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BOOK OF ABSTRACTS

Block B

B2 External organic matters for circular economy

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B2 External organic matters for circular economy

Session Description

Involved projects: EOM4SOIL, BIOCASH

Conveners: Sabine Houot (INRAE), Walter Rossi Cervi (WR)

The use of external organic matters (EOM) in agriculture has been realized since many years through the application of animal manures and slurries. Now it becomes mandatory to recycle biowastes from urban activities (from homes, restaurants, stores) and their application on soils after treatment contribute to nutrient cycling and bioeconomy in territories, together with organic carbon contribution to soils and climate mitigation. Before application, different treatments may be applied that increase the diversity of characteristics of the EOM applied on soils, increase or decrease the efficiency of nutrient recycling. Such EOMs may also carry contaminants (organic contaminants, impurities, trace elements) that needs to be known and controlled to prevent environmental impacts associated with EOM recycling. To consolidate the uses of these EOMs in fertilizing practices with maximum nutrient use efficiency, positive carbon budget and economically viable without environmental impacts, it is important to improve the knowledge of the available EOM (quantity and quality), on the relationship between treatments and EOM characteristics and efficiencies and on the multi and simultaneous impacts of their use. Long-term experiments with repeated EOM application are useful tools for such assessments. Recommendation for good management of organic wastes treatment and use as fertilizers need to be produced for end users at the farm or territory scale together with policy recommendation at the territory or national level. Moreover, understand the economic potential of these EOMs and their impact on the current fertilizer market as well as on farmers cash flow.

The session will address these questions of best management practices in recycling EOMs to close nutrient and carbon cycles for sustainable territorial bioeconomy.

Soil Organic Carbon in farm level economic models: data needs for considering local specific contextual factors

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FarmDyn is a bio-economic farm model that simulates farmers` production and investment decisions under different macro-economic policy scenarios and international prices. Although *FarmDyn* is a farm-level model, an aggregation of farms is often made at European NUTS2 in order to reduce computational costs and to better integrate with its data sources as well as to provide comprehensible outputs for policy makers at regional level. The majority of the parameters and indicators in *FarmDyn* are composed by agro-economic indicators, such as production volume and costs, taxes, subsidies, among others. Moreover, additional agronomic-biophysical variables also considered in the model`s parameters (e.g. soil type, tillage levels, nutrient needs), which are relevant for capturing environmental externalities and add value to better agricultural practices (e.g. carbon price and valuing ecosystem services). The downside is that *FarmDyn* does not capture the high spatial granularity of these parameters; instead, it considers simplistic assumptions. This limits the model in providing more coherent information on environmental economic indicators. Given that, the objective of our study is to create a coherent integration of *FarmDyn* with an agronomic-biophysical model in order to incorporate more detailed information on Soil Organic Carbon (SOC).

We opted to improve the SOC representation because FarmDyn presents a pre-defined structure to calculate the SOC dynamics (so-called in the model as "*FarmDyn-HumusBalance*), which accounts for the humus input and output from arable farms. However, the structure is very specific for the German context and provide no linkage between Organic Carbon (OC) and soil texture (i.e. clay, sand). In the current version, *FarmDyn-HumusBalance* is composed by four main variables: *i*) initial OC removal (i.e. accounts for the deficit in OC due to harvest removal of above-ground biomass), *ii*) OC incorporation from crop-residues (i.e. accounts for the OC that can be incorporated in the soils if crop-residues are kept on the field), *iii*) OC deduction from crop-residues (i.e. accounts for the deficit in OC if crop-residues are removed from the field), *iv*) additional OC from external organic fertilizers (i.e. accounts for the OC that can be incorporated in the soils if organics fertilizers such as animal manure is used as fertilizer).

To improve the SOC balance quantification in *FarmDyn*, we make use of *Miterra-EU* model, which is a dynamic agronomic-biophysical model that estimates soil health indicators. The advantage of using *Miterra* is that all the outputs are available at NUTS2 level, which integrates well in FarmDyn parameter resolution at NUTS2 level. Hence, we have initially requested: a) baseline SOC stocks of arable and grassland areas at NUTS2 level, b) SOC lost rate in arable and grasslands areas and c) a relational table between C emissions and C stocked under different soil textures levels at NUTS2 level. The implementation of these new components is currently ongoing, and we expect as a result that *FarmDyn* could indicate regions where a given economic policy could lead to major SOC depletion/increase, and therefore steer appropriate measures at regional levels. Further results about the model integration will be presented in EJP-ASD 2024 in Vilnius.

Keywords: Farm-Economics; Soil Organic Carbon, Model integration

Economic, soil health and environmental impacts of use of renewable fertilisers at farm level in the EU

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With valuable nutrients often ending up in the form of waste such as sewage sludge, food waste, and green waste, this provides the opportunity for composting and then reuse these now often lost and unused nutrients. Further innovation in manure processing techniques can also create opportunities for use of manure based products that are better aligned with the crops nutrient demand. The use and implementation of these recycled and waste based renewable fertilisers can help reduce the dependency on artificial fertilisers and help close the nutrient cycle for agricultural production. For both farmers and policy makers it is important to know what renewable fertilisation products, as different types compost and animal manure products, would suit within arable production systems and how use of these products will impact farm income, use of artificial fertilisers, soil health and nutrient balances. Here we present the results of an extensive literature review regarding carbon content, nutrient content and user prices of a list of more than 25 renewable fertiliser products. The list contains two compost products, one from green waste and one from food waste. The remaining fertilisation products can be categorised as untreated animal manure and thick fraction, thin fraction and mineral concentrates from processed pig and cattle manure. Next we will use bio-economic farm models to assess impacts of different fertilisation strategies on farm income, nutrient balances and average organic matter balance, depending on availability of renewable fertiliser products and policies. The bio-economic farm models optimise farm income and it is expected that policies and the availability of more renewable fertiliser products against competitive prices, will lead to different production management choices regarding production and fertilisation. The first bio-economic farm model that is used focusses on some typical arable farms in the Netherlands. For upscaling to the EU, a second bio-economic farm model is applied to EU average NUTS2 arable farms, as derived from individual farm data from FADN.

Keywords: Renewable fertilisers, Arable farms, farm-Economics; Soil Organic Carbon, nutrient balances

Assessing agronomic and environmental impacts of external organic matter amendments in diverse agricultural practices: a comprehensive study

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Agricultural practices that utilize external organic matter (EOM) amendments have a notable impact on agroecosystems. Evaluating these impacts relies on long-term field experiments, encompassing soil organic carbon (SOC) assessment, greenhouse gas (GHG) emissions, and soil contamination post-EOM application. However, effective waste management and fertilization practices, specifically for the farmers, play a crucial role in optimizing nutrient utilization efficiency, achieving a positive carbon balance, and ensuring economic viability without adverse environmental consequences. The specificity and territorial nature of the experiments, influenced by factors such as climate, soil type, cropping systems, and EOM application methods, necessitate a nuanced approach. This study aims to evaluate the agronomic and environmental performance of various EOM utilization scenarios across diverse agricultural contexts in different regions. Emphasizing both short-term and long-term effects, we use the PROLEG tool, which integrates the AMG model, the STICS model, pedotransfer functions, and fundamental calculations of GHG balance, to comprehensively assess the impacts of EOM application in farmers' fields. Representative case studies in European regions, defined with local experts, include diverse soil types, cropping systems, and the main EOM used by farmers. Our investigation focuses on SOC assessments, soil fertility dynamics, nutrient balance and fertilizer savings, as well as quantifying nitrogen losses through leaching and volatilization, balancing GHG emissions, assessing soil trace element contamination, and conducting economic evaluations. These simulations are conducted across diverse cropping systems and consider both the short and long-term

effects of EOM application across varied pedoclimatic conditions. Data collection and case study definition across several European regions enable us to simulate these effects, acknowledging significant differences in EOM usage between regions based on availability and farmers' cropping systems. Additionally, this study explores prospective scenarios involving various EOM treatments, including methane production, to anticipate future agricultural practices in selected regions. In conclusion, our study provides valuable insights into the diverse practices of EOM use and their effects on agriculture. It offers guidance for implementing sustainable practices tailored to specific agricultural contexts and environmental conditions.

Keywords: Cropping systems, EOM application, GHG emissions, PROLEG tool, SOC assessment.

Renewable horticultural substrates as source of external organic matter: the link between circular horticulture and soil friendly practices

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Future use of C-rich external organic matter for a variety of applications including C storage in soil is expected to increase, potentially resulting in a shortage of these sources of exogenous organic matter. Using C-rich materials in a cascade is one strategy to avoid competition for these types of bio-circular waste streams. Biomass use in cascade, i.e., first using biomass in an application in the bio-economy will affect the characteristics of the biomass and its agronomic value for the second use, and the final use as external organic matter for soils. In some case, the transformation of the biomass may improve its value for soil application afterwards. One case study of the BioCASH project explored the opportunities in horticulture to use biomass in cascade in order to avoid competition for renewable biomass. The case study is an example of the use of renewable biomass in horticultural substrates, with the spent growing media having a higher stability and a more optimal nutrient profile after use in controlled environment agriculture. In the current transition from linear to circular horticulture, horticultural substrates (growing media) play an important role. Circularity for growing media means that renewable materials are used, reused and then finally applied as soil improver and for C storage.

The study starts from a comparison of chemical characteristics (organic and inorganic C, total N, P, K, Ca, Mg, C/N and C/P, CEC, pH, EC), biochemical composition (Lignin/cellulose/hemicellulose), microbial biomass and biological stability (C and N mineralization) of green composts and woody biochars versus spent horticultural substrates as such or further processed into compost or biochar. This comparison allows to assess the changes in the quality of external organic matter when used directly in the soil or only after use in a horticultural cascade. The green composts and wood-based biochars are examples of materials that are produced and then in most cases directly applied in the soil but that also can be used as bulk replacement for peat in growing media. The spent horticultural

substrates applied directly or after further processing into compost or biochar are examples of materials used in a cascade.

It is concluded that exogenous organic matter from circular use of renewable growing media may result in materials with a higher added value as soil improver and source of stable C than green compost when nutrient retention during the horticultural cascade is managed. Biochars produced from spent growing media have clearly different chemical characteristics than wood-based biochars and may have a lower biological stability when produced at 400-450°C. Although spent growing media have a high biological stability and low N mineralization rates, they still carry a high microbial biomass. The case study indicated potential for biomass use in cascade, i.e., first using and reusing biomass in horticulture combined with the final use as external organic matter for soils.

Keywords: green compost, wood-based biochar, peat replacement, controlled environment agriculture, biochar-based fertilizers

The effects of cattle manure and straw co-digestion on the digestate carbon stability

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Maintaining or even increasing soil organic carbon (SOC) content is crucial for soil fertility. The use of bio-based fertilizer products not only increases the amount of organic matter in the soil but also promotes nutrient recycling. The stability of organic matter and carbon in soils is dependent on the characteristics of the material and applied treatment. For example, anaerobic digestion alters the composition of the treated organic matter and influences the stability of carbon by transforming easily degradable organic matter into biogas, concentrating more stable forms of carbon into digestate.

In the EJP SOIL program funded EOM4SOIL project, the goal was to investigate whether the digestate's carbon content and stability could be increased through the co-digestion of cattle manure and straw. The hypothesis was that the lignin-rich straw, added along more easily degradable manure, introduces less degradable carbon into the digestion process. The objective was to examine the effects of co-digestion on the whole process, considering both gas production and digestate properties, especially from the perspective of carbon stability and retention in soils.

The co-treatment of cattle manure and straw was studied in two 1 m3 pilot-scale leach-bed batch reactors. The experiment was conducted under mesophilic (37°C) conditions by circulating leachate through the bed of manure and straw. Manure and straw were added to the reactors in a carbon ratio of 60/40, where straw comprised 16% of the total mass of the raw materials. The biogas production was monitored throughout the 139-day experiment. The produced digestate was characterised and the digestate carbon was fractionated into acid-soluble (A), water-soluble (W), ethanol-soluble (E), and non-soluble (N) fractions, i.e., AWEN fractions. Additionally, the results of the AWEN fractionation were utilized in Yasso07 modelling to examine the stability of digestate carbon in the soil.

As a result, the co-digestion of manure and straw converted 23–27% of the feedstocks' carbon into biogas, while 53–63% concentrated into digestate (Fig. 1). According to the AWEN extraction, 37–40% of the carbon in the digestate consisted of more stable carbon (E and N fractions). Thus, about 22% of

the carbon input into the biogas process was considered as more stable carbon (Fig. 1). The same value would be 26% in a mixture of untreated cattle manure and straw. Despite slightly lower carbon retention, the co-digestion converts part of the carbon into valuable methane and contributes to the production of renewable energy.

The Yasso07 modelling indicated that approximately 26% of the digestate carbon remained in the soils 20 years after the application. This is higher than with untreated manure (21%) and straw (17%), which supports the use of anaerobic digestion as the processing step for manure and straw, to aid the build-up of SOC. This type of organic amendments are often repeatedly applied regularly each year, and thus, their application has potential to gradually increase SOC also over long-term.

Keywords: co-digestion; digestate; carbon stability; cattle manure; straw

Bottom-up dialogue with local actors of biochar and digestate value chains in Italy

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In order to support the development of useful guidelines for end-users and fair policies promoting the sustainable use of Exogenous Organic Matters (EOMs), a bottom-up dialogue among actors of biochar and digestate value chains has been established, in Italy, in spring 2024. More specifically, two focus groups on biochar and digestate production and use have been conducted to gather more realistic knowledge of the EOMs value chains in specific local contexts.

For example, the Italian Northern Regions can be described as a case study, where common strengths and problems connected with the production and use of digestate are present. In fact, in these Regions biogas plants are highly concentrated (83,4% of the 2.201 biogas plants in Italy in 2021), with a consequent high production (the majority of the 3 million tonnes per year produced in Italy) and application of digestate. However, application rates are limited by the European Directive 91/676/CEE for Nitrate Vulnerable Zones (NVZs) vs. non-Nitrate Vulnerable Zones (nNVZs).

On the other hand, biochar value chain is still very poorly developed in Italy. Out of 29 authorized biochar producers in Italy, only 6 are currently producing biochar (around 1000 t/year) because of strict regulations on physicochemical characteristics of the biochar, economic unsustainability of the production plants and no demand by farmers.

These examples highlight the diversity of EOMs value chains and the importance of the local context on EOMs availability and use.

In this context, in the framework of the EOM4SOIL project, CREA researchers organized the two focus groups with the aim of collecting information about:

gaps in legislation for EOMs producers and farmers;

environmental sustainability of EOMs use in different contexts (e.g. where relevant, NVZs vs. nNVZs);

economic sustainability for EOMs producers and farmers.

The focus groups were opened to a maximum of 30 invited participants, to facilitate interaction, representing each phase of the value chain. The actors that participated to the focus groups were highly relevant: Ministry of Agriculture, Regional authorities, Environmental quality inspectors,

research institutes, EOMs producers and producers' associations, farmers, farmers' association, multinational enterprises, carbon credits certifiers, EOMs dealers and distributors.

Focus groups were conducted with the following structure:

introductory session about the EoM4SOIL project goals and findings;

introduction of participants (affiliation and role in the EOM value chain);

division of participants into 4 working groups for discussion around tables. Each group was guided by a mentor to define the Strengths, Weaknesses, Opportunities and Threats of EOM production and use. A rapporteur was chosen among the participants of each group;

the rapporteur presented to the whole audience a summary of the discussion ran in each of the table and the debate was opened.

Based on this fruitful discussion, common views on Strengths, Weaknesses, Opportunities and Threats of EOMs value chains were observed and will be valued to formulate policy recommendations as well as guidelines for end-users. These results will be presented during the Annual Science Days of EJP Soil 2024.

Keywords: Exogenous Organic Matter; focus groups; farmers; policy recommendations; barriers

Fertilizer quality of anaerobic digestate produced from marine residual resources (CIRCULIZER)

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The access to marine residual resources is large in Norway, yet its use in agriculture remains limited. **Circulizer project** aims to improve the circularity between the blue and green sector, by increasing the knowledge of the use of marine residues (i.e. fish sludge and fish silage) for biogas production and its effects on the fertilizer quality (digestate) and environment. While the quality of digestate from food waste and animal manure has been extensively studied, the impact of incorporating increasing proportions of new marine residual resources remains to be investigated. To be able to substitute mineral fertilizer with digestate derived from marine residues, farmers require knowledge of its nutrient composition and availability. In contrast, biogas plant operators need assurance of a market for both biogas and digestate before investing in new facilities. Circulizer will run lab and field scale experiments where the biogas process performance and digestate quality will be assessed. Expected outcomes are: (i) Enhancing the green transition and circularity of Norwegian food production by recycling valuable nutrients from fish production for agricultural use; (ii) Ensuring environmental safety by addressing concerns related to heavy metals and organic pollutants; (iii) Increasing the utilization of marine residual resources for biogas production; (iv) Supporting the growth of the fish farming industry in Norway by improving waste treatment and recycling options for unavoidable residual resources, thereby facilitating increased fish production and nutrient recycling.

Long-term impact of anaerobic digestion of dairy cattle slurry on grass clover yields and soil properties

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Anaerobic digestion (AD) of animal manure generates renewable energy in the form of biogas. However, there is a gap in our understanding of the long-term impacts of AD-treated manure on soil attributes and crop productivity in comparison to untreated manure. To address this, a long-term field experiment was initiated in 2011 within a perennial grass-clover ley. The objective was to investigate the effects on key soil and crop parameters when slurry from organically managed dairy cows underwent AD.

The results (2011-2021) indicated that while the application rate of manures influenced soil nutrient levels and pH, these parameters were unaffected by AD treatment. Higher slurry application rate (220 kg of total N $ha^{-1}year^{-1}$) led to a surplus of N, while deficits were observed in the untreated (non digested) control and the treatments with low application rates (110 kg of total N $ha^{-1}year^{-1}$). Treatments were not limited by P. For K, there were deficitsin all treatments. Soil organic matter (SOM) concentrations decreased across all plots, especially in those with inherently high SOM levels. This decline in SOM was similar with both untreated (non-digested) slurry and anaerobically digested slurry, and there was no significant effect of application rate. The decline may be attributed to the initial high SOM content, prolonged drainage, and increasing temperatures due to climate change.

Notably, both US and ADS demonstrated similar yields of grass-clover ley (2 cuts $year^{-1}$) and green fodder, averaging 7.9 and 4.0 kg DM ha^{-1}, respectively. Additionally, within the same production year the mean clover yields of the fertilized treatments did not differ from the control. In terms of crop yields and chemical soil characteristics, the long-term effects (over 10 years) of AD within an organic dairy cattle farming system were generally minor. The advantages of harvesting energy from slurry did not compromise the long-term productivity of grasslands or the soil chemical characteristics.

Keywords: Grass-clover ley; botanical composition; digestate; soil organic matter; organic farming

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The DeliSoil Project - Delivering safe, sustainable, tailored & socially accepted soil improvers from circular food production processes for boosting soil health

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The poster presents the EU-funded 'DeliSoil' project (years 2023-27), which supports the EU Mission 'A Soil Deal for Europe'. DeliSoil focuses on improving the sustainability of food systems and enhancing soil health by developing improved recycling and processing solutions for food industry residues. It focuses on delivering safe, sustainable, customized and societally acceptable soil improvers from circular food production processes to promote soil health. The project will establish 5 regional Living Labs (in Finland, Denmark, Germany, Italy and Spain), including 5 Lighthouses.

Different processing methods and best practices for food industry residues are discussed and co-created with partners, members of DeliSoil Living Labs, and other stakeholders, taking environmental aspects into account. Information is distributed to the actors of the entire food value chain and to the general public. The project ensures the acceptability and safety of soil improvers and organic fertilizer products made from food industry side streams, as well as their effectiveness in promoting soil health.

Natural Resources Institute of Finland (Luke) is coordinating the DeliSoil project and 13 other partners from 10 different European countries are involved. Acknowledgement: DeliSoil project is funded by the European Union under the Horizon Europe Program, Grant Agreement No. 101112855.

Keywords: EU Mission Soil, soil improvers, food value chain, soil health, circular bioeconomy

Effects of Anaerobic Digestates and Biochar Amendments on Soil Health, Greenhouse Gas Emissions, and Microbial Communities: A Mesocosm Study

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This study addresses the need for a comprehensive understanding of digestate and biochar in mitigating climate change and improving soil health, crucial for sustainable agriculture within the circular bioeconomy framework. Through a mesocosm experiment, soil was amended with digestates from pilot-scale reactors and two concentrations of biochar produced by pyrolysis of digested sewage sludge and waste wood. The Germination Index (GI) assay assessed phytotoxicity on *Lactuca sativa* and *Triticum aestivum* seeds. Greenhouse gas emissions (CO_2, CH_4, N_2O) measurements, soil characteristics analyses, and the study of microbial community structure enriched the study's depth. The GI assay revealed diverse responses among by-products, dilution rates, and plant types, highlighting the potential phyto-stimulatory effects of digestate and biochar water-extracts.

While digestate proved to be effective as fertilizer, concerns arose regarding microbial contamination. Biochar application reduced Clostridiaceae presence in soil but unexpectedly increased N_2O emissions at higher concentrations, emphasizing the need for further research on biochar's role in mitigating microbial impacts. CO_2 emissions increased with digestate application but decreased with a 10% biochar concentration, aligning with control levels. CH_4 uptake decreased with digestate and high biochar concentrations. The study underscores the critical role of biochar composition and dosage in influencing soil GHG fluxes, emphasizing the need for tailored approaches to optimize its impact on microbial communities and nutrient availability. The unexpected stimulation of N_2O emissions by high biochar concentrations challenges previous hypothesis, highlighting the complexity of biochar-soil interactions. Understanding the specific soil and biochar characteristics and origin is crucial for sustainable agricultural practices. The results offer new insights into the short-term effects of anaerobic digestates and biochar on soil microorganisms, emphasizing the complexity of microbial responses. Persistence and contrasting effects on microbial functional groups highlight the need for

continued research, especially exploring biochar as a tool to mitigate the impact of Clostridiaceae in soil ecosystems influenced by digestate application.

Keywords: digestate; biochar; soil nutrient; greenhouse gas emission; microorganisms; Clostridiaceae

Biological activation and N enrichment as tool to optimize biochar-based fertilizers

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Biochar-based fertilizers are a new type of engineered fertilizers, where biochar is formulated with mineral fertilizers and/or beneficial microorganisms for precise plant nutrition and the enhancement of soil properties. For soil application, biochar as a source of stable C can have an added value when it is enriched in N. Activation of the biochar is used to maximize their N retention capacity but some chemical activation methods may result in strong mass and C losses during the treatment. In one case of the BioCASH project we focused on the optimization of biochars by biological activation and increasing their N concentration, to develop a new type of engineered fertilizer. We compared: 1) biological activation of biochar by simultaneosly adding elemental S and chitin, and 2) addition of chitin to already chemical activated biochars by either hydrogen peroxide or nitric acid. Chitin and elemental S were applied for optimizing these biochars. Chitin was tested as N source to enrich the biochars. Elemental S was tested to optimize the pH of alkaline biochars in order to allow for N mineralization from the biochar. The pH of the biochar determined the effect of the treatment: only in the optimal pH range for microbiological activity, effects of elemental S and chitin in terms of S and N mineralization were observed. When chitin (2g/L biochar) was added to the intact biochar with pH 9.1, the pH increased to 9.7 and no net N mineralization occurred. The chitin addition to the biochar activated by hydrogen peroxide resulted in biological N enrichment, while chitin addition to the intact and HNO_3-treated biochars did not produce significant microbial changes. The biological acidification of the biochar with elemental S was a slow process due to the high acid-buffering capacity of the biochar, but resulted in a pH decrease from pH 9.1 to pH 6.5. Then additional chitin was added to the S-treated biochar, which resulted in a further pH decrease to pH 4.2 and clear mineral N release. When higher doses of chitin were tested to assess the potential of N enrichment, it was observed that only the combination of the intact biochar with elemental S resulted in a strong increase of the mineral N content. In this biochar, mineral N was only present as NH_4-N, not as NO_3-N or NO_2-N. After N mineralization, there were indications of immobilization of mineral N on the biochar. The addition of

higher doses of chitin did not result in mineral N release for the biochar after oxidation with hydrogen peroxide. However, lower doses resulted in significant NO_3-N release in biochar activated with hydrogen peroxide. Biochar oxidated with nitric acid showed a decrease in mineral N contents with higher chitin doses. Biological activation and N enrichment of biochar with higher chitin doses was only successful for the intact biochar after S amendment, indicating a positive interaction between chitin and elemental S. This study illustrates that specific combinations of chemical or biological activation of biochar result in higher N release after chitin addition.

Keywords: wood-based biochar, biochar-based fertilizers, biological acidification, chitosan

Impacts of biochar on nitrous oxide emissions and ammonia volatilisation in wheat and maize cropping systems

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Agriculture and other land use practices are major contributors to greenhouse gas emissions, especially for N_2O and NH_3. Nitrous oxide (N_2O) is a highly potent greenhouse gas and ammonia (NH_3) can re-react with soil and forms N_2O or can cause other environmental issues in the surrounding. Biochar is known for its carbon sequestration potential due to its high proportion of recalcitrant organic compounds, however, biochar can also positively influence soil properties like water holding capacity, nutrient leaching and mitigation of nitrous oxide emissions and ammonia volatilisation. However, these effects depend on pedoclimatic conditions, the properties of the applied biochar, and other agricultural practises. Therefore, it is necessary to expand the knowledge of these effects, especially under field conditions, to generate valid estimates on biochar's mitigation potential for N_2O and NH_3 emissions. A good and extensive data basis is essential for recommendations and a large-scale application in agriculture. In a two-year field experiment in Grabenegg (Lower Austria) we cultivated silage maize (Zea mays) in 2022 and spring wheat (Triticum aestivum) in 2023 with different organic (external organic matter, EOM) and inorganic (NPK) fertilisers. For the biochar treatments we applied 7 t/ha hardwood biochar additionally. The original soil was loamy, low in organic carbon and slightly acidic. We found substantial reductions with 36% (NPK) and 53% (compost) for N_2O and 56% (NPK) and 40% (compost) for NH_3 emissions. There are several factors discussed in literature how biochar mitigates N_2O and NH_3 emissions. We suggest that the immobilisation effect of biochar on NH_4^+ and NO_3^- (which was observed in the soil) and possibly an increased dinitrogen monoxide reductase activity are responsible for this reduction. Our data support that biochar can be a suitable amendment for highly productive agroecosystems where high amounts of fertiliser are needed and often applied at one timepoint. Still, further investigations on the long-term effect on emission mitigation of biochar and the mechanisms behind are necessary.

Keywords: nitrous oxide, N_2O, ammonia volatilisation, biochar, external organic matter

Shrimp shells valorization for chitosan and chitosan nanomaterial synthesis and their applications as antimicrobial agents in agriculture.

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The valorization of the large portion of shrimp biowaste as a sustainable source for chitosan extraction and chitosan nanomaterial synthesis is a novel approach that presents a promising avenue for addressing environmental challenges and promoting circular economy principles. Shrimp shells, a byproduct of the seafood industry, are rich in chitin, a polysaccharide that can be converted into chitosan through deacetylation. Chitosan, a biopolymer with unique properties, has garnered attention for its potential applications as a sustainable in various fields, including agriculture. additionally, the antimicrobial properties of chitosan nanomaterials make them effective against a wide range of plant pathogens, including bacteria and fungi. This research aims to evaluate the optimization feasibility of the inorganic and organic acidic demineralization phase on chitosan extraction and characterization of morphological and physicochemical properties. Furthermore, we will shed light on the applications of chitosan nanomaterials as antimicrobial agents in agriculture, particularly in the context of plant disease management and soil remediation. Shrimp shells were collected from the Lithuanian market. The optimization experiment was carried out using various concentrations of 1, 2, 3, 4, 5, and 10% of hydrochloric, acetic, and lactic acids for acidic demineralization at room temperature at stabilized deproteinization and deacetylation conditions to study the effect of acidic demineralization of inorganic and organic acids on the physicochemical and structural characteristics of yielded chitosan. Chitosan production with a high deacetylation degree > 80% for all samples was confirmed by FT-IR spectroscopy compared to commercial chitosan. The ash content, moisture content, and chitosan yield were in the ranges of (0.24-4.2%), (0.19-5.1%), and (15.1-51.3%), respectively. Furthermore, XRD and SEM combined with EDS showed that commercial chitosan had a complete amorphous structure. In contrast, the isolated chitosan samples showed a bit higher crystallinity index than commercial chitosan due to the formation of natrite (Na_2CO3) and thermonatrite ($Na_2CO_3.H_2O$) in the samples recovered using HCl. Whereas the samples extracted using acetic and lactic acids showed the existence of calcite and halite crystals. Finally, this study found that chitosan production can be optimized from shrimp biowaste with a high resemblance to commercial

chitosan using the concentration manipulation approach of inorganic and organic acids in the demineralization stage. Our future research will discuss the green synthesis of Chitosan nanomaterial from chitosan samples obtained in this study. Moreover, we will test their antimicrobial activity against soil pathogenic microorganisms (In vitro assay). Moreover, testing the efficiency of chitosan-nanomaterial among Fusarium graminiarum fungi will be determined in the greenhouse experiment, The fungicidal effect on spring wheat growth, development, and the prevalence of the disease will be assessed.

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Keywords: Shrimp Biowaste, Chitosan, Nanomaterial

A stocktaking of long-term field experiments in Europe dealing with the application of exogenous organic matter: current knowledge, gaps and perspectives

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Extending and optimizing recycling of organic wastes in agriculture is a key element in shifting conventional agriculture towards systems adapted to both energy depletion and climate change. Long-term field experiments (LTEs) play a crucial role in assessing and modelling the effects of repeated exogenous organic matter (EOM) application to soil, which allows to formulate locally adapted recommendations of use. Nevertheless, a meta-database gathering exclusively LTEs dealing with organic fertilization in Europe and specifying fertilisation conditions is currently missing. To close this gap, we listed LTEs dealing with repeated application of EOM from existing online databases and scientific literature, and collected and harmonized all available metadata. The aim of this work was threefold: (1) to facilitate connections between comparable LTEs to foster data harmonization and compilation, (2) to map the diversity of pedoclimatic contexts and experimental designs in the LTE list and, (3) to highlight current knowledge gaps and research needs. Data were collected from five online databases, allowing us to describe 201 LTEs. Key characteristics such as trial name, responsible institution, location, pedoclimatic context, duration, crop type and availability of online resources are well-described in contrast to LTE goal and owner contact, experimental design, soil type, studied EOM and monitored parameters (EOM characteristics, soil and crop properties), which are more difficult to gather and harmonize. The analysis of LTE metadata highlighted first that substantial harmonization efforts are required, particularly regarding the reporting of soil, crop and EOM properties over time. Second, the survey outlined that some European regions are poorly represented in the database, which may result either from an absence of LTE or from a lack of reporting. In the future, improvement of predictive models could contribute to provide recommendations of EOM use to uncovered situations, whether in terms of soil, climate or type of EOM. Third, long-term effects on soil properties such as changes in soil biology composition or accumulation of organic contaminants (PFAS, microplastics, antibiotics, ...) appear to be poorly documented. LTEs have a key role to play in

answering these emerging questions, having the potential to provide the rationale to fix acceptable thresholds in soils and EOMs for emerging pollutants and accordingly provide the best possible guidelines for the use of EOM in agriculture.

Keywords: Long term experiments; Organic fertilization; Metadata; Network; Harmonization

Effects of sheep wool pellets and black soldier fly (*Hermetia illucens*) frass on soil biota

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Black soldier fly cultivation has been conducted in the pilot laboratory of the Estonian University of Life Sciences since September 2018. The sheep wool pellets mixed into the soil release nutrients to plants gradually throughout the entire growing season. Nitrogen, potassium, phosphorus, and other essential nutrients are slowly released as they degrade.

The experiment was carried out at the Eerika Experimental Station in Tartu, Estonia. The experiment with sheep wool pellets had three different treatments (80, 60, 40 kg N ha^{-1}), followed by a control, and then two areas treated with black soldier fly manure (1.65 kg and 2.2 kg). In first year the summer wheat 'Mistral' was sown and on second year the oat 'Symphony' was cultivated. The following sown crop is rye 'Elvi'. In total, there were 6 different treatments, each replicated three times. Soil biota (earthworms, microbes) samples were taken on September 23, 2022, and August 26, 2023. Earthworms were collected using the vermifuge method, where a 50x50 cm sample square was made in the centre of each test plot and soaked with a 15% mustard powder solution. Earthworms were collected, and their abundance was calculated per square meter of land. A composite soil sample was collected with a soil auger, with a diameter of 5 cm and a depth of 10 cm, and from the composite soil sample, soil chemistry and microbiological biomass and respiration activity were determined. The crop yield and yield structure was analysed following harvest (29.08.2022; 24.08.2023, respectively). Upon analysis of the results, it was observed that 2022 was more favourable for earthworm abundance compared to 2023. In 2022, the treatment with sheep wool pellets had a higher abundance at the higher rate (880) (80.0±18.9). There were three earthworm species in 2022 and four in 2023 (with a total of 13 species in Estonia). In areas treated with black soldier fly manure, it appeared that the greater impact on earthworm abundance was at the higher rate (2.2 kg) (2.2 kg: 96.0±14.1 vs 1.65 kg: 85.3±23.4 in 2022). Microbial respiration was the highest in 2022 in the control area and the lowest in the area treated with the higher rate of sheep wool pellets. A greater impact on respiration was observed with the lower rate treatment of black soldier fly manure (1.65 kg). The subsequent effects

in 2023 on microbial community respiration activity and biomass due to sheep wool pellets and black soldier fly frass seemed to be relatively similar. The lower abundance of earthworms in 2023 could be attributed to the extreme drought conditions during the same year. The yields from experiment were 6.4 -7.9 t ha^{-1}.

Keywords: organic fertilizers, earthworms, field experiment

The impact of Black Soldier Fly (*Hermetia illucens*) larvae frass on the abundance and diversity of springtails (Collembola) and on cereal crop yield

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Insect farming is a novel but potential industry in Estonia. Black soldier fly cultivation has been conducted in the pilot laboratory of the Estonian University of Life Sciences since September 2018. *Hermetia illucens* larvae are highly efficient decomposers of various types of organic waste, food waste, and agricultural by-products. Throughout their growth cycle, they decrease the amount of organic matter and transform it into valuable organic fertilizer, which can be successfully used as an alternative to mineral fertilizers. Like most organic fertilizers, larvae frass can improve the physical, chemical, and microbiological properties of soil and add essential nutrients for plants. In addition to nutrient supply, larvae frass acts as a biostimulant for plants by adding biomolecules and microorganisms that enhance germination, increase plant growth, improve nutrition, enhance abiotic stress tolerance, and increase resistance to pests and pathogens. The aim of this research is to assess how soldier fly larvae frass affects the abundance and diversity of springtails (Collembola) and how it influences cereal crop yield. The experiment was carried out at the Eerika Experimental Station in Tartu, Estonia. In the field trial, there were six different treatments: control (unfertilized), mycorrhiza (unfertilized), mycorrhiza + frass (74 kg N/ha), small dosage of frass (74 kg N/ha), large dosage of frass (150 kg N/ha), and full agrotechnology (fertilized with NPK mineral fertilizer, 150 kg N/ha). Each treatment was replicated three times. In 2021, the crop culture was spring wheat (*Triticum aestivum L*), variety ´Quarna´. In 2022, it was winter barley (*Hordeum vulgare L)*, variety ´Tenor´. Soil biota (collembola) samples were taken on September 2021 and 2022. Soil samples of springtails were collected using a soil corer (Ø 5 cm) at a depth of 0-10 cm, four soil samples were taken from each sample plot, a total of 12 soil samples were collected per treatment in September 2021. In September 2022, two soil samples were taken from each plot, a total of 6 samples per treatment. A composite soil sample was collected with a soil auger, with a diameter of 5 cm and a depth of 10 cm, and from the composite soil sample, soil chemistry and microbiological biomass and respiration were determined. Although the average abundance of springtails differed between 2021 and 2022, it was

observed that in both years, the highest average abundance was in the treatment where mycorrhiza + frass was applied (respectively 2021: 134.0±38.0 and 2022: 83.7±30.9). A total of 42 species of springtails were identified. The most abundant species were *Xenylla grisea*, *Parisotoma notabilis* and *Folsomia quadrioculata*. Due to the very hot and dry conditions in the experiment conducted in 2021, the yield of spring wheat remained very low, averaging 1.3-1.6 t/ha. This was higher in the variant with mycorrhiza + frass. The yield of winter barley in 2022 averaged 3.5-6.1 t/ha. This was higher in the variant with a large dosage of frass.

Keywords: frass; springtails; yield

The impact of various organic materials in pot experiments on the survival of forest trees

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Estonia, like many other countries, has a rich history of mining activities, with its landscape punctuated by the remnants of quarries. Mining is essential to provide the resources for industries but can result in a destruction of pre-mining and post-mining ecosystem. The aim of this research project is to find techniques and materials that retain moisture for forest trees to assist in better rooting in mining areas. The goal is to promote plant growth and thus accelerate forest ecosystem establishment. In the pot experiment, we used two different mixtures. One was an imitation of oil shale quarry tehnosol (50% gravel and 50% soil), with the tree species being used pine (*Pinus sylvestris*). The other was sand from sandy quarry and the tree species used were pine (*Pinus sylvestris*) and spruce (*Picea abies*). In the pot experiments, the control variant varied according to the mixtures - either the imitation of oil shale quarry technosol (50% gravel and 50% soil) or sand. The following materials were tested: soil (100%), 2.3% sheep wool pellets (N-9.03%; K_2O-5.61%; S-1.15%; MgO-0.14%; P_2O_5-0.16%; OM-89.79%), sheep wool discs, 2% humate, 0.63% biochar (pHKCl – 8.75, Ntot – 0.08%, Ptot – 0.05%, Ktot – 0.13%, 60% ash content), 3.3% sewage sludge, 3.3% surface-applied sewage sludge substrate, 0.27% silica fume (by-product from the production of elemental silicon or alloys containing silicon, the particles are very fine, having a mean size of 0.1–0.3 µm), a mixture of materials (sheep wool pellets, biochar, sewage sludge on top). A total of 10 different variants, all in three replicates. The trees were planted in June 2023, and the monitoring of their survival is still ongoing. Based on the preliminary results, it can be stated that biochar and sheep wool discs had a positive impact on survival of forest trees. The sheep wool pellets and mixture of materials (sheep wool pellets, biochar, sewage sludge on top) had a negative impact on the survival of the forest trees. This research is supported by the Circular Economy program of the Environmental Investment Centre through a project with the number RE.4.09.22-0034 and by developmental project of Estonian University of Life Sciences “Valorization of sheep wool for agricultural utilization”.

Keywords: organic matter; pine, spruce; quarry reclamation

Short-term study on the fate of organic contaminants in soil after the application of biowaste compost or biogas digestate

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There is a significant interest in recycling waste to promote a circular economy. Using organic waste as soil amendments can improve soil fertility and structure. However, these amendments may contain organic contaminants or affect the behaviour of contaminants in the soil by adding organic matter.

In this study, we assessed the effect of applying biowaste compost or biogas digestate to a silty loam soil on 34 organic contaminants, including 18 polyaromatic hydrocarbons (PAHs), 7 polychlorinated biphenyls (PCBs), 2 bisphenols (BPA and BPF), 2 alkylphenols (octylphenol (OP) and nonylphenol (4-n-NP)), 2 parabens (methylparaben (MeP) and propylparaben (PrP)) and 3 organophosphates (TBP, TCEP, and TCPP) in a 12-month field experiment. The biowaste compost or biogas digestate used in this study derived from regional providers. The effect of these amendments on the fate of the mentioned above compounds was assessed by analysing the content of the contaminants in the soil before and after applying the treated wastes as amendments.

The application of organic amendments in soil may enhance the retention of compounds, resulting in lower availability. To determine the maximum extractable amount of organic contaminants in the soil samples, a mixture of ethyl acetate and methanol was used as extraction solvent, while their bioavailability was determined by analysing the soluble fraction (aqueous extract).

The extraction of soil using organic solvents revealed that five out of the 34 compounds evaluated were not present in the soil before or after its amendment. Additionally, the concentration of others, such as PCBs, was either very low or could not be quantified. In addition, the analysis of the soluble fraction of the soil suggests that the contaminants are more readily adsorbed in compost-treated soil, resulting in lower availability of contaminants in the aqueous fraction.

Although an increase in the concentration of some target contaminants was observed immediately after soil amendment, the overall concentration remained constant for the 12 months following

application. The analysis of the soluble fraction shows that the availability of the compounds remains throughout the 12-month period.

Keywords: organic contaminants; soil, compost, digestate, amendment

Assessment of the presence of microplastics in compost samples

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Compost application is a widely recommended practice in order to maintain and improve soil fertility. However, such practice could be a main entry path for plastic into soil. Accordingly, in the present work, different compost samples and corresponding feedstocks (substrate and biochar) were analysed in order to evaluate the presence of microplastics.

Samples were processed by oxidation, flotation and filtration. Microplastics on the filters were first visualised and counted by using a stereomicroscope. Those microplastics large enough to be separated from the filter with micro tweezers were stored for further observation using an inverted microscope equipped with a digital camera for size calibration. Those microplastics larger than 1 mm were further characterised by Attenuated Total Reflectance Fourier Transformed Infrared Spectroscopy (ATR-FTIR).

In all samples measured, there was a concentration of microplastics in the 1-3 fragments/g of dry sample range. Fragments presented different shape, size and colour. Microplastics were identified by comparing FTIR spectra with open access databases and with our own database. Three polymers represented the totality of identified plastic items: polyethylene (including both low and high density), polyethylene terephthalate and polypropylene in order of abundance. These results confirm the continued presence of plastics in this food waste compost and highlight one of the major challenges related to the potential for microplastics pollution when applying these wastes as organic fertilizer in agriculture.

Keywords: microplastics, compost, environmental pollution, agricultural soils