially, on soil health.

Keywords: microbial communities; soil chronosequences; NGS sequencing; climate change; agricultural management

Towards a harmonized system for the monitoring of soil microbial biodiversity

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Soils are healthy when "they are in good chemical, biological and physical condition, and thus able to continuously provide as many ecosystem services as possible", and they are generally characterized by a diverse and resilient microbial community. In the last decade, metagenomic methods have been increasingly applied to characterize microbial communities in soils. To constantly monitor soil health, prevent its degradation and promote its sustainable management, in 2009 the Land Use and Coverage Area Frame Survey (LUCAS) European soil survey was established by the Joint Research Centre (JRC) of European Commission (EC). As of 2018, it also evaluates soil biodiversity.

However, comparability assessment of biodiversity data obtained from LUCAS and individual Countries is still lacking. Indeed, many factors may lead to biases, from the experimental setup to the computational analysis. One of the aims of the European Joint Programme on Soil (EJP-SOIL) is to compare the EC with national biodiversity assessment methodologies and, thus, harmonize the analytical pipelines.

Over the 2022 LUCAS sampling campaign, 102 samples were collected across Italy. Of these, 14 were also sampled following national strategy. Soils will be analyzed through both experimental protocols, targeting bacterial 16S rRNA gene and fungal ITS region.

Obtained data will be compared to assess similarities and differences between methods, and to identify a unique Italian experimental strategy. This knowledge will define a standard procedure to provide data to a single, comprehensive and continental database, thus, promoting the integration of national systems to the EC's soil data platform, the European Soil Observatory.

Keywords: microbial communities; soil biodiversity; soil health

Variation of dsDNA and enzyme activities in fresh and air-dried samples with different storage time, collected in three different soil types.

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Building on the themes of the MINOTAUR project, the work aimed to quantify the dynamics of dsDNA and extracellular enzymatic activities (EEAs) in soil samples archived over time in our laboratory. Samples were collected from the same locations in two different years (2002 and 2014) to cover a storage time of 0, 7 and 19 years. Sample locations were selected according to a stratified random design in which the layers consisted of three different soil units (SUs) with an increasing degree of soil evolution. Two of them, belonging to Calcaric Cambisols, developed on Eocene turbidites characterized by different particle-size distributions: clay loam (soil unit *Buje*) and silty clay (*Kontarini*) in our investigation. The third SU – a slightly acid, silty clay Chromic Luvisol – originated from Triassic-Eocene limestones (*Turinja*). In the investigation we used high throughput methods ending with quantitative determinations in fluorimetry. The variables measured were the dsDNA content (proxy of the soil microbial biomass) and the activities of the following eight extracellular enzymes: acid (ACP) and alkaline phosphatase (ALP), bis-phosphatase (BISP), pyro-phosphatase (PYROP), arylsulfatase (ARYS), β-glucosidase (BG), leucine amino peptidase (LAP) and chitinase (CHIT). To make the data comparable, dsDNA was standardized in the form of dsDNA/Corg ratio and enzyme activities were expressed as specific activities, i.e. enzyme activities per mg of dsDNA.

The data were analysed using the linear model method considering SUs and the storage time of the air-dried samples as factors. The analysis was done using the general least squares approach to reduce the heteroscedasticity determined by SUs. Specific enzyme activities were affected by both variability factors, whereas dsDNA was only affected by storage time. The values recorded in the SUs *Buje* and *Kontarini* split the activities into two groups. On the one hand ALP, BISP and LEU, which showed high values in alkaline soils (the Cambisols *Buje* and *Kontarini*) and significantly lower values in slightly acidic soils (the Luvisol *Turinja*), and on the other hand the remaining enzymes, which had high values in clay loam soils (*Buje*) and frequently low values in silty loam soils (*Kontarini* and *Turinja*), with the exclusion of ACP and BG, where the Luvisol showed values similar to those in *Buje*.

Regarding the effect of storage time, dsDNA showed a clear decrease in values after seven years, followed by a stabilisation (Turinja) or a slight increase (Buje and Kontarini) at year 19. In contrast,

specific enzyme activities generally increased seven years after sampling and decreased at year 19. A different behaviour was shown by BG and CHIT – with greater variations between the year of sampling and the second time step – and by ALP and LAP, whose activities increased further from year 7 to year 19.

Our results, while showing an effect of storage on the microbial parameters measured in air-dried samples stored for several years, suggest on the one hand the feasibility of investigating chronosequences of soils stored in archives, and on the other hand to pay attention to the types of soils investigated, which vary according to the chemical-physical characteristics acquired during their evolution.

Keywords: extracellular enzyme activities; dsDNA; soil units; length of storage.

What can accelerate hemp residues mineralization?

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Climate change is also affecting soil health, which is critical for supporting healthy plant growth. Rising temperatures can accelerate the breakdown of organic matter in the soil, reducing soil fertility and nutrient availability. Changes in precipitation patterns can also impact soil health, with heavy rainfall events leading to soil erosion and nutrient runoff, while droughts can lead to soil compaction and reduced water infiltration. Straw or other organic raw material residues mineralization is an important process that can impact soil health and nutrient cycling in agricultural systems. Further research is needed to fully understand the factors that influence straw mineralization rates and to develop management strategies that optimize this process for sustainable crop production. The aim of this study was to find a preparation that would accelerate the mineralization of straw or other organic waste in the soil. For the experiment, we selected hemp residues. 5 g of the Hemp residues were put into nylon bags or left on the soil and put in the experimental pots containing 1 kg of loamy soil. Four treatments were selected, 1- control, 2 – nitrogen fertilizer pellets, 3 – liquid nitrogen fertilizer, 4 – organic fertilizer, 5 – preparation from ,,Bioverso". One part of the bags was put into the soil, another part left on the soil and the other incorporated to evaluate the rate of mineralization. The preliminary study showed that the fastest mineralization was observed in the treatment where bags were put in the soil and applied the preparation due to the rich Nitrogen content available in the hemp residues needed by soil microorganism for mineralization.

Keywords: Hemp, residues, mineralization.

Assessing the effect of agricultural management practices on soil biodiversity indicators across the EU

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Agricultural management practices that are proposed to be sustainable aim at sequestering carbon and improve soil fertility, yet they effect on the different components of the soil biodiversity and how it is modulated by soil physico-chemical properties is unclear. The MINOTAUR project, funded by European Joint Programme SOIL, seeks to address this knowledge gap. To that end, we selected seven

long term agricultural experiments across a wide gradient of edaphoclimatic conditions across Europe. These long-term experiments encompassed a range of agricultural practices that included combinations of three tillage systems (conventional, reduced and no tillage) and two fertilization practices (mineral and organic). At each of these experimental sites we assessed the abundance, diversity and composition of selected indicators for macro-, meso- and micro-fauna and soil microbiota (bacteria, fungi are archaea).

The results will highlight to what extent the implementation of more sustainable agricultural practices can preserve and promote soils biodiversity and the functionality that it provides. Furthermore, the wide geographical coverage across different European regions will allow us to assess the sensitivity of the evaluated indicators under different edaphoclimatic conditions. This will be key to identify the suit of most relevant indicators to measure changes in soil quality and soil health for each region as we move towards a EU-wide implementation of more sustainable to agricultural management practices.

Keywords: agricultural management, macrofauna, mesofauna, microfauna, microbiota

Agro-ecological strategies for promoting climate change mitigation and adaptation by enhancing soil ecosystem services and sustainable crop production (ARTEMIS)

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Soils provide a multitude of ecosystem services that can contribute to both, the mitigation as well as the adaptation to climate change. Land management practices have a large effect on the ability of soils to provide these services. Within the ARTEMIS project we aim to determine how specific agro-ecological (AE) land management practices affect soil ecosystem services. This will be done in a four-pillar approach:
i) Buy conducting a scientific literature meta-analysis the available knowledge on the effect of AE practices (in particular organic farming) on crop yield stability will be synthesized on a European level. To determine the effect of these AE practices to climate change mitigation the effect on N_2O emissions will be looked at in particular.
ii) Buy statistically analysing data of long-term field experiments we aim to demonstrate how AE practices (reduced tillage, organic matter management, …) are affecting crop yield stability and how this stability is reacting in specific years with climatic extreme events. We further want to determine the soil-related drivers of a potentially different yield stability in specific AE system compared to a conventional control.
iii) Buy numerical modelling (ARMOSA) we will determine how specific changes in land management practices may affect crop yield stability in both current but also future climate conditions. This will potentially allow to predict which AE practices will show higher crop yield stability in combination with fewer detrimental environmental effects (e.g., nutrient losses, SOC losses, …) in the future.
iv) By developing and testing a framework for an on-farm monitoring network on the impacts of AE practices on soil related ecosystem services we want to determine the possibilities but also limits to determine these indicators in the field by practitioners.

ARTEMIS thus aims to provide a better understanding on how specific AE practices affect soil ecosystem service indicators that drive an AE system performance and how these indicators can be assessed in the field. To do so the project team will partly build on existing knowledge that was created in previous research activities of EJP SOIL but will also closely work together with several still ongoing research projects.

Keywords: agro-ecology, long term field experiments, numerical modelling, meta-analysis, lighthouse farms, soil quality indicators