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THÜNEN

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Session I

Soil biodiversity as a companion for farmers

Soil Biodiversity for Regenerative Agriculture

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Soil is to be considered as natural capital. Soil degeneration means living off the soil as natural capital, which is obviously not sustainable. Soil regeneration means return to living off the interest on that capital. Soil regeneration is an important aspect of regenerative agriculture, the basis of which is working with nature to deliver ecosystem services. In agriculture, soil-mediated ecosystem services are regulation of carbon, nutrient, soil structure and water, and control of pests and diseases, all of which have important bearings on plant and animal health and, ultimately, human health. In my lecture, I will present how groups of farmers I worked with in regions with predominantly arable agriculture and dairy farming, respectively, (strive to) replace external inputs that damage their soils, by management of the soil biota. I will, henceforth, highlight the scientific state-of-the-art on (soil) biodiversity that may be integrated in the local knowledge of farmers in the search for sustained delivery of ecosystem services.

Effects of earthworm activity on bulk density - a meta-analysis

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Soils are increasingly recognized as a limited resource fundamental to soil functions, such as biomass production, water filtering and storage, carbon storage or nutrient cycling. Nonetheless, soils are threatened worldwide, e.g. by land degradation, which is problematic as the soil's functionality cannot simply be replaced once lost. To maintain a sustainable soil use, a comprehensive functional understanding of soil systems is needed.

Soil fauna and their interactions play a key role in a number of ecosystem processes and functions, e.g. through the modification of soil structure. For instance, bulk density is considered important for water dynamics and plant root growth. Bulk density is also commonly used as an indicator for soil compaction, a major threat to soil functions.

While earthworms are expected to counteract compaction by their burrowing activity, a quantitative understanding of the impact of earthworm activity to bulk density is lacking. To fill this gap, we conducted a global meta-analysis on earthworm effects on bulk density within the research program "BonaRes - Soil as a Natural Resource for the Bio-Economy".

Overall, earthworm effects were found to depend on the specific species, soil texture and earthworm body mass. Specific interactive influences of different factors could not be disentangled due to the paucity of data. Consequently, knowledge gaps regarding compacted soils, the interactive influence of soil characteristics, and the replication within the different factor categories are identified. Understanding how such factor combinations influence earthworm effects on soil structure is, however, a prerequisite for developing soil-management strategies that strengthen biotic interactions with soil-structure dynamics. Comparative studies taking the soil's complexity into account are therefore still highly necessary.

Reduced tillage, but not organic matter input, has increased nematode diversity and food web stability in European long-term field experiments

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Nematodes are abundant and diverse in soils, and directly and indirectly contribute to important soil functions such as nutrient cycling, decomposition, and pest and pathogen regulation. In addition, nematode communities have been shown to be sensitive to changes in their soil environment. As such, soil nematodes are promising indicators for soil quality. Morphological assessment of nematode communities and indices such as the maturity index (MI), enrichment index (EI), structure index (SI) and channel index (CI) have been used for soil quality evaluations. Molecular methods to study community composition and diversity offer advantages compared to traditional methods in terms of cost, time, resolution and throughput. Thus far, the use of molecular data to calculate food web indices has not received much attention. In the present study we used molecular methods to: i) assess the effects of soil management on nematode qPCR counts, alpha- and beta-diversity, and food web indices; ii) identify nematode taxa specific to certain soil management, and iii) investigate the relationship between nematode community parameters and soil chemical, physical and biological parameters. We assessed nematode communities with amplicon sequencing in 10 European long-term field experiments to study the effect of tillage (conventional vs reduced) and organic matter addition (low vs high). Nematode communities were more strongly affected by tillage than by organic matter addition. Compared to conventional tillage, reduced tillage increased nematode diversity and shaped the nematode communities towards more stable (12% higher MI), more structured (24% higher SI), and more fungal decomposition oriented (59% higher CI). Organic matter additions promoted the bacterial decomposition channel, increasing nutrient cycling and N availability, and decreased the relative abundance of plant feeding nematodes. Nematode communities were closely linked to total and labile organic carbon, available K and microbial parameters, which indicates that nematode communities are equally sensitive indicators of soil quality. Hence, nematode communities and their food web indices assessed with amplicon sequencing appear to be an excellent indicator of the effect of soil management on soil quality.

Plant symbiotic mycorrhizal fungi in agriculture and restoration

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The roles of soil biota, including plant root symbiotic arbuscular mycorrhizal (AM) fungi, in agricultural and restoration systems are increasingly appreciated. However, understanding of impact of management practices on AM fungi, as well as potential of AM fungi to contribute to crop production or vegetation restoration is still fragmentary.

I will present results from experiments exploring dynamics of AM fungal diversity and abundance under the conditions of conventional and organic farming practices and vegetation restoration settings. I will explore how the AM fungal diversity relates to crop yield and vegetation recovery.

Farming practices showed a consistent effect on richness and community composition of AM fungi in six European countries studied. Notably, AM fungal communities differed among countries (sites), but within each country, communities shifted depending on farming practices. In restoration systems, inoculation with regional-origin AM fungal mix was successful and effective, bringing about considerable increase in plant cover and diversity.

I will discuss the results in the context of species pool concept, which indicates important regional and biome-wise differences in the availability of AM fungal species diversity. In conclusion, regional diversity and availability of AM fungi needs to be considered for efficient choice of management in both conventional and organic farming systems as well as in vegetation restoration.

Session II

Soil biota driven ecosystem services as a societal value


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Sustainability assessment of agricultural soil management

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A globally increasing demand for food, fiber, and bio-based products interferes with the ability of arable soils to perform their multiple functions and to support sustainable development. Sustainable soil management under high production conditions means that soil functions contribute to ecosystem services and biodiversity, that natural and economic resources are utilized efficiently, farming remains profitable, and production conditions adhere to ethical and health standards. Research in support of sustainable soil management requires interdisciplinary approaches to three interconnected challenges: (i) identification of emerging trends, opportunities and constraints of farmers' decision making on soil management,; (ii) assessment of sustainability impacts of soil management decisions taking into account the heterogeneity of geophysical and socio-economic conditions; (iii) systemic understanding of how private and public governance instruments may, in interaction with other driving forces, steer sustainable soil management. This talk presents an analytical framework to conceptually link the socio-economic processes of external drivers and soil management with the natural processes of soil functions and connect them back to impacts on the social system. The framework is based on the DPSIR approach. The Application of the framework helps strengthen the science-policy interface and to systemically assess and compare the opportunities and threats of soil management practices, such as new technologies and digitization from the perspective of societal goals at different spatial and temporal scales. Insights gained in this way can be applied in stakeholder decision-making processes and used to inform the design of governance instruments aimed at sustainable soil management. The research was conducted in the frame of the National Project BonaRes – Soil as a Natural Resource for the Bioeconomy funded by BMBF.

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Do crop rotations including temporary grassland improve provision of soil ecosystem services?

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Agricultural practices strongly modify the provision of soil ecosystem services like biodiversity conservation, water regulation, erosion control and as well as plant biomass production. In the western part of France, a large proportion of cropping systems include grass in the rotations. Grassland is known to have a higher provision of soil ecosystem services compared to cropland; nevertheless, the legacy effect of grass on the following annual crops on soil biota, water infiltration, aggregate stability, soil suppressiveness or yield is still largely unknown. In this context, the aim of the present study was to determine the duration effect of grassland (3 versus 6 years) in crop rotation compared to a rotation where permanently annual crops were grown. Several parameters were evaluated in a long-term field observatory in Lusignan (France): soil biota conservation or biodiversity (i.e. microbial and arbuscular mycorrhizal fungi diversity, microbial biomass, microbial functional diversity, springtails, mites, enchytraeids, and earthworms), water infiltration, aggregate stability, soil suppressiveness and yield to derive conclusions on the provision of ecosystem services. Three treatments were assessed: (i) annual crops in rotation without grass (AC), (ii) crop rotation with 50 % grass with up to 3-year-old grass (3G) and (iii) crop rotation with 2/3 of grass with up to 6-year old grass (6G). Sampling was taken for (3G) and (6G) in a 4-year-old grassland. Each treatment was replicated in four separated randomized blocks. The first results show that compared to the annual crop (AC), the inclusion of grass in the rotations (3G, 6G) significantly enhanced earthworm abundance, biomass and richness, arbuscular mycorrhizal fungi abundance and microbial biomass. Comparing the two treatments with grass (3G vs 6G) earthworm abundance, biomass and richness, arbuscular mycorrhizal fungi abundance and richness and yield were not significantly different. Nonetheless, microbial biomass,

enchytraeids abundance and richness was significantly higher in the 4-year-old grassland with a high percentage of grass in the crop rotation (6G) compared to that with 50% of grass (3G). Springtails and mites abundance were not significantly different between the three treatments. Soil suppressiveness to Verticillium wilt evaluated using an experimental model system was significantly greater for the soil samples in the rotation with annual crops (AC) as compared to any of those with grass included in the rotation irrespective of the percentage of grass (3G or 6G). Results of each parameter will be presented and interactions between ecosystem services will be discussed as well as the perspectives about grassland management in Europe.

Earthworms affect decomposition of soil-borne plant pathogen Sclerotinia sclerotiorum in a cover crop field experiment

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For sustainable agriculture, ecosystem services that suppress fungal diseases become increasingly important. White mould (Sclerotinia sclerotiorum) is a harmful soil borne plant disease threatening over 400 crop species worldwide, including soybeans (Glycine max), rapeseed (Brassica napus) and sunflowers (Helianthus annuus). Sclerotia, the few mm long survival body of S. sclerotiorum can stay viable for five years, depending on its burial depth in soil (Cosic et al., 2012). In a laboratory food choice test we investigated the potential of the earthworm Lumbricus terrestris to reduce S. sclerotiorum. We hypothesized that depending on its moisture content sclerotia would be a food source for earthworms. Additionally, we determined the relationship of earthworms and sclerotia in field plots.

In the food choice arenas we conducted two experiments, therefore we fed two sclerotia sizes (2 mm or 4 mm). We submerged the sclerotia into moistened soil and stored them for 0, 5, 7, 9 and 13 weeks for hydration.

For the field trial, we inoculated sclerotia in July 2016 in mesh tubes (earthworm accessible: 3 x 10 mm; non-accessible: 1 x 1 mm) in 3 cm depth in cover crop plots (N=6). In October 2016 and March 2017 we excavated the remained sclerotia and excavated soil monoliths for earthworm sampling.

Hydrated and non-hydrated sclerotia of 2 mm and 4 mm were reduced, but hydrated were clearly preferred by L. terrestris. Furthermore, earthworms showed a stronger interested in the substrates containing sclerotia and especially hydrated sclerotia than in soil only.

Results of the field experiment showed that more sclerotia decomposed in the earthworm accessible inoculation tubes than non-accessible tubes. However, we found no evidence that the decaying process of sclerotia were correlated with earthworm populations in

field plots. Furthermore, earthworm abundance was not affected by the presence of sclerotia, but by Brassicaceae cover crops.

Despite the size of sclerotia (2 mm or 4 mm), L. terrestris showed a clear feeding preference for hydrated sclerotia suggesting that earthworms can actually reduce the soil borne pathogens. Our finding may be related to previous studies of the consumption of L. terrestris on dark pigmented fungi (Bonkowski et al., 2000) and food with smooth surfaces such as melanin layer of sclerotia (Shumway and Koide, 1994).

Many aspects of the potential pathogen suppression of sclerotia by earthworms are still unclear and deserve further investigations.

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X-ray CT assessment of soil structure: a tool for monitoring soil biota driven ecosystem services in agricultural soils

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Indicators are needed for the evaluation and identification of management systems that promote soil biota driven ecosystem services in agro-landscapes. It is necessary that these indicators integrate different factors, can be applied across scales, and operationalised. Ideally, they are not only helpful for research and policy makers but also for farmers. Soil structure analysis by means of X-ray computed tomography (CT) meets these requirements. The aim of the DIWELA project was to develop a farmer's tool based on X-ray CT scanning of agricultural soils for deriving soil quality criteria with special consideration of soil biota and their role in ecosystem services.

179 undisturbed top-soil cores from long-term field experiments and farmers' fields located mainly in Germany were taken between 2015 and 2019. Additionally, selected European sites from COST Action ES 1406 were included. The cores were scanned with medical or industrial X-ray CT scanners and data were analysed with different digital and statistical techniques.

The results show clear relationships between soil management, soil biota and soil biota driven ecosystem services, such as soil structure development and carbon dynamics. The data set provides the basis for a potentially generalizable soil quality index which will require further validation.

In addition, we demonstrate that CT technology, combined with modern sensor technologies, provides a tool to incorporate information on soil biota and their ecosystem services into practical agricultural management.

European mesofauna under drought stress - Evidence from wheat fields

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Climate change models predict altered rainfall patterns including more frequent and severe drought events for Europe. Accompanied by an increase in overall temperature this will result in a decrease in soil moisture, especially during the growing season, putting pressure on soil fauna by increased drought stress. Agroecosystems are of particular relevance for food security and at the same time facing a decrease in biodiversity due to increased land-use intensity. In the BiodivERsA project SoilClim we investigated the effects of reduced rainfall on soil biodiversity and ecosystem services in winter wheat fields across a European climatic gradient with field sites in Sweden, Germany, Switzerland and Spain. We experimentally simulated reduced precipitation using rainout-shelters with a partial interception of natural rainfall (65 %). We developed a new rainout-shelter design which minimizes potential shelter artifacts and being suitable for experiments in agricultural fields. During the first period of the project in 2017 we established rain exclusion experiments on plots with different long-term fertilization schemes on the DOK trial in Switzerland. Here, I present first results of the combined effect of reduced soil moisture and organic carbon content on soil fauna in winter wheat fields.

Session III

Future opportunities for soil biota preservation in agriculture

How can policy strengthen the synergies between agriculture and soil biodiversity?

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Today, the trade-offs between the common need of food and fiber production in our landscapes and the need of conserving or even increasing biodiversity are very obvious in public debates concerning the loss of bees and the general starvation of insects. In these debates farmers as land users are often seen as antagonists with competing interests to biodiversity and its needs. However, synergies are hardly mentioned or taken into account. We think synergies between agricultural production and biodiversity can build the bridge in the communication and the process towards a sustainable agriculture. In the context of social-ecological research ecosystem services can be taken as an expression of these synergies, since they connect an organism, a population or a community as a driver of processes which finally serve as a human or societal benefit. Or straighter: Agriculture for Biodiversity is equal to Biodiversity for Agriculture.

What is needed to strengthen these synergies? In a basic sense, policy in democracies works as a system of expressing and executing the political will of a society by balancing the political will of different groups. Political parties, associations and lobbyists take important parts in this competition and mediation of interests. The Common Agriculture Policy of the European Union exemplifies such a policy process. When it comes to (soil) biodiversity it is often claimed that organisms, biodiversity and ecosystems have no voice in the political debate and supporting spoke persons are needed. These spoke persons can be associations for environmental issues but also politicians that need to rely on scientific knowledge.

Assuming that people (including politicians) are much less aware about soil and soil biodiversity compared to other ecosystems, the creation of a political will concerning soil biodiversity will hardly evolve as a political process alone. Expert knowledge, multi- and transdisciplinary approaches as well as a relevance based evaluation of concerns are needed to bring soil biodiversity issues into a political process. Here the results of SoilMan show how important soil biodiversity is for agricultural production and the provision of ecosystem services at micro- or at macro-level to ensure a sustainable food supply at regional but also at global level.

In the public debate agriculture faces on one hand a decreasing trust and acceptance with rising public and societal awareness of consequences of intense agricultural production system in crop and livestock production as well a strong concentration processes in land markets. On the other hand, strategies towards the transition to a more bio-based economy indicate an increasing demand for food and fiber. Taking benefit from ecosystem services in adjusted or even low input systems might help to balance trade-offs in agricultural production. However, this requires a clear political strategy which follows the target of a sustainable agricultural production with a long-term perspective protecting not only the above-ground but also the below-ground soil biodiversity.

The role of collective action at a territorial level in promoting agroecological practices. A case study of a deliberation process between farmers and consumers.

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The study focuses on social interactions that take place within 3 Groups of Economic and Environmental Interest (GIEE) supported by an agricultural cooperative in the South of France. The idea is that sharing of experiences between farmers may highly facilitate the transition to more agroecological practices. These practices are materialized by the inclusion of pulses in the crop rotations such as chickpeas, lentils and beans and by reducing the use of agricultural inputs.

The different projects set up by the farmers inside the GIEEs consist in acquiring technical references on these pulses, and also in improving the soil fertility (by introducing legumes in the rotations, plant cover, optimization of tillage, ...).

On the methodological level, we first made an inventory of farmers' perceptions regarding the general agricultural context and the integration of pulses in the rotations. We used interviews and questionnaire addressed to a panel of producers in organic and conventional agriculture. Then, we observed the dynamic effects of deliberations organized specifically between farmers of the GIEEs and citizens-consumers in the territory. These groups were invited to deliberate on quality, a central concept we had used as mediation tool, on the interests of pulses, then on the implications of their development for the territory.

Concerning the results, for the majority of the farmers, the reasons for integrating pulses in the rotations are economic (attractive price, reduction of expenses, income diversification) and agronomic (longer rotations, better soil fertility, good precedent). We also observed that organic farmers were more open to the nutritional issues and evoked more societal links than the conventional ones.

The discussion groups between farmers-members of the GIEE and citizens focused on social dimensions and territorial projects. These societal aspects included sustainable practices and fairness. Furthermore, we observed that a relationship based on trust was established between producers and consumers, either through quality standards or local proximity. In addition, two GIEEs decided to launch local projects including citizens.

Consequently, we argue that agroecological practices may be strengthened by the integration of societal concerns in the farmers' reasons for acting. The deliberation process permitted the social learning, the expression of collective creativity and led actors towards common and legitimates goals in accordance with the principles of agroecology promoted by the public policies.

About the conceptual framework:

Our theoretical framework is based on the old institutionalism and pragmatism. We are interested in the role of social interactions to update the actors' reasons for action. Especially, we focus on the deliberation process between the implied actors as we claim that it facilitates social learning and the expression of shared values. Furthermore, we completed our approach by tools of the culturalhistorical psychology stream, in order to develop the notions of meaning and reflexivity about the practices.

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Integration of values plurality in the definition of soil management strategy by European farmers

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Soils provide a wide range of ecological, economic and social functions whereof many are depending on soil biota. Human activities, such as agriculture, benefit from these functions, hence considered as ecosystem services (ES). However, some widely spread cultural practices can threaten soil biodiversity.

We build our study up on the basis of a focus groups methodology to address soil biota values both at individual scale and within a collective process. However, this qualitative method involves only a limited number of farmers in each group and implies group-dependent outcomes.

The environmental pragmatism theory, developed by John Dewey, assesses the link between values which individuals develop in a given situation and their actions. From this perspective, values, which are influenced by ones experience and knowledge, are constructed by individuals as a solution to a problematic situation. Previous results show that (i) farmers attribute plural values to soil biota but (ii) they tend to value soil in its entirety, rather than soil biota in particular.

In this context, we implemented focus groups in Sweden, Germany, Romania, Spain and France during winter 2018-2019. Each group was composed of 6 to 11 farmers. In most cases, we invited farmers who had already been involved in previous, related focus groups. Our aim was to understand how plural values, that might sometimes be antagonist, can coexist and steer a single coherent soil management action.

First, we investigated their knowledge about soil biota, its nature, its diversity and its degree of precision. This represents the basis on which values can emerge. In the next step we focused on the type(s) of indicators, European farmers use when assessing both, their soils and the success of their management practices. We investigated in particular if they use biological components. The need to adapt to difficult climate conditions in 2018 was used as a basis for discussion.

This leads to an improved understanding of the compromises, farmers have to make for their soil management.

Soil biota preservation in the post-2020 Common Agriculture Policy

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At a time when the European Soil Framework Directive seems to be definitively abolished after its withdrawal in 2014, soil protection is even more dependent from the integration into sectoral public policies. The way how the future Common Agricultural Policy (CAP) will deal with agricultural soils is therefore crucial. One of the often overlooked challenges is the preservation of the biodiversity in agricultural soils.

We will highlight possibilities to address the preservation of agricultural soil biodiversity under the new CAP. This will consist in analysing the new "green architecture" of the CAP proposal. To this end, several normative indicators will come to our attention.

The first one concerns the scope of the stated objectives of the new CAP. The CAP is now focused on 9 specific objectives. Both objectives, the effective management of natural resources, including soils, as well as the protection of biodiversity and the improvement of ecosystem services are relevant for soil biota preservation. In addition, soil organisms playing a key role in carbon sequestration could contribute to the climate action objective, too.

The second one concerns measures undertaken for soil conservation. The ambition of these measures with regard to soil biodiversity will be explored through several criteria: the autonomy or not of measures to protect soil biodiversity, i.e. the existence or not of specific measures to protect soil biodiversity, the mandatory or voluntary nature of soil protection and the consequences of this distribution on soil biodiversity (conditionality, agri-environment-climate measures (AECM) and a new instrument (eco-schemes)). Finally, the impact of the temporality of soil protection measures on soil biodiversity (in particular their annual and multi-annual nature) will also be analysed here.

The third one relates to the unprecedented level of flexibility of this new CAP. Strategic plans to be drawn up by Member States would set the level of ambition and the instruments to protect soil biodiversity. This analysis is to be done at several levels. The first level will be that of the Member States being the recipients of European legal standards. Does subsidiarity benefit soil biodiversity? In other words, do Member States have direct or indirect soil biodiversity protection mechanisms in place to meet the expected results of the CAP? If so, how are these devices designed (result-oriented accompanied by the development of appropriate bio-indicators? Developed or not with the farmers concerned?). Therefore, a second level of reflection concerns farmers themselves. Do they have a greater latitude in choosing the measures to be taken or in the ways in which these measures are implemented in order to promote soil life?

Poster pitches

Biodiversity effects on farmland carbon sequestration (TWINWIN)

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In 2017 a multidisciplinary initiative started in Finland with an aim to promote actions supporting the 4 permille initiative in Finland. This Carbon Action network (see www.carbonaction.org) links scientists, farmers, policymakers and enterprises to work together towards the common goal: to increase soil C storages in Finnish agricultural soils. As part of this action, a project funded by Maj and Tor Nessling foundation started in 2019 with the emphasis on biodiversity and soil C sequestration. The new project, its aims, its participants and work packages are presented in the poster.

Towards an improved understanding of carbon sequestration in grassland soils – the impact of soil fauna on aggregate formation

Lea Spelzhausen, Laura Schnee, Juliane Filser

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How to retain carbon in the soil has been intensely discussed recently, especially in the context of combatting global climate change. Soil is the largest terrestrial carbon pool and contains more C than the atmosphere and vegetation combined. Considering that half of European soils are under agricultural use, this offers an enormous potential for carbon sequestration in fields and semi-natural grasslands (pastures). Especially the latter bear a high potential for soil C sequestration due to improved aggregation under undisturbed conditions. Particularly microaggregates are considered to support long term carbon sequestration, due to their high mechanical stability and hence long residence times of their C stock in soil. Recently, it has been argued that soil C stability is mostly determined by its accessibility to decomposer communities which is impeded by adsorption to mineral surfaces and incorporation into aggregates Soil fauna significantly contributes to soil aggregate formation by defecation, but also as their produced biomass act as starting points for decomposer-initiated aggregates. Moreover, their feeding activity considerably stimulates microbial activity and soil organic carbon turnover. Earthworm introduction is hence a successful management strategy for soil carbon sequestration in semi-natural grasslands. However, except for earthworms, the impacts of complex interactions of soil fauna groups on aggregate formation and soil carbon sequestration have rarely been studied in a quantitative fashion. Moreover, only few studies have investigated the impact of grassland management and grazing on soil organisms.

This study aims at facilitating a better understanding of the connections between soil fauna (meso- and macrofauna) and aggregate formation in grassland ecosystems under different management intensity. A field study will be conducted to assess (i) the effect of grassland management on the soil fauna community, (ii) the relation between community composition and aggregate structure, and (iii) we will quantify the amount of SOC in aggregates. Furthermore, (iv) the respiration of soil microorganisms of soil samples from the different treatments will be quantified. In order to complement the field study, (v) we will perform controlled experiments with different soil biota functional groups in order to understand the effect of soil fauna composition on the process of aggregate formation. In summary, we will investigate how grassland management affects soil biota, their provision of ecosystem functions (aggregate formation) and associated ecosystem services (carbon sequestration).

Plant genotype, soil and climate as drivers of the olive microbiome composition

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Unravelling the function and structure of microbial communities prevailing in soils and the endosphere of plants is essential to understand plant life cycle. Soil microorganisms play essential roles through the transformation of organic matter and mineral solubilisation and are also key determinants for supporting plant growth and health, since they act as a natural defence against soilborne plant pathogens. Understanding of the plant microbiome (microbial ephiphytes and endophytes) is becoming of relevant importance for promoting plant health as it could include microbes that may protect against plant pathogens sharing same niches. In this study, we sampled during Autum 2018 and Spring 2019 the soil, rhizosphere, roots, xylem sap, stem tissues, leaf and fruits from three olive cultivars (Picual, Arbequina and Frantoio). Olive trees, originally propagated from same mother plants and hypothetically sharing same microbiome within each plant genotype, were transplanted in three field plots located in the provinces of Córdoba, Málaga and Jaén, in Andalusia, Southern Spain. The three locations differ in physicochemical soil characteristics and climate. Bacteria and fungal populations in each of those plant niches was analyzed using the Illumina MiSeq platform to determine the structure and diversity of olive microbial communities, and to estimate the principles governing their assemblages and dynamics (plant genotype, plant niche, soil type, climate or seasonality). This basic information can contribute to generate new knowledge that may contribute to control olive diseases or increase plant health by manipulating, inoculating or selecting highly-specific microbiomes, better adapted to specific genotypes of olive, or with the greatest potential to survive under different climatic conditions.

Influence on soil aggregation by mycorrhizal inoculation of maize on a sandy soil

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In agricultural practice, stable aggregation is of growing importance in times with higher frequencies of droughts. Well-aggregated soils can improve water infiltration and water holding capacity. Biological processes are responsible for the formation and persistence of aggregates but vary in time, and therefore aggregation varies.

The aim of the presented study was to monitor how aggregation varies over time and to test whether inoculation of arbuscular mycorrhizal fungi (AMF) can improve the formation of water-stable macroaggregates of sandy soils. From mid of April until end of July 2018 a randomized field experiment with two variants (+ mycorrhiza, - mycorrhiza) and four replicates was set up in Hollage, Lower Saxony. Inoculated maize seeds were coated with propagules of AMF, a mix of R. irregularis, F. mosseae and F. caledonium, to guarantee mycorrhizal colonization of the maize roots. Whereas the frequency and intensity of AMF colonization were studied within maize roots, water-stable macroaggregates, soil organic carbon, microbial biomass, and respiration were analyzed within pooled soil samples of the upper 10 cm.

Over the investigation period, an almost linear increase in water-stable macroaggregates from 40 % to 80 % was observed. Frequency of mycorrhization showed a similar linear increase, whereas water content was decreasing during the period. An analysis of variance showed no differences in mycorrhizal colonization between the inoculation treatments. Obviously, there was a high occurrence of native AMF in the investigated soil. However, there was a slight tendency that inoculated treatments (+ mycorrhiza) colonized faster at the beginning of the growing season than noninoculated (- mycorrhiza) and native AMF adapted better to drought. Besides a small increase in plant N- and P- uptake was observed in inoculated (+ mycorrhiza) treatments before water became limiting. A multiple linear regression indicated that aggregate stability was mainly explained by the frequency of mycorrhization within biological predictors, with a positive and significant correlation of both parameters. The water content and soil texture defined aggregate stability best within physical predictors.

Fungi stabilize soil aggregates with their hyphal network and especially AMF foster aggregation due to the production of gluey substances like glomalin related soil proteins. Decreasing water contents can influence the release of gluey extracellular substances and higher their concentration during desiccation. Therefore desiccation can affect aggregate stability via soil microbiology.

Exploring biodiversity in Romanian vineyard to promote sustainable management and conservation of biodiversity

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Biodiversity is considered as a driving force for the delivery of important ecosystem services to agriculture such as soil fertility and natural pest control. Viticulture is among the most pesticide-dependent land use types in Europe and therefore ecological intensification of viticultural agroecosystems is urgently needed. SECBIVIT is a new European project that aims to study the ecosystem services provided by biodiversity in different wine-growing areas from Europe. The present work give information about how the study is designed and implemented in Romania. A network of 24 vineyard sites was created in the hilly area of Podișul Târnavelor in order to study above- and below-ground biodiversity (plants, soil biota, spiders, insects and birds) with respect to taxonomic and functional diversity and conservation value. The ecosystem services supported by these communities studied in the project will comprise provisioning (grape quality and yield), regulating (pest control, nutrient cycling) and supporting ecosystem services (soil conservation). During the project development we will quantify effects of local and landscape-scale land-use decisions on multiple ecosystem services such as pest control, soil fertility, carbon sequestration and nature conservation value to validate the model for analyzing trade-offs and synergies between biodiversity and ecosystem services under different ecological, economic and market conditions.

Snapshots from the SoilMan Project

Suppression of plant pathogens and detoxification by soil biota – belowground support for healthy arable soils

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Sustainable arable management promotes soil biodiversity and offers the potential to optimize benefits from functions and ecosystem services, fulfilled and provided by soil biota. To adapt agricultural activity to current demands while ensuring a sustainable agricultural production, knowledge of management impacts on the ecosystem service/disservice balance and the self-regulation of soils is essential. In this context, it is known, that the reduction of soil tillage intensity and the application of mulching techniques, on the one hand, promote the survival of soil borne, mycotoxin-producing plant pathogenic fungi aboveground, but on the other hand, enhance the diversity of antagonistic, fungivorous and mycotoxin-degrading soil biota. However, so far the resulting ecosystem service/disservice balance and involved self-regulation mechanisms are still unclear.

To analyse and assess the role of fungivorous decomposer key species (earthworms: Lumbricus terrestris, collembolans: Proisotoma minuta, enchytraeids: Enchytraeus crypticus and E. christenseni) during bioregulation of economically important plant pathogenic fungi (Fusarium) and degradation of their mycotoxins (deoxynivalenol (DON), zearalenone (ZEN), 3-acetyl-deoxynivalenol (3-AcDON) and fumonisin B1 (FB1)), mesocosm field studies in Germany (loam soil) and Romania (clay soil) as well as microcosm laboratory studies were conducted as part of the SoilMan project.

In the context of the detoxification of Fusarium mycotoxins, it is hypothesised that

(1) fungivorous soil faunal key species and their interactions regulate and control the mycotoxin degradation in crop residues,

(2) degradation rates differ between mycotoxins depending on substrate size and soil texture,

(3) leaching of mycotoxins represents a potential risk to arable soils.

The results reflect that fungivorous soil faunal key species significantly enhance degradation rates of mycotoxins by up to 300%. The detoxification potential of primary decomposers (earthworms) is higher as compared to that of secondary decomposers (collembolans, enchytraeids). Degradation rates differ depending on respective mycotoxin and soil conditions but are independent of substrate size. Moreover, mycotoxins leach from infected crop residues. Whereas some of them enter the soil water and can potentially reach the ground water (DON), the fate of others is, so far, unclear (ZEN).

The present study contributes to a deeper understanding of the interrelationship between soil management and the ecosystem service/disservice balance.

Effects of tillage intensity in arable land on ecosystem services driven by soil biota

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Diversity, abundance and biomass of soil biota depend on habitat characteristics in the soil environment. In agricultural land use systems, these characteristics are under control of long-term history of farming practices and recent decisions of the farmer. The other way round, soil biota is providing important ecosystem services directed to soil fertility and self-preservation of the soil. Many authors have already shown the importance of the soil-fauna composition as the control of litter breakdown and nutrient cycling as a key function for plant growth.

Undisturbed soil columns were taken from a long-term experimental field-site to carry out a microcosm experiment. Three organism treatments were applied: (i) endogeic earthworm species, (ii) anecic earthworm species and (iii) a combination of two enchytraeid species. Two tillage treatments were simulated: No-Tillage (organic material on the surface) and inverse tillage (organic material in a depth of 15 cm). Four replications were used for each treatment combination (organism x tillage simulation). For investigation of processes across scales, microbial soil parameters such as microbial biomass and ergosterol were measured. Analyses of stable isotopes were used to trace the fade of carbon from crop residues to organisms in the soil. First results show that soil annelids respond differently to the location of the organic material, depending on size scales and on ecological performance. The position of organic material in a depth of 15 cm seems to be beneficial for endogeic earthworms. For anecic earthworms, results showed that they picked up the same amount of maize material in both treatments.

To evaluate decomposition rates of simulated crop residues under field conditions, a litterbag experiment was carried out on three long-term observation field-sites across Europe. In Sweden, litterbags were buried in in three tillage treatments: No-Tillage (NT), Minimum Tillage (MT) and Conventional Tillage (CT), for Romania and Germany there were only MT and CT. The litterbags were placed in the soil according the respective tillage depths. Two different mesh sizes were used to exclude parts of the decomposer community. The larger mesh size (2mm) allows mesofauna to get in the litterbags, whereas the small one (48 µm) only let in microfauna. Litterbags were buried in October 2017 and dug up at three dates, latest in May 2018. The experiment shows the importance of mesofauna as part of the decomposer community and the influence of tillage on litter breakdown under different climatic conditions.

Can tillage management induce changes in functional diversity of the soil microbial community?

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Agricultural soil management can have a large impact on soil physical, chemical and biological properties. Minimum tillage is increasingly used by farmers due to the economic and environmental benefits. Furthermore, minimum tillage have been reported as being beneficial to soil microbial community, but clear evidence of this benefits are still under questions. Because soil microorganisms are directly linked to soil biochemical processes, a dynamic and diverse community is essential for a healthy and fertile soil.

The aim of our study was to measure soil microbial catabolic activity in arable soils where conventional tillage (ploughing) and minimum tillage (unploughing soil with low-till) was applied. We selected 15 sampling points in different farms from N-W part of Romania where both kind of treatments was applied. Soil samples were taken during spring from fields where wheat was growth. We used MicroResp multi-SIR technique to assess the soil microbial catabolic activity. Briefly, soil samples were preincubated for 3 days at room temperature and 15% soil water content then loaded into the deep-well plates and incubated for six hours at 25ºC with 15 different carbon sources (30 mg g-1 soil H2O concentration) in a closed system which includes also a detection microtitre plate with a colorimetric CO2 trap. The color changes in the detection plate was measured at the beginning (T0) and after 6 hours of incubation (T6) at 570 nm. The difference in absorption between T1 and T0 was converted in C-CO2 (µg·g-1soil·h-1) released from each carbon source used.

Average of microbial catabolic activity for all organic sources was higher in conventional treatments compared with minimum treatments. In both kind of tillage treatments the most used organic substrates were carboxilic acids, folowed by carbohydrates, aminoacids and amino sugar.

For minimum tillage treatment malic acid, fructose and glucose showed higher respiration values than in conventional tillage while α-ketoglutaric and citric acid registered higher values in conventional treatments. The lowest respiration activity was measured for arginine in both tillage treatments. The obtained results suggests that tillage practices have an influence on soil catabolic activity and are able to direct the diversity of microbial community in arable soils.

The performance of microannelid communities at SoilMan sites

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The relationship between agricultural management practices and the performance of soil organisms is compared across the SoilMan long-term observation sites, covering different environmental zones and soil conditions in Europe. We focus on microannelids (mainly enchytraeids) that contribute to organic matter decomposition and formation of aggregates, like earthworms, but at a smaller spatial scale. Management practices include tillage field trials (conventional ploughing, minimum tillage, direct seeding) as well as rotation field trials (annual crop, rotation with years of grass).

A total of 91 microannelid species (89 Enchytraeidae, 1 Naididae, 1 Parergodrilidae) were identified, of which 39 % are new to science still waiting to be described. Species richness and total abundance of microannelids follows a latitudinal gradient, being highest at the intermediate latitudes (lusitanian, atlantic, nemoral, continental) and decreasing both at the northern (boreal) and the southern (mediterranean) observation sites.

The field trials show heterogeneous results. In 47 % of the studied cases, no tillage and reduced tillage caused an increase in species diversity compared to conventional ploughing, while in 33 % a decrease and in 20 % no change occurred. The same applies considering the total abundance of the community and its response to various rotation trials. Results of a repeated survey in two consecutive years, carried out at one location, suggest that the soil moisture condition is more significative for the development of the microannelid community than the soil management type.

The comparatively slight changes in the diversity of microannelid communities caused by the studied management practices indicate that the resilience of the soil system is biologically in sound condition. However, there is evidence that climate change (leading to increased drought periods) is a major threat to soil biodiversity and the ecosystem services that depend on it.

Effect of tillage intensity on earthworms and their bioturbation activity

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Earthworms are considered one of the most important groups of soil organisms due to the ecosystem services (ESS) they provide. As so called 'ecosystem engineers' they "bioturbate" i.e. they relocate and mix soil while moving and feeding and in this way strongly affect soil structure, nutrient cycling, and soil organic matter dynamics. Annual bioturbation, i.e. the amount of soil relocated by earthworms per year, can serve as a proxy for the general impact of earthworms in e.g. an agricultural field. We have developed a formula that allows to calculate annual bioturbation at a particular location for different functional earthworm groups. In many agricultural systems, the so called 'anecic' and 'endogeic' earthworms are the most important functional earthworm groups that strongly differ in their feeding and burrowing activity and therefore also in the ESS they provide. Anecics mainly feed on litter on the soil surface from where they transport organic matter (OM) into their deep vertical burrows, distributing it more evenly in the soil layers and simultaneously improving soil structure and drainage. Endogeic earthworms are important for horizontal OM transport and decomposition in the mineral soil where they stimulate microorganisms and nutrient mineralization.

Intensive agricultural management practices like conventional ploughing are known to reduce earthworms and thus also their provision of different ESS including bioturbation. We assessed the effects of different tillage intensities - ploughing, reduced tillage, direct sowing – on earthworm communities and bioturbation at a long term field experiment in Uppland, east central Sweden.

The different functional earthworm groups have different activity zones in the soil and are impacted differently by agricultural methods, so that the 'ecological impact' of agricultural management in regard to the 'earthworm ESS' depends not only on the effect of earthworm abundance but also community composition.

There was no difference in the effects of direct seeding and reduced tillage on earthworm communities. However, conventional ploughing significantly reduced earthworm species diversity and abundance compared to the other management types. In particular the large anecic species Lumbricus terrestris was not found at the conventionally ploughed plots.

Bioturbation was highest in the directly sown plots. In comparison, bioturbation was reduced by 12,4% under reduced tillage and by 66,6% under conventional ploughing. The strong reduction of bioturbation by anecic earthworms due to ploughing also affects all other 'soil functions' these species provide, in particular soil aeration and water infiltration. We recommend to apply less intensive tillage whenever possible to maintain functionally important earthworm species and the ecosystem services they provide.

Collembolan biodiversity in agricultural fields across Europe as affected by farm-based soil management practices

Jörg Hanisch

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Soil biodiversity is pivotal for delivering food, fiber, biofuels, clean air, drinking water and carbon storage to the society. However, our understanding of the link between soil biodiversity, soil functions and ecosystem services is still limited. Future cropping systems need to increase agricultural productivity while keeping production sustainable. In order to reach this goal, we need to better understand and valuate the relationships between soil biodiversity, soil functions and ecosystem services in the context of agricultural management practices. The presented project forms part of the European Science Foundation project "SoilMan", aiming at deeper understanding of the interrelationship between soil management, soil biodiversity and ecosystem services. To achieve this goal "SoilMan" is quantifying soil ecosystem functions and multiple ecosystem services based on biodiversity parameters in representative agricultural systems across Europe. The project focusses on two soil management regimes, tillage and crop rotation. In the framework of "SoilMan" we focus on collembolan diversity as a function of land use characteristics and regional habitat conditions. Samples were taken from long-term experimental field sites and farms in Germany, France, Spain, Romania and Sweden. We expect that soil biodiversity in agricultural fields is determined by farm based soil management practices and shaped by regional constraints.

Additional posters

The SoilMan project

SoilMan
Ecosystem services of soil biota in agriculture

Conference on Soil Biota driven Ecosystem Services in European Agriculture

22nd – 23rd October 2019, Braunschweig, Germany

biodiversa

SoilMan – Ecosystem services of soil biota in agriculture

Overview

Motivation

Soil biodiversity is essential for productive, healthy and fertile agricultural soils. But below-ground biodiversity is not immune to the observed ongoing decline in biodiversity on agricultural land. Many knowledge gaps exist on linkages between diversity and abundance of soil biota, soil functions and ecosystem services and the resulting economic implications for farmers. Within the **SoilMan** project, a broad range of soil biota involved in plant decomposition, soil formation, water and nutrient retention as well as disease repression is analysed on arable land.

Project

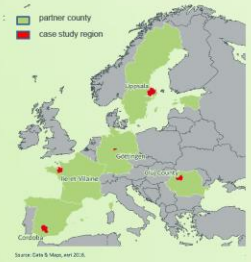
SoilMan evaluates four basic management practices affecting soil biota:

- Tillage
- Crop rotation
- Fertilization
- Management of crop residues

Lab and field experiments are conducted to gather new knowledge on soil-related ecosystem services and to determine their socio-economic value for farmers and society.

Farmer discussion groups and stakeholder interviews are conducted to gather insights through the participatory process. With the help of models, the effects of soil biodiversity friendly practices are assessed and quantified.

Policy recommendations are derived from the results of **SoilMan** targeting national and European decision makers.




earthworm


collembola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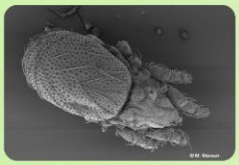
mite


arbuscular mycorrhizal fungi


gastropod

Project tasks

- **SoilMan** conducts a systematic ecological, economic and political assessment of soil biodiversity in typical European agricultural systems.
- **SoilMan** assesses the impact of soil management practices on the provision of ecosystem services by soil organisms.
- **SoilMan** identifies indicators to quantify soil functions and multiple soil-related ecosystem services in different European regions.
- **SoilMan** provides ways how to get farmers engaged for a better soil protection
- **SoilMan** shows how to further valorise soil-based ecosystem services through policy.
- **SoilMan** develops recommendations for the agriculture sector on sustainable soil management practices.

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Effects of digestates and cattle slurry on aggregate stability of a loamy soil

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Digestates from biogas plants are often used as fertiliser in agriculture. However, the effects on aggregate stability have not yet been fully investigated. As initial investigations by Voelkner and Horn (2015) show, fermentation residues differ in their effect and can also lead to dispersion of soil particles. The properties of the digestates depend on the input materials of the biogas plant, their degradability, the type of fermentation (mesophilic, wet) and the residence time in the fermenter.

In this thesis it was examined how cattle manure and digestates from three different origins with different proportions of manure and renewable raw materials affect the aggregate stability. The liquid organic fertilizers were mixed with a medium to strong loamy sand (Sl3) and incubated at 20 °C for 8 weeks. The fertilizer quantity corresponded to half the nitrogen equivalent of the maximum application quantity of 170 kg TN ha-1 a-1 (DüV 2017). Sampling took place on five dates: directly after incorporation, after one, two, four and eight weeks. In order to test the dispersing effect, the waterstable macroaggregates were analysed using the wet sieving method. In addition, the dispersed clay (RDC readily dispersible clay) was examined following Voelkner and Horn (2015) by turbidity measurement on the turbidimeter. The microbial biomass by CFE and the respiration according to Iseremeyer were analysed as important parameters for the understanding of the processes taking place.

Reference

Voelkner, A. und Horn, R. (2015): Einfluss von Biogasgärresten auf Dispergierungsprozesse in Böden – welche Bedeutung hat die Körnung und Wertigkeit von Kationen. Die Bodenkultur 66 (1-2). S. 5-15

Incorporating the role of microbial diversity and plant soil feedback effects in agricultural managements

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Most information on plant-soil feedback (PSF) effects – soil priming by preceding plant affecting the growth of succeeding plant – are procured from natural ecosystems with the perspective of species invasion, community assembly and succession and primary productivity. We know very little about PSF mechanisms in agroecosystems, although from a belowground perspective, crop rotation is founded on the PSF hypothesis. According to PSF hypothesis, growing the same crop over and over again results into 'soil fatigue' and consequently reduced productivity. In contrast, altering crop species in time via rotation usually eradicates negative impacts of soil on productivity. Testing these mechanisms of PSF through indispensable plant-microbial interactions and crop productivity have rarely been empirically tested. Therefore, we apply the PSF framework in agricultural settings with two cash crops (Avena sativa and Vicia faba). Also, we aim to investigate if nutrient availability (via N fertilization) diminish the PSF effects on productivity. We sought to identify the functional aspects of soil microbiota by using soil inocula harboring distinct microbial (especially mycorrhizal) diversity. Here, we also compare the strength of effects of soil microbiota to that of PSF on plant productivity. Preliminary results show a strong effect of soil microbiota relative to N fertilization on plant productivity for both Avena sativa and Vicia faba. To compare microbiota driven effects relative to PSF effects, growing both crops in conspecific vs. heterospecific trained soils is underway and due for harvest in July 2019. Results from this study will pave the foundation of incorporating PSF effects and the role of microbiota through empirical evidences in agricultural managements.

How grassland introduction into permanent crop rotation (maize/barley/wheat) affects earthworm communities and forage production?

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Earthworms contribute to a wide range of ecosystem services in cropland. Nevertheless, crop practices can strongly modify earthworm communities. Most studies focusing on the impact of agricultural practices on earthworm communities are related to soil tillage, fertilization or pesticides, while the inclusion of grassland in crop rotations remain largely unknown. In this context, aims of the present study were to determine the effect of three years of grassland in a crop rotation and grassland fertilisation on earthworm communities. Earthworms were sampled in a long-term observatory in the western France. A fertilized grassland of three-year-old preceded by three years of crop rotation was compared to a permanent crop and to a fertilized six-year-old grassland. In addition, the fertilized six-year-old grassland was compared to an unfertilized six-year-old grassland. Three years of grassland increased significantly earthworm abundance and biomass by 4.6 and 8.3 times compared to the permanent crop with a strong return of the epi- and strict-anecic earthworms. Nonetheless, earthworm abundance and biomass in the three-year-old grassland were significantly 1.5 and 1.5 times lower than in the six-year-old grassland mainly due to strict-anecic earthworms. In the six-year-old grasslands, grassland fertilization enhanced significantly earthworm abundance and biomass by 1.6 and 1.4, especially for strict-anecic earthworms. Earthworm richness and Shannon index were no different between the 3 grassland treatments but 1.7 and 2.1 times higher in the 3 grassland treatments than in the permanent crop. This study provides further evidence of the value provided by including a period of fertilized grassland in crop rotation for a rapid recovery of earthworm community.

Do annelids or litter locations influence the water-stable aggregate distribution?

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It is well known that annelids such as earthworms and enchytraeids provide ecosystem services concerning soil fertility and sustainability, e.g. by structuring the soil and building stable aggregates, which reduces soil erosion. The objective of this study was to quantify the combined effect of soil annelids and organic matter location on water-stable aggregate size class distribution.

In a microcosm experiment, undisturbed soil columns (30 cm height, 15 cm diameter) were used, which were taken at the long-term field trial "Garte Süd" near Göttingen, Germany, in reduced tillage plots. The soil type of the field trial is a Haplic Luvisol with a silt loam texture. As annelids we used (i) the endogeic earthworm species Octolasion cyaneum (four individuals), (ii) the anecic earthworm species Lumbricus terrestris (two individuals) or (iii) a combination of the two enchytraeid species Enchytraeus crypticus and E. christenseni (350 individuals). As litter we used maize leaves (5 g per column) and either put them on the soil surface (simulation of organic matter location of no-till systems) or in 15 cm soil depth (simulation of organic matter location of conventional tillage systems). All three annelids were combined with both litter location treatments. We also included control columns with and without maize leaves, in both cases without annelids. The columns were incubated for three months at a temperature of 10 °C.

First results show that the macroaggregate concentration in the top 10 cm was lowest in the columns without annelids and highest for the soil columns with O. cyaneum. The location of the organic material influenced the aggregate distribution in the soil columns with L. terrestris (more large and less small macroaggregates in the columns with maize leaves at the soil surface in the top soil) and with Enchytraeus (less microaggregates in the columns with maize leaves at the soil surface in the top soil), while having no effect on the columns with O. cyaneum.

Therefore, we can conclude that the influence of different annelids on the aggregate distribution is small or not evident and that the addition or non addition of litter has a larger effect. However, the location of the litter within the soil columns shows no clear pattern among the soil annelids.

SoilMan

Ecosystem services of soil biota in agriculture

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