EJP SOIL
European Joint Programme

Annual Science Days 2023

BOOK OF ABSTRACTS

Block B

Session B2

Closing nutrient and carbon cycles

Table of Contents

B2 Closing nutrient and carbon cycles

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 are applied to these organic wastes that could also produce services such as energy production with anaerobic digestion. Other innovative treatments like pyrolysis producing biochars or new sources of recycled materials like human urine 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. The use of EOM may also have impacts in relation with the nutrients fluxes (ammonia volatilization, N2O emission, nitrate leaching) and it is important to control and prevent these impacts. To ensure the uses of these EOMs in fertilizing practices with maximum nutrient use efficiency, positive carbon budget and economically viable without environmental impacts, 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. The session will address these questions of best management practices in recycling EOMs to close nutrient and carbon cycles.

Abstracts of Oral Presentations

Carbon sequestration with biochar as soil amendment

Gerhard Soja[*1,2] **and Christoph Pfeifer**[2]

[1] *AIT Austrian Institute of Technology GmbH, Vienna, Austria*

[2] *University of Natural Resources and Life Sciences - BOKU, Vienna, Austria*

** Presenting author: gerhard.soja@boku.ac.at*

A fundamental property of biochar is the high proportion of carbon. Biochar usually contains 70-80 % carbon, whereas plants consist of 45-50 % C and the mass fraction of C in the atmosphere is about 0.016 %. The basic step for this enrichment takes place in plant photosynthesis, which causes a carbon enrichment factor of about 3000 compared to atmospheric carbon dioxide via several intermediate steps. The enrichment up to a factor of 5000 is made possible by the thermochemical processes during pyrolysis. These concentrate carbon in the solid residue (= biochar) in a condensed polyaromatic molecule structure. When biochar is incorporated into the soil, this carbon-rich product increases the content of soil organic carbon. This carbon accumulation in the soil is effective in the long term (100s to 1000s of years). In contrast to other organic soil amendments such as manure, harvest residues or compost, the carbon of biochar is difficult to access for microbiological degradation. Only a small fraction (few %) of the carbon is present in low-molecular, more metabolizable compounds, which remain as residues of the volatile pyrolysis products on the surfaces of the biochars or are recondensed again. It can be assumed that at least 75% (according to EBC) to >90% of the carbon contained in biochar can be described as stable. IPCC (Intergovernmental Panel on Climate Change) lists biochar as one of six terrestrial options for "negative emission technologies".

The importance of soil for long-term carbon storage is based on the enormous amount of carbon stored in the soil (about 4000 billion tons in organic and inorganic form), which corresponds to about five times the amount of carbon present in the atmosphere or four hundred times the amount of carbon emitted annually by fossil fuels and cement production. Therefore, even small relative changes in soil carbon can have significant climate-relevant effects. A meta-analysis by Gross et al. (2021) on the effects of biochar application on soil carbon content (64 studies lasting up to 10 years) showed a mean increase in soil organic carbon of 14-20 t C/ha under field conditions with a total biochar application rate of 20-30 t/ha.

A correct first approach to the calculation of the carbon sink potential and the certification of the verified carbon sinks of biochar is provided by guidelines published by EBC (Euorpean Biochar Certificate). The greenhouse gases produced during the production, preparation and pyrolysis of the biomass are included in the carbon balance. Considering a 10 % safety margin, the C-sink potential is calculated, which applies until the sale of biochar. The carbon sink potential only becomes a certifiable carbon sink when an accredited tracking system tracks the use of the biochar, and long-term carbon storage is ensured.

Keywords: carbon storage; pyrolysis; carbonization; carbon sink; biochar

Animal manure digestate and its effect on greenhouse emissions and soil microbial biomass

Doyeni Modupe*, Drapanauskaite Donata, Baksinskaite Ausra, and Barcauskaite Karolina

Lithuanian Research Center for Agriculture and Forestry, Akademija, Lithuania.

** Presenting author: modupe.doyeni@lammc.lt*

Climate smart agriculture continues to receive deep interest in a bid to contribute to climate change mitigation by reducing greenhouse gas emissions. At the top of this sustainable approach is the use of external organic materials from agricultural wastes in soil application. Most important in this discussion are livestock waste, a recurring agricultural waste that has consistently served as feedstock for biogas systems to produce digestate. The objective of this study was to assess the influence of animal manure digestate fertilization on greenhouse gas emissions and soil microbial activity in agricultural fields. Three annual crops were fertilised with distinct types of animal manure digestates (cow manure digestate, chicken manure digestate and pig manure digestate) and synthetic nitrogen for three years (2019–2021). The 170 kg N ha^{-1} presented in digestates were split fertilised at an application rate of 90 and 80 kg N ha^{-1}. The soil microbial activity could be predicted significantly using the dehydrogenase activity and soil microbial biomass carbon. By combining the two different monitoring approaches, the different methods applied in this study were sensitive to enzymatic activities and organic carbon in the living component of the soil organic matter. The emissions of greenhouse gasses (carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) were captured directly by a closed static chamber system. The period of digestate application witnessed higher cumulative fluxes of CH_4 (0.000117 ug $ha^{-1}h^{-1}$) and N_2O (0.085 mg ha^{-1} h^{-1}) emissions in the first year compared to the subsequent years of emissions. CO_2 emission peaks were consistently linked to the microbial activity in the soil with irregular patterns observed in all the years of digestate application. However, cumulative emissions were higher in the first and second year of the manure digestate application. Microbial biomass carbon and dehydrogenase activity were affected by the fertilized organic digestates. A significant difference ($p<0.05$) was recorded between the control and the digestate amended soils for the microbial biomass carbon. The animal manure digestate fertilization induced an increased microbial activity but with varying effects across the years under different climatic conditions.

The first year of digestate fertilization (2019) witnessed statistically lower SMBC value at 143 µg g^{-1} than the subsequent years, with the highest SMBC observed in the second year. Results showed individual and cumulative emissions of CO_2, CH_4 and N_2O from the animal manure digestates were relatively low while the soil microbial biomass C became more pronounced in subsequent years increasing by 20.2 - 75% when compared to unfertilized soil. This suggests digestate fertilization can be an efficient method for improving soil quality and reducing greenhouse gases from agricultural sources in temperate climate conditions.

Keywords: greenhouse gas emission, manure digestate, microbial activity, organic waste

Anaerobic co-digestion with biochars – A way to improve carbon sequestration in soils?

Tampio Elina[1*], Laaksonen Ilmari[1], Honkala Niina[1], Kymäläinen Maritta[2], Tiainen Satu[2], and Laakso Johanna[1]

[1] *Natural Resources Institute Finland (Luke), Biorefineries and bio-based fertilizers, Finland*

[2] *Häme University of Applied Sciences (HAMK), Bio Research Unit, Finland*

** Presenting author: elina.tampio@luke.fi*

Anaerobic digestion has multiple benefits in circular bioeconomy, it produces renewable energy from different waste and side-streams preserving nutrients and organic matter, which can be recirculated back to food production. Digestate contains macro- and micronutrients essential for plant growth, and organic matter, that has crucial role in maintaining soil structure and productivity. Organic matter in digestate also contributes to carbon (C) sequestration, but it is dependent on the degradability of the material. During anaerobic digestion process, the proportion of recalcitrant and complex organic compounds increase, which increases the retention of C in soils compared to untreated material (Heikkinen et al., 2021). As the share of undegradable organic matter promotes C sequestration in soils, adding such material to the digestion process could be beneficial.

Thermochemical processes, such as pyrolysis, are used to produce carbon-rich biochars. Application of biochar to soils is known to positively contribute to C sequestration (Bolan et al., 2022) as they mainly consist of recalcitrant C. Biochar has also been reported to enhance methane production in anaerobic digesters (Kumar et al., 2021). Especially for wastewater sector, thermochemical processes, such as pyrolysis, provide potential sludge valorization method.

In the present study, the aim was to use biochars as co-feedstocks in anaerobic digestion, and to improve the value of digestate as soil amendment in C sequestration. First, different biochar co-feedstocks and addition rates were studied to examine, how much biochars can be added without compromising methane production. The studied biochars were i) pyrolyzed 80%/20% mix of digested sewage sludge and waste wood (referred as sludge-char) and ii) biochar from willow pyrolysis. Different rates of biochar additions (0, 5, 10, 20 or 40% of C content of feedstock mixture) were studied in 500 ml batch reactors. Solid cow manure and municipal biowaste were used as the main feedstocks. As a result, up to 20% of feedstock's C-content could be replaced with sludge-char or willow-based biochar without compromising methane production.

In the next phase, the studied sludge-char and willow-based biochar were digested in continuous anaerobic digesters with biowaste as the main feedstock. The selected co-feedstock ratio was 10% of

C of feedstock mixture, which corresponded to 4% and 1% (m%) of the feedstock mixture with sludge-char and willow biochar, respectively. A biowaste-fed reactor was run as a control. Reactor performance was continuously monitored and after the digestion process had stabilized, digestates were collected for further analyses. To find out to what extent the chemical composition of the digestates affected their resistance in soil, the acid (A), water (W) and ethanol (E) soluble and non-soluble (N) fractions were determined (Berg et al., 1991). Furthermore, the results obtained from AWEN-extraction will be used to evaluate the carbon decomposition by Yasso07 model.

The acid soluble fraction was the main component of the studied digestates followed by non-soluble fraction. Generally, processing (anaerobic digestion, pyrolysis) decreases the decomposability of the materials and increase the share of complex carbon. Thus, the processing of organic waste materials is highly recommended also from the view of soil C sequestration.

Keywords: anaerobic digestion; co-feedstock; biochar; digestate; C sequestration

References

Berg, B., Booltink, H., Breymeyer, A., 1991. Data on needle litter decomposition and soil climate as well as site characteristics for some coniferous forest sites, Part II, Decomposition data. Report. 42. Uppsala: Swedish University of Agricultural Sciences, Department of Ecology and Environmental Research.

Bolan, N., Hoang, S.A., Beiyuan, J., Gupta, S., Hou, D., Karakoti, A., Joseph, S., Jung, S., Kim, K.-H., Kirkham, M.B., Kua, H.W., Kumar, M., Kwon, E.E., Ok, Y.S., Perera, V., Rinklebe, J., Shaheen, S.M., Sarkar, B., Sarmah, A.K., Singh, B.P., Singh, G., Tsang, D.C.W., Vikrant, K., Vithanage, M., Vinu, A., Wang, H., Wijesekara, H., Yan, Y., Younis, S.A., Van Zwieten, L., 2022. Multifunctional applications of biochar beyond carbon storage. International Materials Reviews 67, 150–200. https://doi.org/10.1080/09506608.2021.1922047

Heikkinen, J., Ketoja, E., Seppänen, L., Luostarinen, S., Fritze, H., Pennanen, T., Peltoniemi, K., Velmala, S., Hanajik, P., Regina, K., 2021. Chemical composition controls the decomposition of organic amendments and influences the microbial community structure in agricultural soils. Carbon Management 12, 359–376. https://doi.org/10.1080/17583004.2021.1947386

Kumar, M., Dutta, S., You, S., Luo, G., Zhang, S., Show, P.L., Sawarkar, A.D., Singh, L., Tsang, D.C.W., 2021. A critical review on biochar for enhancing biogas production from anaerobic digestion of food waste and sludge. Journal of Cleaner Production 305, 127143. https://doi.org/10.1016/j.jclepro.2021.127143

Biochar and digestate production, regulation, and value chain: the Italian case study

Maria Valentina Lasorella[1]*, Irene Criscuoli[1], Ilaria Falconi[1], Daniela Quarato[1], Assunta Amato[1], Francesca Varia[1], Tiziana Pirelli[1], Francesco Galioto[1], Giovanni Dara Guccione[1]

[1] *CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy*
**Presenting author: mvalentina.lasorella@crea.gov.it*

Introduction

Based on Italian agriculture Census, farms are moving towards a more modern and multifunctional management model, which aims at diversifying their activities. The production and use of renewable energy sources (RES) has grown exponentially (+200% of farmers in ten years), allowing farms to diversify their incomes and to reducing production costs by self-producing energy. Bioenergy is among the various RES largely used in Italy and their by-products (i.e., digestate and biochar) are largely used as soil amendment. Farmer awareness on the possible impact of soil management practices has been increasing, especially in relation to Soil Organic Matter content and how to increase its level.

Drawing upon experiences from Italy, trends of large-scale production of biochar, the by-product of pyro-gasification plants, and digestate, the by-product of biogas and biomethane plants, are described. Conclusions are drawn by identifying major obstacles for the deployment of biochar and digestate in Italy and by recommending policy directions for biogas and biomethane production.

Research methodology

Digestate

Data about digestate production from the agricultural sector and the associated biogas/biomethane, were provided by the *Centro Ricerche Produzioni Animali* (CRPA), *Consorzio Italiano Biogas* (CIB) and combined with data published by the *Gestore dei servizi energetici* (GSE) about number of plants and power production.

Biochar

In Italy, no official figures are available about biochar production at national level. For this reason, CREA-PB researchers made a survey contacting all the biochar producers authorized by the Ministry of agriculture and were able to describe the total amount of biochar produced, its average physico-chemical characteristics and the production processes used.

Results and conclusions

Digestate

In 2021, 1,734 biogas plants were present in Italy, mainly in Emilia-Romagna, Veneto and Lombardy Regions, producing about 2 billion standard cubic meters of biomethane, starting from over 40 million tons of agricultural biomass treated (around 60% from livestock effluents, 30% from dedicated crops and 10% from agro-industrial by-products), and producing around 3 million tons of digestate. The main obstacles for the development of the value chain are: the high digestate production concentrated in northern regions, the prohibition to commercialized it because it is still not registered as agricultural amendment and the thresholds of the Nitrates Directive for agronomic use (91/676/CEE).

Biochar

In Italy, 6 companies are currently producing wood-chips biochar, mainly through downdraft gasification plants, while 5 companies deal with its packaging and distribution. All companies value syngas for power or heat production. The annual national production is around 1,000 t with different physico-chemical characteristics.

The main obstacles for the development of the value chain are: the high cost of the raw material, lack of demand, high production cost, low incentives for renewable energy production from syngas.

In conclusion, based on lessons learned, useful reflections and recommendations for decision-makers will be defined to consider the interconnections between renewable energy and the agricultural sectors as well as possible structural solutions for the sectoral development.

Keywords: Biochar, digestate production, regulation, value chain, Italy

A stocktaking of long-term field experiments in Europe dealing with the application of external organic matter (project: EOM4SOIL)

Van Der Smissen Hélène [1*], Hardy Brieuc [1], Sabine Houot[2] and Huyghebaert Bruno [1]

[1] *Walloon Agricultural Research Centre, Department of sustainability, Systems & Prospective – Soil, Water & Integrated Crop Production, Gembloux, Belgium*

[2] *French National Institute for Agriculture, Food, and Environment (INRAE), Paris, France*

** Presenting author: h.vandersmissen@cra.wallonie.be*

The main goal of the EOM4SOIL project is to provide guidelines for an optimal processing and application to soil of external organic matter (EOM) to promote soil carbon sequestration, nutrient recycling and soil health while preventing soil contamination. In particular, the aim of WP 3 is to study the multiple effects of repeated EOM application to soils. To meet this goal, Task 3.1 consists in establishing a list of long-term experiments (LTEs) dealing with the application of external organic matter in Europe, in order (i) to map LTEs dealing with EOM application at European scale and (ii) to feed the EOM4SOIL project with data to analyse the long-term effects of repeated EOM application on soil properties and on the performance of agricultural systems.

To map European LTEs dealing with EOM applications as exhaustively as possible, we relied on available online databases. Resources include (i) the stocktaking of European LTEs currently in progress within the WP7.3 of EJP-SOIL; (ii) three resources from the BonaRes portal, with two databases originating from a collaboration between BonaRes and EJP-SOIL whereas the third one includes data from six different networks; and (iii) the GLTEN metadata portal (https://glten.org/) listing trials around the world. The main challenge to identify relevant LTEs and gather useful metadata is the redundancy and lack of harmonization between the several databases. For example, a same trial may have distinct denominations between the different lists. The description of the goal of the trial is not always accurate and contact point and pedoclimatic information are sometimes missing. Currently, 75 LTEs dealing with EOM applications were identified but the list is non-exhaustive and will be completed by the end of the project.

For a selection of 27 LTEs, we consolidated metadata with the help of LTE managers to select the most relevant trials for a multicriteria analysis of the long-term effects of repeated EOM application on soil properties (T3.3) and modelling of the impact of EOM application on the overall performance of agricultural systems (T6.1). Information includes the goal of the trial, contact information of the LTE manager, the trial coordinates, the duration of the trial, soil type and textural class, mean annual temperature and pluviometry, trial design, EOM type and properties, period, rate and frequency of

EOM application, decision rule for treatment definition, crop rotation, availability of phytotechnical information and of data on soil and plant quality.

The two lists are committed to be open-access once completed and may promote further research on the long-term effect of repeated application of EOM to soil.

Keywords: Manure, digestate, compost, biochar, sludges

Bio-economy and Circular Agriculture for Soil Health (BioCASH): modelling soil health in multiple scales and connecting disciplines

Walter Rossi Cervi[1*], John Helming[1]

[1] *Wageningen Economic Research, The Netherlands*

** Presenting author: walter.rossicervi@wur.nl*

BioCASH aims at creating a modelling framework (toolbox) that scales up the assessment of biocircular supply chains of waste streams (hereafter named as EOM – external organic matter) from the level of site specific production systems to landscape level. To enable the scaling up, we create a structured database that links agro-climatic features of site specific indicators with landscape level agro-climatic features. For example, soil samples containing EOM have multiple *soil health indicators* being assessed (e.g. C content, biological activity, chemical and nutrient properties, GHG emissions) in the lab. These soil samples belong to certain agro-climatic thresholds that can be mapped at much broader regional scale. We expect that regional soil-agronomic models like Miterra Europe could play a key role in connecting scales and thereby enabling an the assessment of soil health indicators in regional case studies. Therefore, it facilitates the connection with multi-thematic models (mostly available at regional level) that address overall sustainability impacts of EOM in large scale.

As the soil health indicators are shocked by the EOM modelled at regional level, we are able to assess consequential effects on *agronomic indicators*, e.g. crop yield, nutrient uptake through crop-yield models, such as Wofost, which make use of soil health indicators to model plant features. Moreover, agronomic indicators have major influence on agro-economic models, which quantify the effect of yield variation on agricultural prices. Hence, we also intend to address farm-economic models (i.e. FarmDyn) to understand the impact of agronomic indicators (previously shocked by soil health indicators under EOM treatment) on *farmers cash flow*.

The utilization of the toolbox at regional level derived from the assessment of soil health indicators under EOM treatment at micro level should be able to capture policies and drivers of large scale structural changes on bioeconomy as well as agricultural transitions. Hence, the toolbox also explore *policy scenarios* within the context of European strategies (e.g. Farm to Fork) to assess the potential of EOM on medium and long term. The assessment of different policy scenarios are unlocked by macro-economic models (e.g. MAGNET and AGMEMOD) that simulates supply and demand of agricultural inputs as well as fertilizer and energy prices. These indicators should also feed farm-economic models to assess the willingness and the conditions of the farmer to afford bio-based fertilizes.

Keywords: waste streams on soils, soil health indicators, soil health indicators, agronomic indicators, farmers cash flow, policy scenarios, soils

Combining chemical analysis of organic pollutants and cytotoxicity testing for studying differences between fresh and processed external organic matters

Albero Beatriz[1], Pérez Rosa Ana[1], Sánchez-Arguello Paloma[1], Tampio Elina[2], Laaksonen Ilmari[3], and Martín-Esteban Antonio[1,*]

[1] *INIA-CSIC, Madrid, Spain*

[2] *Natural Resources Institute Finland (Luke), Helsinki, Finland*

[3] *Natural Resources Institute Finland (Luke), Jokioinen, Finland*

** Presenting author: amartin@inia.csic.es*

External organic matter (EOM) sources, especially urban residues are known to carry contaminants to soils upon EOM application. In this regard, the beneficial effects of EOM on climate change mitigation and soil health may, in some cases, be limited by EOM contamination. However, it is expected that some treatment processes could reduce the concentration of certain contaminants initially present in EOM. Accordingly, the objective of this work was to evaluate the efficiency of treatment processes in reducing the concentration of selected organic contaminants as well as evaluating the cytotoxicity in both organic and aqueous EOM extracts.

For this purpose, municipal and agricultural side-streams were selected as original EOMs and subjected to pyrolysis and anaerobic digestion to produce biochar and digestate samples, respectively. The municipal side-stream consisted of 80% digested and dewatered sewage sludge and 20% of waste wood. These materials were pyrolyzed in 565 °C for 75 min. Agricultural side-streams, 84% cow manure and 16% straw were digested in mesophilic conditions in a batch-type leach-bed reactor. Target organic contaminants (18 polycyclic aromatic hydrocarbons, 7 polychlorinated biphenyls, bisphenol A, bisphenol F, octylphenol, nonylphenol, methylparaben, propylparaben, tri-n-butyl phosphate, tris(2-chloroethyl) phosphate and tris(2-chloroisopropyl) phosphate) were determined by in-port derivatisation gas chromatography-tandem mass spectrometry. A short-term cytotoxicity test using fish-derived cells was used for the ecotoxicological evaluation of EOM extracts.

It was concluded that, in general, although all target analytes were detected at the ng/g concentration level, they are strongly bound to the matrix considering the low concentrations detected in the aqueous EOM extracts. Thus, their low bioavailability prevents the eventual soil contamination after EOM application. Treatment of the fresh EOM reduced the levels of some of the target contaminants after pyrolysis, but, in general, no reduction in the concentrations was found after anaerobic digestion. In parallel, cytotoxicity of aqueous EOM extracts was only observed in manure that was reduced by the digestion process. Whereas, cytotoxicity of organic EOM extracts was observed in sewage sludge and its biochar product.

Pyrolysis process was shown to be effective in reducing concentrations of certain organic contaminants but leading to cytotoxic effects. For anaerobic digestion, the result was opposite. Consequently, further studies are needed to be able to propose best management practises for the processing and utilization of different EOMs.

Keywords: external organic matter; processing; organic contaminants; cytotoxicity; bioavailability

External organic matters for climate mitigation and soil health (EOM4Soil)

Sabine Houot[1*]

[1] *National Research Institute for Agriculture, Food and the Environment (INRAE), ECOSYS, Palaiseau, France*

** Presenting author: sabine.houot@inrae.fr*

Many external organic matters (EOM) are used in agriculture to recycle nutrients, enhance carbon storage in soils and improve related soil properties. The EOM can be defined as organic matters applied on soil but not directly issued from the amended plot and applied after treatment or not. These EOMs are issued from anthropic activities (agriculture, industry, urban metabolism). Their diversity has been increasing with the development of renewable energy (anaerobic digestion for instance). Their use on soils forms part of the circular economy of the territories. However, these EOM can carry contaminants (trace elements, organic contaminants, microplastics, pathogens,…) and their use may provoke environmental impacts such as enlarged greenhouse gas (GHG) emission, nitrate leaching, ammonia volatilization, in relation with un-adapted application practices or low quality of EOM produced. The general objectives of the EOM4Soil project are (i) to propose best management practices of EOM treatment and application for climate change mitigation and improved soil health, (ii) for representative farming systems in Europe (arable crops and vineyards), (iii) and finally considering a large diversity of pedoclimatic conditions. Additional specific objectives of the EOM4Soil project are (i) to assess multiple effects of EOM applications including contaminants, (ii) to evaluate the C balance between C storage and GHG emission including during treatments, (iii) to recommend innovative pr-processing to improve C budget and soil health, (iv) to define best management practices from scenarios of use based on multicriteria simulation tool.

The EOM4Soil project started in November 2021 for 3 years. It is organized in 6 work packages (WP) in addition to the ccordination and dissemination WP. Two WP concern EOM production and quality assessment: WP1 aims at developing a database of characteristics of EOM in the participation countries and WP2 focus on 3 treatments (anaerobic digestion, pyrolysis and biochar production, composting) to improve EOM quality and C budget. Three WPs concern the use of EOM in field condition and assessment of their effects: WP3 aims at developing a database of metadata concerning long-term experiments available to assess the multiple effects of repeated applications of EOM in field conditions. WP4 focusses on C balance including C use efficiency by the degrading microflora and gas emission with the objective of collecting data of GHG emission, ammonia volatilization and volatile organic compounds in order to produce emission factors and/or simulate their emission in different conditions. Finally WP5 aims at collecting information about regulation in the participating countries, analyzing the effects of treatments on contaminant in the EOM, and making a specific focus on microplastics in EOMs and amended soils. The WP6 will propose best management practices and policy recommendations based on scenarios of use and multicriteria evaluation.

Some first results will be presented during the session as oral and poster presentations.

Keywords: treatment process, anaerobic digestion, digestate, biochar, compost, long-term experiment, scenario, multicriteria evaluation, best management practices, soil.

Abstracts of Poster Presentations

Recycling wastewater products for its use in Mediterranean agriculture: impacts in the soil microbial community and grapefruit physiology.

Felipe Bastida[1], Marta Díaz-López[1], Celia García-Díaz[1], Cristina Romero-Trigueros[1], Emilio Nicolás [1]
[1]CEBAS-CSIC, Campus Universitario de Espinardo, Murcia, Spain

**presenting author: fbastida@cebas.csic.es*

Keywords: sludge, ash, organic amendments, soil fertility, microbial communities, crop physiology

The development of sustainable agriculture is becoming more and more desirable for the environmental and human wellbeing. Consequently, a green circular economy that promotes zero waste is pursued, so there is a strong focus on product development with fertilizer capacity from the waste of other activities (i.e. wastewater treatment plants (WWTP), livestock industry, etc.). In this context, a rationale application of wastewater by-products as fertilizers is becoming quite common because of their high content of nutrients available to plants and soil microorganisms. However, before adopting these strategies in commercial crop fields, the effect of such products on soil fertility, microbial community and crop production and physiology must be evaluated. Here, we assessed the impact of the sludge and sludge ash obtained from a WWTP, as well as their combination, on the soil microbial biomass and activity, nutrients, organic C content, and crop eco-physiology. The assay was implemented in a grapefruit orchard in Murcia, Southeast Spain, and results correspond to one year after application of products in soil. Overall, results indicate that ash, sludge and their combination increased total organic C and N contents in comparison to the control without organic amendments. Moreover, both ash and sludge increased microbial biomass, particularly bacterial biomass -as evaluated through fatty acids-, soil respiration and enzyme activities related to C, N and P cycles (β-glucosidase, urease and alkaline phosphatase, respectively). However, the combination of both materials did not promote these biological and biochemical parameters in comparison with the control treatment which is likely due to the accumulation of some heavy metals. Furthermore, the results showed that the sludge and the combination of ash plus sludge decreased the intrinsic water-use efficiency of grapefruit trees, possibly due to the increase in stomatal conductance. Finally, the analyses of fruit quality showed the increase in maturity index by the ash plus sludge treatment. Therefore, the use of sludge and sludge ash is a promising approach to ensure a sustainable agriculture and foster a green circular economy.

Soil restoration with organic amendments: microbial and metagenomics insights into the nutrient cycles

Felipe Bastida[1*], José Luis Moreno[1] , Carlos García[1], José Siles[1]

[1] *CEBAS-CSIC, Murcia, Spain*

** Presenting author: fbastida@cebas.csic.es*

Keywords: organic amendments; soil fertility, long-term; microbial communities

The application of organic amendments in soil has been proposed as an effective way of improving the quality and fertility of degraded soils and protecting the environment because their use could be a strategy to eliminate and recycle massive amounts of waste. The lasting effects of organic amendment in soil microbial communities have not been sufficiently investigated. Here, a degraded soil located in a Mediterranean semiarid region was characterized 18 years after being amended with sludge or compost (different stabilization degree) regarding: (i) physicochemical properties, (ii) basal respiration and enzyme activities, and (iii) abundance (fatty acids), taxonomic composition and functionality (shotgun metagenomics) of microbial communities. Soil contents of macronutrients, basal respiration, β-glucosidase and phosphatase activities, and bacterial and fungal abundances were higher in the amended treatments in comparison with the unamended control soil. Differences between the two types of amendments were not observed. Most of the annotated sequences in the metagenomic study were of bacterial origin. Although some differences in taxonomic community structure between treatments were observed, the same microbial phyla dominated in the three treatments. Differences in functional community structure between treatments were not that large as initially expected. However, amended soils showed a higher abundance of functions related to nutrient cycling at the lowest SEED subsystem levels. The beneficial effects of soil amendment application on nutrient contents, microbial abundance, and enzyme activities remain after 18 years. However, the impact of soil amendments on microbial taxonomy composition and functionality dilutes with time.

Anaerobic digestion of cow manure – long-term implications for soil fertility and crop yield

Rittl, T. F.[1]*; Pommeresche, R.[1]; and Løes, A.-K.[1]

[1] *Norwegian Centre for Organic Agriculture, Tingvoll, Norway*

** Presenting author: Tatiana F. Rittl, tatiana.rittl@norsok.no*

Anaerobic digestion of animal manure can help farmers to produce renewable energy and reduce greenhouse gas emissions. Compared to non-digested slurry, digested slurry has a reduced content of organic matter, which may affect the soil fertility and crop productivity in the long-term. Hence, a field experiment with two slurry-application levels (ca. 110 vs. 220 kg of total N ha^{-1} $year^{-1}$) was established in 2011, to study how application of anaerobic digested slurry (ADS) versus untreated dairy cow slurry (US) affects soil characteristics and crop yields. Anaerobic digestion of the slurry did not affect soil concentrations of extractable nutrients and pH, but the rate of slurry application did. A decline in SOM in all the plots from 2011-2021, contrasts with our expectations that long-term application of slurry would increase the SOM concentrations in the topsoil. The decrease of SOM concentrations (0-20 cm) was faster on plots with high intrinsic SOM (> ca 10 % ignition loss), and did not differ among slurry treatments. Higher slurry application rate led to a surplus of N, while a deficit was observed in the control and the treatments with low application rates. Treatments were not limited by P. Even in the treatments with low application rate, the total P deficit was minimal, 18 kg P ha^{-1} across 2011-2021. For K, there was a deficit in all treatments. US and ADS gave similar yields of grass-clover ley, on average 7.9 Mg DM ha^{-1} $year^{-1}$. Clover biomass was similar in manured treatments and the non-fertilized control. Anaerobic digestion of the slurry before its application into soil did not seem to reduce grassland productivity or soil fertility in the long term, but the decline in SOM over time deserves attention.

Keywords: Grass-clover ley, digestate, soil organic matter, organic farming, Norway

Pig manure digestate-derived biochar an organic soil amendment tool to decrease ammonia volatilisation

Karolina Barčauskaitė[1]*Zeineb Louati[2], Donata Drapanauskaitė[1], Modupe Doyeni[1], Aušra Bakšinskaitė[1]

[1]Lithuanian Research Centre for Agriculture and Forestry, Institute of Agriculture Instituto al. 1, Akademija, LT-58344 Kėdainiai distr., Lithuania

[2] Water Research and Technology Center, Univ. of Carthage, P.O. Box 273, Soliman, 8020 Tunisia

** Presenting author: Karolina.Barcauskaite@lammc.lt*

Agriculture is the main source of NH_3 emissions globally and in Europe (> 80%). For the majority of scenarios, it is expected that current NH_3 emissions would rise due to (1) global temperature increases and (2) anticipated increases in the consumption of animal products worldwide. Agricultural organic soil amendments such as biochar incorporation in the soil could help to mitigate NH_3 emissions, increase soil pH, water retention capacity, and sequestrate soil organic matter. Biochar can be produced from a wide range of organic wastes via pyrolysis. The properties of the final product mainly depend on feedstocks and pyrolysis conditions. The biochar used for this study was produced under the following conditions: Heating temperature 700 °C; duration of temperature rise 1:45 h. (heating speed 6.7 degrees/minute); holding time 2 hours; nitrogen flow about 100 litres per hour. This study aimed to investigate pig manure digestate-derived biochar on Ryegrass green biomass yield, soil physicochemical properties and microbial activity, as well as on NH_3 emissions after different origin nitrogen fertilization. The experiment was carried out under controlled conditions as a two-way trial. Two rates of biochar 1.5% and 3.0% were applied and different fertilizers (urea, liquid digestate and pelletized organic chicken manure) were spread on the soil surface without injection after 4 weeks of plant sowing. Each experimental pot was filled with 1 kg of soil and biochar according to the experiment schema. "Ryegrass" was sown at a ratio of 1 g of seeds per pot. The controlled climate chamber was set day and night mode, the length of the day 16 hours, T= 20 ± 1.0°C and night - 8 hours, T = 16 ± 1.0°C respectively. Relative humidity was set at 70 ± 1%.

Urea treatment proved our hypothesis that a higher amount of biochar could reduce ammonia emissions, 72 hr after urea application higher ammonia volatilisation determined in the treatments with 1.5% biochar. On the other hand, the opposite observation was noticed when liquid digestate was applied. Soil pH increased in all tested treatments after biochar application. Also, a higher application rate showed a higher increment. Statistically significant ($p \leq 0.05$ effect on green biomass has demonstrated the used type of fertilizers. Neither the amount of biochar nor their interaction doesn‘t have a significant effect. A bit higher green biomass was obtained in the treatments with 3% biochar, but not significant.

The initial results indicate that biochar could be a promising tool to decrease NH_3 emissions from agricultural soil but further investigations should be carried out.

Keywords: pig manure digestate; biochar, ammonia emissions

Nitrous oxide emissions and ammonia volatilisation in a field experiment with different organic and inorganic fertilisers with biochar combinations

Hartmann Ferdinand[1*], Fernandez Balado Celia[1], Spiegel Adelheid[2] and Hood-Nowotny Rebecca[1]

[1] *University of Natural Ressources and Life Sciences, Vienna, Austria*

[2] *Austrian Agency for Health and Food Safety GmbH, Vienna, Austria*

** Presenting author: ferdinand.hartmann@boku.ac.at*

Agriculture is contributing substantially to anthropogenic greenhouse gas emissions and pollution. The application of nitrogen fertilizers increases N_2O emissions and NH_3 volatilisation. 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 lead to other environmental issues in the surrounding. Further, to keep economic (fertiliser prizes drastically increased due to the energy crisis) and ecological (Haber Bosch process is very energy intense and still based on fossil fuels) costs for fertiliser low, a high fertilizer use efficiency is worthwhile. Therefore, advances in agricultural practices reducing atmospheric N-losses are highly relevant in order to mitigate global warming and related environmental issues. Biochar can reduce N_2O emissions and NH_3 volatilisation by influencing various soil properties. However, this depends on pedoclimatic conditions, the applied biochar, and other agricultural practises. To refine biochar's use to mitigate atmospheric N-losses more data for different soils and fertilizers are needed, especially from experiments coming close to common agricultural settings. In a field experiment we cultivated corn (Zea mays) with different organic (external organic matter, EOM) and inorganic fertilizers with and without biochar combinations. The original soil was a loamy brown earth, low in organic carbon and slightly acidic. Our results are showing significant and substantial reductions in N_2O emissions and NH_3 volatilisation within the first weeks after fertiliser application. This pattern was especially observed for synthetic fertiliser. We suggest that biochar is a suitable amendment for fertilisation, especially for highly productive agroecosystems where high amounts of fertiliser are needed, to reduce environmental impact and increase fertiliser use efficiency.

Keywords: nitrous oxide, ammonia, biochar, external organic matter, nutrient use efficiency

The quality of various origins of external organic matter in Lithuania

Drapanauskaitė Donata[1*], Karolina Barčauskaitė[1], Aušra Bakšinskaitė[1], Modupe Doyeni[1]

[1] *Lithuanian Research Centre for Agriculture and Forestry, Institute of Agriculture, Akademija, Kėdainiai distrc., Lithuania*

** Presenting author: donata.drapanauskaite@lammc.lt*

Waste management has become one of the biggest environmental challenges in recent decades. This increased extraction and consumption of natural resources, pollution of water, soil, and air. Also, climate change, which lead to irreparable damage to the environment and health. In response to these challenges, the United Nations announced the Sustainable Development Goals, which aim to achieve a better and more sustainable future for all. Also, the European Green Deal encourages reducing the use of chemical fertilizers, so the use of organic fertilizers is one of the ways to achieve the goals set by the European Green Deal and the United Nations.

Nutrients such as nitrogen, potassium and phosphorus are essential for plant growth. Excessive use of chemical fertilizers causes loss of nutrients, increases groundwater and surface water pollution, acidifies the soil, and reduces the population of microorganisms in the soil. Also, natural resources are limited. Organic waste can be treated in various ways, such as composting, anaerobic digestion, pyrolysis. So is very important to know not only the nutrients concentration in them but also the amounts of contaminants too.

The objective of this study was to investigate the quality of used external organic matters in Lithuania.

Keywords: external organic matter; quality

Effects of organic and synthetic fertilizers on soil chemical composition

Baksinskaite Ausra[1*], Tilvikiene Vita[1], Barcauskaite Karolina[1], Drapanauskaite Donata[1], Modupe Doyeni[1]

[1] *Lithuanian Research Centre for Agriculture and Forestry, Instituto al. 1, LT-58344 Akademija, Kėdainiai distr. – Lithuania*

** Presenting author: ausra.baksinskaite@lammc.lt*

The use of synthetic fertilizers promotes the development of modern agriculture, but their extensive use increases environmental pollution and negatively affects the quality of the soil. Chemical fertilizers contain many nutrients necessary for plants and are soluble, so they are immediately available to plants. Nevertheless, excessive use of chemical fertilizers creates the risk of leaching, makes plants more susceptible to diseases, and reduces the amount of organic carbon in the soil. Therefore, to reduce the negative impact of synthetic fertilizers on the environment, it is encouraged to use more organic fertilizers. The use of organic fertilizers is a widely accepted strategy for maintaining or accumulating crop yields and soil organic carbon stocks. Proper use of organic fertilizers can not only improve soil quality but at the same time promote plant growth and suppress soil-borne diseases. One of the most common solutions for recycling organic waste is the biological process, which turns organic materials into biogas and at the same time produces a secondary raw material - digestate. Digestate can be used as agricultural biological fertilizers, as they are rich in mineral and organic nutrients, which positively affect the chemical and physical properties of the soil and increase productivity. Because of this, the effect of organic fertilizers on crop yield is slow. Mixing organic fertilizers into synthetic fertilizers is a promising alternative to synthetic fertilizers that will help reduce the impact of synthetic fertilizers on the environment.

The field experiment was performed at the Institute of Agriculture, Lithuania (55 ° 23′50 ″ N, 23 ° 51′40 ″ E). Winter wheat was fertilized twice during the growing season using mineral, organic (pig manure digestate), and the same organic-mineral fertilizers. The first fertilization is carried out when the plants are at the growth stage of 21-25 BBCH, and the second is at the growth stage of 30-35 BBCH. Also, all treatments used synthetic pesticides for plant protection. Soil analyses were carried out before sowing and after harvesting.

The first year showed that the amount of organic carbon in the soil not increased after wheat was fertilized with different fertilizers compared with the results obtained before the experiment. No increase in organic carbon in the soil was detected when fertilizing plants with organic fertilizers or organic-mineral fertilizers. The soil became more acidic after using mineral fertilizers together with pesticides, it changed from 6.61 to 6.30 pH. By combining mineral fertilizers with organic fertilizers, the amount of P_2O_5 in the soil increased up to 38%. Fertilization with different fertilizers did not have a significant effect on the amount of K_2O in the soil.

Summarizing the preliminary data, it can be noted that in order not to weaken the soil, it is best to combine mineral fertilizers with organic ones. This creates an opportunity to preserve soil fertility and grow productive wheat.

Keywords: soil quality; organic fertilizer, synthetic fertilizer, digestate