EJP SOIL
European Joint Programme

Annual Science Days 2023

BOOK OF ABSTRACTS

Table of Contents

Block A

A1 Carbon sequestration at national and European scale

Session Description

Involved projects: CarboSeq, SIMPLE

Conveners: Sonja Keel (Agroscope), Felix Seidel (Thuenen)

Carbon sequestration in agricultural soils is a strategy that can contribute to climate change mitigation and generates large expectations on ecosystems to take up carbon dioxide from the atmosphere. The key for soil carbon sequestration is reaching a positive balance between carbon inputs and outputs. Enhanced inputs of organic matter to the soil can be achieved by improved management options, such as use of cover crops, increased incorporation of crop residues, addition of organic matter, optimization of varieties with increased root biomass, land use change, or introduction of agroforestry measures. As these measures are affected by bio-physical (e.g. soil type, climate) and technical constraints (e.g. irrigation) a differentiated analysis at national and European scale is necessary in order to assess the true potential of agricultural measures that enhance soil carbon sequestration when implemented on large scale. In this session, we welcome contributions that give insights into the topic of soil carbon sequestration in agricultural lands. A special focus will be given to management practices affecting this process in European countries and at the European scale.

A new framework to estimate soil organic carbon targets in European croplands.

Lorenza Pacini[1,2]*, Pierre Arbelet[2], Songchao Chen[3], Aurélie Bacq-Labreuil[2], Christophe Calvaruso[2], Florian Schneider[4], Dominique Arrouays[5], Nicolas P.A. Saby[5], Lauric Cécillon[1] and Pierre Barré[1]

[1] *Laboratoire de Géologie, École normale supérieure, CNRS, Université PSL, IPSL, 75005 Paris, France*

[2] *Greenback SA (commercial name: Genesis), 75003 Paris, France*

[3] *ZJU-Hangzhou Global Scientific and Technological Innovation Center, Hangzhou 311200, China*

[4] *Thünen Institute of Climate-Smart Agriculture, 38116 Braunschweig, Germany*

[5] *INRAE, Info&Sols Unit, F-45075 Orléans, France*

** Presenting author: lorenza.pacini@genesis.live*

Adopting land management practices that increase the amount of soil organic carbon (SOC) in croplands is widely promoted as a win-win strategy to preserve soil health and mitigate climate change. In this context, the definition of reference SOC content values is needed to provide reliable targets to farmers, policymakers, and stakeholders. In this study, we used the LUCAS dataset to compare different methods for evaluating reference SOC content values in European croplands soils. Methods gave generally consistent estimates although being built on very different assumptions. In the absence of an objective criterion to establish which approach is the most suitable to determine SOC reference values, we propose an ensemble modelling approach that consists in extracting the estimates using different relevant methods and retaining the median value among them. Interestingly, this approach led us to select values from the different approaches in a balanced way. The use of additional methods in the ensemble modelling approach may further refine our framework designed for the estimation of SOC reference values for croplands.

Keywords: Soil organic carbon, carbon storage, climate mitigation, LUCAS dataset, data-driven modelling.

Investigating the reasons behind the choice of funding carbon sequestration initiatives in the European Union

Francesco Galioto[1*], Irene Criscuoli[1], Ilaria Falconi[1], Maria Valentina Lasorella[1], Andrea Martelli[1], Stefania Maurino[2] and Giovanni Dara Guccione[1]

[1] *CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy*

[2] *CREA Research Centre for Agriculture and Environment, Rome, Italy*

** Presenting author: francesco.galioto@crea.gov.it*

The present study aims at investigating the reasons behind the choice of funding carbon sequestration projects in different European contexts. The study, first, provides an in-depth analysis of the 2014-2020 RDP funds addressed at improving soil health through participatory initiatives, such as Operational Groups and Innovative projects from across European Union (EU). Funding sources are differentiated with respect to their origin and to three main type of management options: crop management; fertilization management; land use change. Crop management encompasses the introduction of new crop rotations, multiple cropping and cover crops, crop residues management (mowing) and conservative tillage (sod seeding and minimum tillage). Fertilization management includes the use of external organic matter and fertilizers application management. Land use change encompasses all the actions related to the transition from arable crop to agro-forestry, permanent grasslands, and permanent tree crops. This first stage of the investigations provides a rough idea on how differently soil issues are addressed across EU contexts, what type of initiatives are promoted and in what way these initiatives are addressed.

Then, the above information is read in the light of some key agri-environmental indicator connected to soil issues such as: soil cover on arable land during winter, change in share of permanent grassland on the utilized agricultural area (UAA) and change in share of cereal crops on the arable land, available from EUROSTAT; loss of High Nature Value farmlands due to agricultural intensification, available from the European Environmental agency; and, UAA addressed by agri-environment-climate (AEC) measures, available from JRC reports and other official sources.

A Qualitative Comparative Analysis, with fuzzy methods, is carried out to draw possible causalities and to cluster observations based on similar combination of conditions (the above mentioned agri-environmental indicator) in addressing carbon sequestration initiatives (Ragin, 2009). The methodology was developed in the framework of social sciences, but it was rarely applied in agricultural economics and especially never adopted in investigating agricultural soil challenges.

Results might allow to identify whether carbon sequestration projects through participatory initiatives are underfunded and whether there is a difference in the allocation of funds among EU countries. Finally, an expected causality between soil pressures and policy responses is recorded and discussed.

The results thus obtained might bring to several considerations, including possible mismatch of needs and funding sources and barriers to the development of participatory initiatives.

The paper concludes by highlighting the key limits of the study which are to have considered only part of the available funding sources addressed to soil related challenges and to having missing to include in the assessment some relevant indicator because of the limited scope of the investigation and because of missing information.

Keywords: Policy evaluation; Qualitative Comparative Analysis, Land use challenges

Soil Organic Carbon Sequestration Potential National Map of Türkiye

Muhammed Halil Koparan1, Sevinc Madenoglu2*, Mehmet Gur3, Mehmet Kececi1, Bulent Sonmez2

[1] *Republic of Türkiye Ministry of Agriculture and Forestry,*
TAGEM-Soil Fertilizer and Water Resources Central Research
Institute muhammedhalilkoparan@tarimorman.gov.tr; mehmet.kececi@tarimorman.gov.tr
[2] *Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies (TAGEM) - sevinc.madenoglu@tarimorman.gov.tr; bulent.sonmez@tarimorman.gov.tr*
[3] *Republic of Türkiye Ministry of Agriculture and Forestry, TAGEM-Atatürk Soil and Water Agricultural Meteorology Research Institute - mehmetgur@tarimorman.gov.tr*
*Corresponding Author

Soil organic carbon, as an important indicator for the soil fertility, is highly related to the climate change, soil/land degradation and soil ecosystem services. This study was conducted to produce a SOC potential sequestration map of Türkiye through applying the FAO-GSP Technical Specifications and Country Guidelines for Global Sequestration Potential Map v1.0 approach. According to the approach, the SOC stock was estimated in 2040 under the business as usual – BAU (current soil management) and for three different sustainable soil management (SSM) scenarios that implemented SSM practices applied with different organic matter inputs. The SSM scenarios consist of 5% increase, 10% increase and 20% increase of organic matter inputs for SSM1, SSM2 and SSM3, respectively. It is also estimated that differences between SOC stock in 2020 and SOC stocks in 2040 under BAU and SSM scenarios that constitute absolute difference maps and the difference between SOC stocks in 2040 under the BAU and SSM scenarios that constitute relative difference maps. The study results showed that in terms of the average absolute sequestration rates (ASR) and relative sequestration rate (RSR) three projections showed a positive SOC evolution with respect to the BAU situation as 0.05 t C ha^{-1} yr^{-1}, 0.06 t C ha^{-1} yr^{-1} and 0.12 t C ha^{-1} yr^{-1}, for SSM1, SSM2 and SSM3, respectively. The SSM3 scenario showed a highest positive absolute SOC sequestration (0.13 t C ha^{-1} yr^{-1}) in tree crops land use. Besides, the relative SOC sequestration (RSR) results showed also a positive rate for the three scenarios with respect to the BAU situation). In terms of relative SOC sequestration, three projections showed a positive relative SOC sequestration in all land uses with respect to the BAU situation. It means that, SSM practices can increase the current status and similarly the highest SOC sequestration rate was obtained in SSM3 (4.33 Mt C yr^{-11}), followed by SSM2 (2.17 Mt C yr^{-1}) and SSM1 (1.09 Mt C yr^{-1}). These results suggest that three SOC sequestration scenarios which consider applying SSM management practices will generally make a positive effect for achieving SOC neutrality and to avoid CO_2 emissions from SOC losses in Türkiye.

Scenario modelling for assessing impacts of policy changes and socio-economic effects on ecosystem services of soils (SIMPLE)

Keel Sonja G.[1*] **and Leifeld Jens** [1]

[1] *Climate and Agriculture Group, Agroscope, Zurich, Switzerland*

** Presenting author: sonja.keel@agroscope.admin.ch*

The central aim of SIMPLE is to set up a modelling framework that allows us to assess effects of policy changes and socio-economic effects on three ecosystem services of soils: production, soil organic carbon (SOC) storage and greenhouse gas mitigation. We will simulate three different scenarios that potentially reduce nitrogen (N) fertilization. Our main focus will lie on a 20% reduction in N fertilization rates as formulated in the Farm to Fork strategy by the European Commission. In addition, effects on fertilization rates as a result of changes in diets and rising fertilizer prices will be assessed. While we expect reductions in soil-derived nitrous oxide (N_2O) emissions if fertilizer inputs are lower, it is possible that trade-offs arise. Yields could be reduced and also SOC losses could occur as a result of lower plant C inputs to the soil. To quantify these effects, we link several European-scale models with national yield and fertilizer statistics. Based on simple fertilizer-yield response functions, potential yield reductions will be estimated for the most important crop types grown in Europe. With the European-scale agro-economic model AGMEMOD changes in crop areas in EU member states will be simulated. The effect of yield reductions on soil C sequestration will be assessed using the SOC model RothC and the setup provided by the EJP soil project CarboSeq. We will consider whether plant-derived C inputs to soil are affected by lower N fertilization as these are important input data for simulations with RothC. For this purpose, we make use of data gathered within the EJP soil projects CarboSeq and MaxRootC. The European-scale N flow model MITERRA-Europe will be applied to quantify changes in N losses with a focus on N_2O emissions. As a response to yield reductions, cropland might need to be expanded to compensate for lower production, under the assumption that Europe does not increase imports. This could potentially result in land-use changes with effects on SOC storage, that we will determine. Finally, a trade-off analysis will we applied to assess the different aspects of reduced N fertilization on the three ecosystem services of soils we focus on and formulate policy recommendations.

Keywords: soil carbon sequestration, greenhouse gas mitigation, trade-off, fertilization

Estimating the effects of different crop management options on SOC stocks and deriving emission factors – the CarboSeq approach based on European long-term field experiments

Panagea Ioanna[1*], Blanchy Guillaume[1], Rosinger Christoph[2,4], Keiblinger Katharina[2], Diacono Mariangela[3], Di Bene Claudia[5], Makoschitz Lisa[6], Sandén Taru[6], Spiegel Heide[6], Alonso-Ayuso María[7], Martinez-Garcia Laura[7], Álvaro-Fuentes Jorge[7], Suhadolc Marjetka[8], Kay Sonja[9], Viaud Valerie[10], Quataert Paul[1], Seidel Felix[11], Don Axel[11], Ruysschaert Greet[1]

[1] *Flanders research institute for agriculture, fisheries and food (ILVO), Merelbeke, Belgium*

[2] *University of Natural Resources and Life Sciences Vienna (BOKU), Department of Forest and Soil Sciences, Institute of Soil Research, Vienna, Austria*

[3] *Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, Bari, Italy*

[4] *University of Natural Resources and Life Sciences Vienna (BOKU), Department of Crop Sciences, Institute of Agronomy, Tulln an der Donau, Austria*

[5] *Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, Rome, Italy*

[6] *Austrian Agency for Health and Food Safety, Department for Soil Health and Plant Nutrition (AGES), Vienna, Austria*

[7] *Spanish National Research Council (CSIC), Department of Soil and Water, Estación Experimental de Aula Dei, Zaragoza, Spain*

[8] *University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia*

[9] *Agroscope, Research Group Agricultural Landscapes and Biodiversity, Zurich, Switzerland*

[10] *UMR SAS, INRAE, Rennes, France*

[11] *Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany*

** Presenting author: ioanna.panagea@ilvo.vlaanderen.be*

Crop management options, such us, choice of crops in the rotation, residue management, fertilisation, tillage and irrigation, are known to affect the soil organic carbon (SOC) stocks and can be considered as effective mitigation strategies to remove atmospheric CO_2.

This research, as part of the EJP SOIL CarboSeq project, aimed at estimating the effect of seven crop management practices on SOC stocks, considering available data and metadata from European long-term experiments (LTEs). Specifically, the evaluated crop management options were: 1) cultivation of cover crops in comparison with not growing cover crops; 2) increase of crop diversification through an increased part of leguminous crops in comparison with less or no legumes in the crop rotation; 3) incorporation of crop residues compared with their removal; 4) non-inversion tillage compared with inversion tillage; 5) zero tillage compared with inversion tillage; 6) irrigated in comparison with nonirrigated systems; 7) the comparison of two agroforestry systems (alley-cropping and hedgerows) with croplands or grasslands without these elements.

The available information from published literature, existing databases, meta-analyses, and personal communication with the LTE owners was collected through a structured homogeneous template, checked for data quality both manually and through an automatic error detection tool, and subsequently deposited in the CarboSeq crop and soil management database. The database is coupled with an export module which allows to explore, filter, query and eventually export the data required for the analysis.

For each management option, emission factors (EFs) were calculated as ratio of SOC stocks of the management option to the SOC stock of the respective control option. Different bio-physical variables (e.g., climatic zone, soil type) as well as variables relevant for each management option (e.g., crop type, tillage depth, amendments type) were used to identify significant predictors of the EFs using a mixed effect model approach. The analysis resulted in different EFs for each crop management option based on the moderators that significantly affect these in each case. Considering the identified data gaps and limitations, the derived EFs can be used as a basis for the estimation of the SOC sequestration potential in the European croplands.

Keywords: SOC sequestration, conservation agriculture practices, climate-smart agriculture, EJP Soil

Soil organic carbon sequestration potential of agricultural soils in Europe (CarboSeq)

Seidel F.[1*] **Don, Axel**[1] **and all project partners**

[1] *Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany*

** Presenting author: felix.seidel@thuenen.de*

Carbon sequestration in soils is a negative emission technology that can contribute to mitigate climate change. However, for European soils, a comprehensive assessment is missing on how much soil organic carbon (SOC) can be sequestered with different management options.

The aim of CarboSeq is thus to identify agricultural management options that increase SOC and subsequently to estimate a feasible SOC sequestration potential considering biophysical, environmental, technical and economic constraints for each identified agricultural measure.

Finally, SOC-sequestration potential maps and data for different management options will guide policy makers regional specific to the most efficient agricultural management options to sequester SOC for climate mitigation.

CarboSeq has reached its midpoint and this project presentation will demonstrate what major steps have already been taken, first results will be shown and a road map on how the project will continue from here will be presented.

Keywords: soil carbon, climate change mitigation, SOC increasing agricultural measures, carbon farming

Refining Soil Conservation and Regenerative Practices to Enhance Carbon Sequestration and Reduce Greenhouse Gas Emissions

Chabbi, Abad[1*], Ananias Soler da Silva, Mellissa[2], et al. whole project consortium

[1] *INRAE - Centre de Recherche Nouvelle- Aquitaine-Poitiers, Lusignan, France*

[2] *Brazilian Agricultural Research Corporation (Embrapa), Goiás, Brazil*

** Presenting author: Email address presenting author*
Abad.chabbi@inrae.fr

Modern agricultural technology, in all its aspects, has enabled increased agricultural production to meet the growing demand for food and fulfill the Sustainable Development Goals of the UN Agenda 2030. Yet the impact of these achievements on soil degradation and greenhouse gas (GHG) emissions is considerable. Agricultural practices that increase soil carbon stocks and reduce greenhouse gas emissions, as outlined under the international 4per1000 initiative, constitute valuable strategies for mitigating global warming while increasing soil carbon stocks and ensuring soil health. The objective of this proposal is to evaluate the influence of conservationist and regenerative agricultural practices on carbon (C), nitrogen (N) and phosphorus (P) cycling, soil biodiversity and GHG emissions with a particular emphasis on long-term SOC stocks, and processes governing C persistence. This project represents an exploratory effort to couple the stoichiometric drivers to microbial populations related to C, N, and P cycling and stocks, and GHG emission under diverse agricultural practices. To this end, we set up a long-term consortium of field experiments that assess the impact of different cropping systems and agricultural practices on soil properties. The participants from twelve different countries represent a total of 37 field sites with different time sequences and/or contrasting agricultural management. Twenty-six sites have been established for at least ten years. At each site, estimates and modelling scenarios of possible N_2O, CO_2 and CH_4 emissions from crop/pasture/forestry systems will be carried out using best available IPCC or local emission factors and GHG emissions will be measured at a subset of sites. To compare the impact of different climatic and edaphic conditions among sites, we propose a standard soil organic matter (OM) physical fractionation procedure resulting in two contrasting soil fractions including particulate organic matter (POM), which consists mainly of partially decomposed plant residues, and the mineral-associated OM (MAOM), principally of microbial origin. This project will build a worldwide database of C and N stocks, bulk density, soil fertility and GHG emissions across different ecosystems and under differential agricultural management. Moreover, the project will determine the extent to which climatic conditions, net primary production of cropping systems and soil type affect carbon and nitrogen stocks, nutrient dynamics and greenhouse gas emissions. The final product of the project will be to recommend best management practices for production of food crops which would promote soil C accumulation, especially MAOM, without increasing GHG emissions thus contributing to the sustainability and resilience of agriculture.

Keywords: soil carbon persistence, sustainable development, nutrients cycling, carbon storage GHG emissions.

Koolstoftool: A carbon calculation tool for the farmer

Mertens Kaat[1*], Pardon Paul[1], Beirinckx Stien[2], Bosch Samuel[1], Pieter Roggemans[2] and Ruysschaert Greet[1]

[1] *Flanders' Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium*

[2] *Policy Department of Agriculture and Fisheries, Brussels, Belgium*

** kaat.mertens@ilvo.vlaanderen.be*

The LIFE CarbonCounts project aimed to enable Carbon Farming in Flanders by establishing a geospatial information system. One of the objectives was to develop a high-resolution geospatial information system to monitor carbon storage for agroforestry, woody landscape features and arable mineral soils. This is established by developing a carbon calculation tool, called the 'Koolstoftool', that is accessible for the farmer and connected with carbon calculation models. The Koolstoftool is implemented in the soil passport. The soil passport is an online application that makes all available soil-related data (both public and private) of agricultural parcels easily accessible for farmers. The soil passport has the objectives to group and visualize data and to stimulate the farmer to use the data to perform to carry out sustainable soil management.

The Koolstoftool uses the gathered data in the soil passport as input for the connected carbon calculation models for mineral soils and agroforestry/woody landscape features through API based data connections. The estimated output from the models are visualised in the Koolstoftool, showing the expected evolution of carbon stocks calculated based on the continuation of current crop rotation, i.e. the sequence of crops and cover crops registered in the past six years in the GSAA. Additionally, the interface of the Koolstoftool allows the farmer to simulate the expected evolution of alternative farming practices such as crop rotation and organic fertilizer application. The mineral soil calculation tool is based on the Rothamsted Carbon model that simulates the turnover of organic carbon in the top-layer of mineral soils. The model takes into account different parameters such as soil type, clay content and monthly rainfall. For the agroforestry and woody landscape features woody elements on parcels are detected using orthodetection on aerial images. These elements are divided based on the crown surface, roundness and area into solitary trees, tree rows, groups of trees, forests and hedges. The dataset resulting from this orthodetection is used as input for the agroforestry calculation model by estimating the carbon stock in the elements based on their crown surface and woody element type. This data is then used as input for the calculation model to estimate the carbon stock.

Keywords: carbon sequestration; RothC model, online tool

Scenario modelling for assessing impacts of policy changes and socio-economic effects on ecosystem services of soils (SIMPLE)

Keel Sonja G.[1*] **and Leifeld Jens** [1]

[1] *Climate and Agriculture Group, Agroscope, Zurich, Switzerland*

** Presenting author: sonja.keel@agroscope.admin.ch*

The central aim of SIMPLE is to set up a modelling framework that allows us to assess effects of policy changes and socio-economic effects on three ecosystem services of soils: production, soil organic carbon (SOC) storage and greenhouse gas mitigation. We will simulate three different scenarios that potentially reduce nitrogen (N) fertilization. Our main focus will lie on a 20% reduction in N fertilization rates as formulated in the Farm to Fork strategy by the European Commission. In addition, effects on fertilization rates as a result of changes in diets and rising fertilizer prices will be assessed. While we expect reductions in soil-derived nitrous oxide (N_2O) emissions if fertilizer inputs are lower, it is possible that trade-offs arise. Yields could be reduced and also SOC losses could occur as a result of lower plant C inputs to the soil. To quantify these effects, we link several European-scale models with national yield and fertilizer statistics. Based on simple fertilizer-yield response functions, potential yield reductions will be estimated for the most important crop types grown in Europe. With the European-scale agro-economic model AGMEMOD changes in crop areas in EU member states will be simulated. The effect of yield reductions on soil C sequestration will be assessed using the SOC model RothC and the setup provided by the EJP soil project CarboSeq. We will consider whether plant-derived C inputs to soil are affected by lower N fertilization as these are important input data for simulations with RothC. For this purpose, we make use of data gathered within the EJP soil projects CarboSeq and MaxRootC. The European-scale N flow model MITERRA-Europe will be applied to quantify changes in N losses with a focus on N_2O emissions. As a response to yield reductions, cropland might need to be expanded to compensate for lower production, under the assumption that Europe does not increase imports. This could potentially result in land-use changes with effects on SOC storage, that we will determine. Finally, a trade-off analysis will we applied to assess the different aspects of reduced N fertilization on the three ecosystem services of soils we focus on and formulate policy recommendations.

Keywords: soil carbon sequestration, greenhouse gas mitigation, trade-off, fertilization

Integrated approach of soil carbon sequestration in the Netherlands

Van der Kolk, Jennie*1, Slier, Thalisa1, Koopmans, Chris2, Westerik, Dorien1, Hendriks, Chantal1, Lesschen, Jan Peter1

1 Wageningen Environmental Research, Wageningen, the Netherlands

2 Louis Bolk Instituut, Bunnik, the Netherlands

3 Wageningen Economic Research, Wageningen, the Netherlands

* Presenting author: jennie.vanderkolk@wur.nl

The Dutch government stated in their climate action plan that annually an additional 0.5 Mton CO2-eq must be sequestered in Dutch mineral agricultural soil from 2030 onwards. This was a reason to start the Dutch research programme Smart Land Use in 2018. The aim of the programme is to come up with scientific based actions to reach this goal. This includes not solely insight in the technical potential of soil carbon sequestration, but also insights in factors that stimulate or inhibit farmers to take up carbon measures. The programme looked for example at costs and benefits of measures, and trade-offs and synergies of soil carbon sequestration regarding nitrous oxide emission and other soil health indicators. In theory, an annual potential of 0.9 Mton CO2-eq extra can be sequestered at national level when all carbon measures are implemented optimally. However, the actual carbon sequestration is still far from this potential. Therefore, effort within the programme also goes to the exploration of incentives for farmers to implement carbon measures. For this, but also for other information on carbon sequestration, the Smart Land Use Programme makes use of data, knowledge and insights generated during EJP SOIL and vice versa.

Keywords: soil carbon sequestration; carbon farming, climate mitigation, soil health

Carbon sequestration at international scale: Towards an International Research Consortium on soil carbon.

Reynders Suzanne[1]*, Mathieu Nogues[1], Eric Ceschia[1], Heather Mcckann[1], Laure Bamière[1], Antonio Bispo[1], Claire Chenu[1], Delphine Derrien[1], Katja Klumpp[1], Manuel Martin[1], Ludovic Arnaud[1], Ahmad Albitar[2] ,Julien Demenois[3], Jean-Baptiste Laurent[3], Emilie Vrot[3], Damien Beillouin[3], Nathalie Pavy[4], Carla Biscotti[5], Mathilde Bazin-Retours[6], Jean-François Soussana[1].

[1] *INRAE, Paris, France*

[2] *CNRS, Toulouse, France*

[3] *CIRAD, Paris , France*

[4] *ANR, Paris, France*

[5] *Vizzuality, Madrid, Spain*

[6] *Arctik, Brussels, Belgium*

** Presenting author: Suzanne Reynders*

Launched in September 2022, ORCaSa is a Horizon Europe project standing for Operationalising the International Research Cooperation on Soil Carbon. Coordinated by the French National Research Institute for Agriculture, Food and the Environment (INRAE), the project aims to establish by 2025 the first International Research Consortium (IRC) on soil carbon, with a first version expected in the fall of 2023.

The idea to create an IRC on soil carbon emerged during the CIRCASA project (2017-2021) together with more than 100 stakeholders and 500 scientists from around the world. The mission of the IRC on Soil Carbon is to support the Paris Agreement on Climate Change by raising both awareness and science-based knowledge on soil carbon. While CIRCASA focused on agricultural soils, ORCaSa goes a step further and considers other types of soils, including forests, pastures, public spaces in urban areas, etc. The IRC's vision is to become an international scientific reference in the domain of soil carbon stock changes. It will also gather public and private funders that will fund multidisciplinary research and innovation still needed to remove the last scientific and technical obstacles that will allow us to go to scale.

The ORCaSa project will :

- Develop KP4SoilCarbon, an online platform where current knowledge on soil carbon will be collected and made accessible by gathering the latest carbon-related publications and practices on the subject, providing maps, aggregating data and facilitating contact with the players in the field,
- Gather the international community on MRV and thus propose co-constructed MRV (Measurement, Reporting and Verification) methodologies that are applicable in different contexts and for different purposes (compliance markets, national incentives, CAP ecoschemes, value chain in-setting or off-setting via voluntary carbon markets),
- IRC will make it possible to go faster and further by aligning Research and Innovation activities and fostering synergies between research efforts at the global level with the strong involvement of all

stakeholders and related initiatives. This will help create breakthroughs, avoid duplication of activities and develop innovation on an international scale.

The poster will focus on two processes : Knowledge Hubs and Thematic Annual Programming for a better alignment, coordination and co-creation of research activities to attract public and private EU&International funders around an enlarged Strategic Research and Innovation Agenda (SRIA). Collaboration with EJP Soil projects are key for these alignement activities.

Keywords: soil carbon, carbon farming, International research consortium, network, research alignment

Where to store additional carbon in European agricultural soils

Schneider Florian[1*], Felix Seidel[1] and Don Axel[1]

[1] *Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany*

** Presenting author: florian.schneider@thuenen.de*

In order to estimate soil organic carbon (SOC) sequestration potentials for European agricultural soils, we need to know the area on which *additional* SOC sequestration measures can still be implemented. In October 2023, the EJPSoil CarboSeq project organized three workshops to define harmonized, measurable and impartial criteria that can be used to define this area at the European scale. Here, we will present the outcome of these workshops and the resulting maps for a set of eleven promising and/or popular SOC sequestration measures individually.

Keywords: CarboSeq; soil organic carbon sequestration; area of implementation; continental scale

Full inversion tillage as a strategy of accelerating soil carbon sequestration during the renewing permanent pastures and grasslands in Ireland

Rahman, Niharika[1*]; Wall, David[1]; Krol, Dominika[1]; Lopez-Sangil, Luis[1]; O'Neill, Macdara[1]; Lanigan, Gary[1]

[1] *Teagasc, Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland*

** Presenting author: Niharika.rahman@teagasc.ie*

Soil carbon (C) sequestration is currently targeted to offset increases in atmospheric CO_2 emissions. Full inversion tillage or deep ploughing offers a strategy to both protect soil organic carbon stocks that have built up over previous decades, whilst providing the capacity for a 'new C sink' to be established. Deep ploughing to approximately 40 cm, inverts grassland soil depositing the carbon-rich topsoil to lower layers, effectively burying and protecting this carbon stock below the zone where soil biology is most active. Once-off or infrequent deep ploughing can increase soil organic carbon stocks via two processes: (i) burying carbon-rich topsoil and possibly slowing the rate of decomposition, and (ii) transferring carbon-deficient soil to the surface to increase C input by plants. However, key questions remain as to how this renovation may impact soil organic carbon stocks, yield and key components of the ecosystem C cycle. This study aimed to assess the impact of full inversion tillage/deep ploughing by quantifying soil organic carbon conservation at different depths with a ^{13}C labelling approach and assessing the impact on ecosystem CO_2 fluxes. A lysimeter experiment was set at a growth room facility under ambient environmental conditions with the treatments i) Deep ploughed (DP) (40 cm), ii) Conventional ploughed (CP) (25 cm), iii) Minimum tillage (MT) and iv) Unploughed control with monoculture ryegrass and multispecies swards (grass + clover + herbs). This study utilised a C tracer approach in order to attempt to characterise key leverage points by which deep ploughing could enhance the C cycle. Net ecosystem productivity (NEP) and total ecosystem respiration (TER) were measured to calculate the gross primary production (GPP) of the systems. The use of carbon tracers revealed significant differences in net ecosystem productivity between the different tillage methods and sward types. The difference in ^{13}C between root and soil was used to partition the soil respiratory flux into auto- and heterotrophic gross component fluxes. There appears to be a consistent pattern in the autotrophic respiration dominates DP treatments, whilst CP/ MT is equally divided and unploughed grassland is heterotrophic dominated. Deep ploughing impacts C balance, which may positively affect net CO_2 sink activity by increasing GPP and reducing TER and heterotrophic respiration. The tillage methods and sward types affect the C sequestration potential. Deep ploughing with mixed species sward showed the highest dry matter yield compared to other treatments. Within two years of deep ploughing the grass production responded positively and was significantly greater than the non-renovated pasture. Results of this project show the potential of the full inversion tillage, i.e. deep ploughing to ~40 cm, as a grassland renovation method to increase carbon sequestration. As carbon build-up occurs slowly over many years and decades and the tillage methods and sward types affect the C sequestration potential, this study proposes field trials for further long-term monitoring of carbon sequestration in the permanent pastures and grasslands in Ireland.

Keywords: Soil organic carbon, C tracer approach, Isotope analysis, Deep tillage, Zero tillage

A2 Using participatory design for developing farmer friendly tools for soil practices and schemes

Session Description

Involved projects: ROAD4SCHEMES, IntoDIALOGUE, PRAC2LIV

Conveners: Sabina Asins (CSIC), Marjoleine Hanegraaf (WR), Martin Hvarregaard Thorsøe (AU)

EJP SOIL aims to promote the use of regionally specific tools to provide either qualitative or quantitative information on agricultural soil-based ecosystem services, e.g., climate change. The trend is for more complex decision support tools (DSTs) that focus on both agricultural production and environmental services. However, the level of implementation of DSTs and guidelines for sustainable soil management in Europe varies considerably among farmers and regions. This maybe partly due to different perspectives of land-users for, e.g., taking up C-farming practices and schemes as compared to monitoring bodies. Studies have identified a large variety in limiting factors for adoption of tools, including differences in advisory frameworks, country-specific data and calibration requirements, issues around language and farmers' ecological identity. Abstracts are invited to share the experiences of your projects in the end-users' involvement, as well as on the use of participatory design in the development and testing of DSTs.

Stakeholders mapping and engagement on socio-ecological research

Lukminė Diana[1], Vilkienė Monika[2*], Mockeviciene Ieva[2] and Valda Araminienė[1]

[1] *Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry, Girionys, Kaunas dist., Lithuania.*

[2] *Vezaiciai Branch, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Vezaiciai, 96216, Lithuania.*

** Presenting author: monika.vilkiene@lammc.lt*

In recent scientific papers, analysing stakeholders mapping, the main described point is stakeholder engagement. It is being increasingly promoted in all kinds of research funding organizations, and indeed by many researchers themselves, as an important pathway to achieving impact. In the scientific papers, which report on issues related to environmental management and environmental policy, a clearly practice-oriented approach to stakeholder engagement is developed. In this research area, the focus is on explaining the processes through which various stakeholders can be included and acknowledged in decision-making and policy-making processes, especially related to environmental and sustainability issues. However, the gap between research results and practice is often one of the biggest problems, when a lot of effort, researchers' time and funding are invested in research, and the results obtained are not satisfactory to either the researchers or the end users. Therefore, the participation of stakeholders and the knowledge and practices they provide are important factors that reduce the gap between research results and practice and ensure the greatest efficiency in later use of research results. Various stakeholder engagement strategies could be found in the literature. The most cited way the bottom-up stakeholder engagement approach is when we identify the most relevant topic during the interview of the target group. Furthermore, they are enrolling in all phases of inquiries into solutions or problem-solving. One of the most challenging issues is to identify the end users, who will implement the research-based solutions. This is one of the main questions that the Into-DIALOGUE project, implemented under the EJP SOIL program, is trying to answer. Identifying potential users and asking them about their usage perspective at the beginning of the research is very useful, but it is still difficult to identify and communicate with potential users at the beginning of the research project. One of the possible ways – to make stakeholders map. The main benefit of a stakeholder map is to get a visual representation of all the people who can influence your project and how they are connected. The aim of Into-DIALOGUE project is to identify why the conjunction of various practices, which farmers are already selectively implementing, is complicated and slow to combine, and on a landscape or a territorial scale, to compare the experience in different countries, and find common solution how to solve the common problems for the same stakeholders. In mentioned research the most important step is to identify our target groups, engage them and to get high qualified answers to avoid gaps between our expectations and real situation, despite the geographical and territorial differences.

Keywords: stakeholders, criterion, engagement, values and practices.

Testing FAO's "TAPE" in Norway: a participatory tool for farmers, policymakers and other stakeholders

Hansdotter Sara[1], Rittl Tatiana[2] and Breland Tor Arvid[3]

[1,2]*Norwegian Centre for Organic Agriculture, Tingvoll, Norway*

[3] *Faculty of Biosciences, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Ås, Norway*

sara.hansdotter@norsok.no

Keywords: TAPE, agroecology, participatory DST

In response to the need for knowledge about how different types of agricultural production systems contribute to more sustainable food systems, FAO has developed "Tool for Agroecological Performance Evaluation" (TAPE, 2019). TAPE characterizes the production system's degree of compliance with agroecological approaches and principles and then evaluates its performance against criteria considered relevant for achieving the Sustainable Development Goals. Amongst several criteria is soil health. TAPE consists of four steps, 1) contextualization of territory, 2) characterization of compliance with agroecological approaches, 3) evaluation of sustainability performance, and 4) participatory interpretation and revision of the results with stakeholders. Here, we have used TAPE to assess the sustainability of an organic dairy farm in Midwest Norway. We observed several shortcomings of using TAPE, the main issues being poor adaptation of indicators to Norway's ecological, climatic, and socio-cultural conditions. Yet, the participatory interpretation and revision of the results with stakeholders showed to be a promising framework for supporting complex decision-making processes with farmers, policymakers, and other stakeholders.

Land-users' perceptions on carbon farming and related rural landscape changes

Graversgaard Morten[1*], Krabbe Kasper[1] and Thorsøe Martin [1]

[1] *Department of Agroecology, Aarhus University, Tjele, Denmark*

** Presenting author: Email address presenting author*

An extensive body of research has shown that land management practices can increase soil organic carbon stocks on agricultural lands. This knowledge has also gained interest among policy makers, and the concept of carbon farming is increasing in attention. Recently, the EU Commission published its proposal for a regulatory framework on carbon removals, in which the European Commission proposes standards for certifying carbon farming activities.

Successful carbon farming presupposes that carbon farming scheme design enables land users' to effectively implement relevant carbon farming practices. Despite these new legislative ambitions on carbon farming, key questions remain, and knowledge is needed on land-users' perceptions of strengths and weaknesses of different designs for carbon farming schemes. The carbon farming initiatives and schemes will significantly change the rural landscapes (arable land will be re-wetted, afforestation and changing farming systems). However, the perceptions of the key stakeholders and people living in rural areas are missing in this transformation. In this paper, we analyse 9 different partner countries in EU, that have conducted focus groups with landowners on carbon farming and land use changes. The paper, presents and discuss the basis for designing carbon farming schemes that are perceived as fair and effective by land-users.

Keywords: Carbon Farming; Stakeholder perceptions; Policy schemes

Does EJP SOIL have what agricultural advisors want?

Matson, Amanda[1*], Afanasjeva, Kristine[2], Budai, Alice[3], D'Hose, Tommy[4], Dirnena, Baiba[2], Getahun, Gizachew[5], Hirte, Juliane[6], Jarosch, Klaus[6], Kasparinskis, Raimonds[2], Keesstra, Saskia[1], Klumpp, Katja[7], Kukuls, Imants[2], Madenoglu, Sevinc[8], Mavsar, Sara[9], Meurer, Katharina[5], Mihelič, Rok[9], Murugan, Rajasekaran[10], Penizek, Vit[11], Péter, Lászlo[12], Phillips, Avion[13], Potters, Jorieke[1], Sanchez, Benjamin[14], Schwarzmann, Ana[9], Tello-Mariscal, Marisa[14], Vilkienė, Monika[15], Wall, David[13] and Iwema, Joost[1]

[1]Wageningen Research, Wageningen, Netherlands; [2]University of Latvia, Riga, Latvia; [3]Norwegian Institute of Bioeconomy Research, Ås, Norway; [4]Institute for Agricultural and Fisheries Research, Merelbeke, Belgium; [5]Swedish University of Agricultural Sciences, Uppsala, Sweden; [6]Agroscope, Zurich, Switzerland; [7]INRAE, Paris, France; [8]General Directorate of Agricultural Research and Policies (TAGEM), Ankara, Turkey; [9]University of Ljubljana, Ljubljana, Slovenia; [10]BOKU, Vienna, Austria; [11]Czech University of Agriculture, Prague, Czech Republic; [12]ATK TAKI, Budapest, Hungary; [13]Teagasc, Wexford, Ireland; [14]INIA-CSIC, Madrid, Spain; [15]Lithuanian Research Centre for Agriculture and Forestry, Kedainiai, Lithuania

** Presenting author: amanda.matson@wur.nl*

Farm advisors play a crucial role in promoting and facilitating the adoption of sustainable soil management practices. To effectively support farmers, advisors need to have access to current, practical insights and tools. EJP SOIL (Task 7.6) aims to address that need by tailoring the format and content of new knowledge and tools to the needs of advisors in different parts of Europe. Our goal is to develop practical mechanisms to put the rich results generated by EJP SOIL to use, both strengthening soil advisory capacity and contributing to Agricultural and Knowledge Innovation Systems (AKIS).

In this interactive presentation, we will share the results of our first step: understanding the current reality of advisors. We present the results of an EU-wide survey and follow-up workshop, targeting agricultural advisors and trainers in 24 countries. The survey invited respondents to share their views on current advisory practices and identify future knowledge needs and interests. In the follow-up workshop, national advisory experts were asked to discuss those themes in more detail, and explore opportunities for EJP SOIL to strengthen soil advisory capacity.

Our next step is to work together with the EJP SOIL community to find synergies. We will invite the audience to start exploring how the results/products that have been generated (or will be generated) in their projects can match the needs and interests identified by advisors. In this way we collaborate to foster sustainable soil management in practice and contribute to one of the key EU Soil Mission objectives: building capacity and the knowledge base for soil stewardship.

Keywords: advisory practices; capacity building; knowledge dissemination; sustainable soil management

Stakeholder and end-user involvement in the formulation and evaluation of terminology for a comprehensive soil health framework

Bondi Giulia[1], Weninger Thomas[2*], Foldal Cecilie[3], O´Sullivan Lilian[1], Asins Sabina[4]

[1] *Teagasc Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford, Ireland*

[2] *Federal Agency for Water Management, Petzenkirchen, Austria*

[3] *Austrian Research Centre for Forest, Vienna, Austria*

[4] *Centro de Investigaciones sobre Desertificación-CIDE (CSIC, UV, GVA), Valencia, Spain*

** Presenting author: thomas.weninger@baw.at*

The EJP-SOIL project SERENA aims to develop a universal framework for the determination of soil threats and ecosystem services across the European Union partner countries. A fundamental pillar of the work is the involvement of stakeholders and end-users in all steps of the project that will actively participate to the validation of the project outputs. By definition, stakeholders are those who have a stake and may be affected by a framework for soil health, have a role in its implementation or have specific experience, expertise or technical knowledge. The nature of their stake in relation to the subject will determine their level of influence or interest in the topic.

As the concept of soil health has gained priority at EU scale, it is pertinent to develop a comprehensive terminology to ensure a shared common understanding across stakeholders. Although a broad high level definition of soil health is now proposed at EU scale, it is true that different stakeholders within and between member states use the same terminology to describe different things, or different terminology to mean that same thing. This challenge occurs across stakeholders and scales.

To overcome this challenge, the SERENA project has developed a database of stakeholders who will be engaged in an effort to harmonise terminology related to soil health. The stakeholder database comprises different backgrounds regarding education, demography, age, gender, and many more characteristics which influence their opinions and answers in different communication processes. This supports the identification of persons for different ways of involvement with different temporal extent, scientific depth, network representation and many more.

In parallel, a survey has been developed and translated into national languages to revise proposed definitions that have been developed as part of SERENA. Definitions have been formulated to be precise, clear, intuitive, complete and relevant. An analysis of the results will guide insights into terminology used by different stakeholders at different scales. Outputs are anticipated to support more enhanced communication strategies that can be targeted to different stakeholder types, intended to support a transition towards healthier soils in Europe. The basic ideas and challenges to compile the SERENA stakeholder database are presented, including practical examples of stakeholder involvement and implementation activities.

Keywords: stakeholders, soil threats, soil ecosystem services, database, targeted communication

Investigating policy pathways to enact soil-based agroecological principles in the European and Turkish farming systems

Francesca Varia[1*], Francesco Galioto[1], and Giovanni Dara Guccione[1]

[1]*CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy*

**Presenting author: francesca.varia@crea.gov.it*

The present study aims at investigating the different policy instruments which can currently contribute to addressing agroecological land use challenges in different context in the European Union and Turkey. Agroecological land use challenges are here meant challenges addressed at recovering degraded soils due to intensive farming with the aim to allow the development of more resilient and sustainable agricultural systems.

Three key policy areas of action are here identified: funding opportunities for farmers; supporting participatory processes; regulating land uses. Funding opportunities encompasses local funding resources addressed to promote the adoption of sustainable climate-and environment-friendly farming practices and approaches (e.g., through the so-called "green architecture" of the new Common Agriculture Policy - CAP). Supporting participatory processes encompasses a wide range of instruments involving local communities through multi-actor, multi-level and collaborative initiatives (European Innovation Partnership for Agricultural productivity and sustainability -EIP-Agri, Living Labs and Lighthouses, the LIFE Programme, the LEADER Strategic local plans, Eco-regions, Land associations, Bio districts, etc.). Regulating land uses consists of minimum requirements farmers must comply with when operating in areas with specific environmental issues (e. g., nitrate-vulnerable zones, Natura 2000 sites, river basins under the Water Framework Directive).

While a growing body of literature has demonstrated several positive impacts of agroecology, evidence of policy contribution to the agroecological transition of farming systems remains fragmented because of heterogeneous concepts and principles, methods, differing scales and timeframes, as well as knowledge gaps. Facing these challenges, the Into-Dialogue project performed a broad, albeit not exhaustive, systematic literature review on the existing frameworks, methods and indicators used in evaluating policies aiming at promoting the sustainable management of agricultural soils.

As a result, what is expected is a conceptual framework will serve as a reference for the continuation of Into-Dialogue project activities. Results reveal how differently soil-based agroecological principles and approaches are embedded into national and regional policies and measures and which are the needs behind.

In this perspective the study represents the initiation and strengthening of a transitional path to agroecology which cannot disregard from the development of consistent and effective political processes.

Keywords: Policy evaluation; Land use challenges; agroecology.

References

Clara I. Nicholls & Miguel A. Altieri. 2018. Pathways for the amplification of agroecology, Agroecology and Sustainable Food Systems, 42:10, 1170-1193, DOI: 10.1080/21683565.2018.1499578

Altieri, Miguel A. and Nicholls, Clara I. 2005. *Agroecology and the Search for a Truly Sustainable Agriculture*. United Nations Environmental Programme, Environmental Training Network for Latin America and the Caribbean, 2005, p. 31.

Gliessman, Stephen R. 1990. *Agroecology: Researching the Ecological Basis for Sustainable Agriculture*. Springer.

Meek, David. 2016. The Cultural Politics of the Agroecological Transition. *Agriculture and Human Values* 33(2):275–90.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

Is there a Stakeholder Dialogue when looking for the integration of soil-based principles in agroecological systems?

Asins-Velis Sabina[1*] and Ün Akin[2]

[1]*Centro de Investigaciones sobre Desertificación-CIDE (CSIC, UV, GVA), Valencia, Spain*

[2]*General Directorate of Agricultural Research and Policies of the Republic of Turkey, Ministry of Agriculture and Forestry (TAGEM), Turkey*

** Presenting author: Sabina.asins@uv.es*

Into-DIALOGUE is a project funded by the EJP-Soil, focused on finding tools to facilitate stakeholder dialogue for the integration of soil-based principles in agroecological systems, in European and Turkish agricultural landscapes. This may be difficult to achieve, in the short term, given the complexity of holistically adopting Agroecology principles. Into-DIALOGUE will provide an integrative multi-stakeholder approach to the integration of soil-based systems, farmers' ecological identity, the design of policy measures and the collaborative possibilities offered by citizen participation to facilitate the transition.

The project partners cover a diagonal transect that includes different climatic regions and very diverse environments, from southwestern to northeastern Europe (Spain, Italy, Czech Republic, Poland, Lithuania and Latvia), with Turkey contributing its own landscapes.

Into-DIALOGUE addresses the challenge of finding out whether the Ecological Identity of Farmers in these countries is directly related to the implementation of agroecological practices in soil management. Which of the soil-based practices, that make up an agroecological system, can be more easily incorporated by farmers? In order to design specific policies at EU and Turkish level, it is essential to provide an overview of the ecological identity of farmers, and their Dialogues with other actors managing the agricultural landscape.

Keywords: Stakeholders dialogue; Farmers ecological identity; Agroecological systems; agroecological soil-based principles.

Fostering soil management PRACtices and uptake and developing decision support TOols through LIVing labs in EU (PRAC2LIV)

Hanegraaf, Marjoleine[1], Räsänen, Timo[2], Kasparinskis, Raimonds[3], Waren Raffa[4], Dylan, Delin, Sofia[5], Zeynep Demir[6], Meriem Jouini[5], Valentina Barantella[4], Alessandra, Trinchera[4], Nienhuis, Ciska[1], Heesmans, Hanneke[1], Ulfet Erdal[6], Olgerts Nikodemus[3] and Jaana Uusi-Kämppä[2]

[1]*Wageningen Research, Wageningen, Netherlands;* [2]*National Resources Institute Finland, Helsinki, Finland*; [3]*University of Latvia, Riga, Latvia;* [4]*CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy;* [5]*Swedish University of Agricultural Sciences, Uppsala, Sweden;* [6]*General Directorate of Agricultural Research and Policies (TAGEM), Ankara, Turkey.*

The project PRAC2LIV will make and evaluate a stock-take of Decision Support Tools (DSTs) that focus on soil organic matter, water retention, and nutrient use efficiency as currently used by EJP Member States. Building on previous stocktakes, EU-projects and national reports, the overview will include DSTs from simple tools to the next generation level support systems. Both the scientific base of DSTs as well as their implementation and adoption at farm level will be assessed, with special attention for soil management practices, regional distance-to-target options, and data sharing for web-portal applications. Guidelines for development of DSTs and designs for (mock-up) web-portal and/or dashboards will be discussed in workshop exchanges with stakeholders. Relevant farming groups will be selected from national projects and/or Living Labs following the Mission Board on Soil Health and Food. The selection will include, if possible, groups with and without experience with selected DSTs. A general script for a workshop will be written based on previous expertise and the literature. The mock-up designs for web-portal and/or dashboard will be translated into the language of countries where the workshops are taking place. Based on the results from the stocktake and these discussions, a tiered approach will be developed for future development of DSTs in agro-ecosystems across EJP Member States.

Keywords: stock-take, Decision Support Tool, sustainable soil management, living Lab

Barriers and opportunities of soil knowledge to address soil challenges: Stakeholders’ perspectives across Europe

Silvia Vanino[a], Tiziana Pirelli[b]*, Claudia Di Bene[a], Frederik Bøe[3a,3b], Nadia Castanheira[e], Claire Chenu[f], Sophie Cornu[g], Virginijus Feiza[h], Dario Fornara[8a,8b], Olivier Heller[k], Raimonds Kasparinskis[l], Saskia Keesstra[11a,11b], Maria Valentina Lasorella[b], Sevinç Madeno˘glu[o], Katharina H.E. Meurer[p], Lilian O’Sullivan[q], Noemi Peter[k], Chiara Piccini[a], Grzegorz Siebielec[r], Bozena Smreczak[r], Martin Hvarregaard Thorsøe[s], Roberta Farina[a]

a Consiglio per La Ricerca in Agricoltura e L’Analisi dell’Economia Agraria, Centro Agricoltura e Ambiente, via della Navicella 2-4, Rome, Italy

b Consiglio per La Ricerca in Agricoltura e L’Analisi dell’Economia Agraria, Centro di Politiche e Bioeconomia, via Barberini, Rome, Italy

3a Division of Environment and Natural Resources, Department of Soil and Land Use, Norwegian Institute of Bioeconomy Research, Oluf Thesens vei 43, 1433 Ås, Norway -3b Soil Physics and Land Management, Wageningen University & Research, Droevendaalsesteeg 4, 6708 PB Wageningen, the Netherlands

e Instituto Nacional de Investigaç˜ao Agr´aria e Veterin´aria, I.P., Soil Lab, Avenida da República, Quinta do Marquˆes, 2780-157 Oeiras, Portugal

f Ecosys, Universit´e Paris-Saclay, INRAE, AgroParisTech, Campus AgroParisTech, 78850 Thiverval-Grignon, France

g Aix-Marseille Univ, CNRS, IRD, INRAE, Coll France, CEREGE, 13545 Aix en Provence Cedex 4, France

h Department of Soil and Crop Management, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry (LAMMC). Instituto al. 1, LT-58344,

Akademija, Kedainiai distr., Lithuania

8a Davines Group - Rodale Institute European Regenerative Organic Center (EROC), Via Don Angelo Calzolari 55/a, 43126, Parma, Italy - 8b Agri-Food and Biosciences Institute (AFBI), Newforge Lane, Belfast BT9 5PX, UK

k Department of Agroecology and Environment, Agroscope, Reckenholzstrasse 191, 8046 Zürich, Switzerland

l Faculty of Geography and Earth Sciences, University of Latvia, Rain¸a Blvd. 19, Riga, Latvia

11a Soil, Water and Land Use Team, Wageningen Environmental Research, Drovendaalsesteeg 3, 6700PB, Wageningen, the Netherlands - 11b Civil, Surveying and Environmental Engineering, The University of Newcastle, Callaghan 2308, Australia

o Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies (TAGEM) 06800 Ankara, Turkey

p Department of Soil & Environment, Swedish University of Agricultural Sciences – SLU, Uppsala, Sweden

q Teagasc, Crops, Environment and Land Use Programme, Johnstown Castle, Co. Wexford, Ireland. Lilian

r Department of Soil Science Erosion and Land Protection, Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland

s Aarhus University, Department of Agroecology, 8830 Tjele, Denmark

** Corresponding author: silvia.vanino@crea.gov.it*

Climate-smart sustainable management of agricultural soil is critical to improve soil health, enhance food and water security, contribute to climate change mitigation and adaptation, biodiversity preservation, and improve human health and wellbeing. The European Joint Programme for Soil (EJP SOIL) started in 2020 with the aim to significantly improve soil management knowledge and create a sustainable and integrated European soil research system. EJP SOIL involves more than 350 scientists across 24 Countries and has been addressing multiple aspects associated with soil management across different European agroecosystems. This study summarizes the key findings of stakeholder consultations conducted at the national level across 20 countries with the aim to identify important barriers and challenges currently affecting soil knowledge but also assess opportunities to overcome these obstacles. Our findings demonstrate that there is significant room for improvement in terms of knowledge production, dissemination and adoption. Among the most important barriers identified by consulted stakeholders are technical, political, social and economic obstacles, which strongly limit the development and full exploitation of the outcomes of soil research. The main soil challenge across consulted member states remains to improve soil organic matter and peat soil conservation while soil water storage capacity is a key challenge in Southern Europe. Findings from this study clearly suggest that going forward climate-smart sustainable soil management will benefit from (1) increases in research funding, (2) the maintenance and valorisation of long-term (field) experiments, (3) the creation of knowledge sharing networks and interlinked national and European infrastructures, and (4) the development of regionally-tailored soil management strategies. All the above-mentioned interventions can contribute to the creation of healthy, resilient and sustainable soil ecosystems across Europe.

Keywords: agricultural soils; soil knowledge, soil organic matter, water storage capacity

Towards agricultural system innovation through crop diversity in the Living Lab 'Nature inclusive agriculture, North-Netherlands'

Nienhuis Ciska[1], Hanegraaf Marjoleine[1], Potters Jorieke[1], Tittonell Pablo[2]

[1] *Wageningen University & Research Field Crops, Lelystad, The Netherlands*
[2] *University of Groningen Agroecology and Sustainable Landscapes, Groningen, The Netherlands*

** Presenting author: ciska.nienhuis@wur.nl*

Keywords: agroecology; strip cropping; transition; ecosystem services

Agriculture in The Netherlands is challenged with biodiversity loss and restriction on inputs like nutrients and pesticides. The number of active farmers is decreasing. It is argued that a new perspective on agriculture is needed for transition and institutional change, transition towards a system that meets ecological and socio-cultural targets. The regional scale could be focus of the agroecological transition, because climate, soil, hydrological and social-cultural values are often regionally defined. In the Netherlands, the region of the Veenkolonien requires a redesign of its agroecosystems, due to, e.g. soil degradation, narrow cropping plan, and difficulties to earn an income out of arable farming. This region is characterized by starch potato, reclaimed peat soil with slow degradable organic matter and poor mineralization of nutrients. Based on the literature and explorative work, crop diversity may be part of the solution, as results on soil biodiversity and innovative fertilization are promising. Crop diversity has been identified as promising for sustainable crop production and other ecosystem services. Intercropping and mixed cropping is challenging in a context of large-scale, mechanized agriculture, crop diversification through strip cropping offers opportunities for this transition at regional level of the Veenkolonien. A strip cropping experiment is set up in spring 2023 for at least 2 growing seasons, at the WUR experimental farm in Valthermond, Netherlands. The experimental design includes 4 treatments: organically managed strips (6 m), conventional managed strips (6 m), and conventional+ managed strips (6m, conventional at the cutting edge) and conventional+ managed strips of 12 m width. The 4 strip cropping systems will be monitored for yield, pest & diseases, biodiversity, soil parameters and economic performance. A regional living lab is being formed to explore and further develop strip cropping alternatives with local stakeholders: arable farmers (10-15), market companies (like potato and sugar beet companies), regional government, knowledge institutions and citizens (cooperatives). The experimental farm serves as a light house, where practices are implemented that impact on carbon sequestration, nitrogen use efficiency, moisture management and biodiversity. This part of the work could be done in cooperation with Farm of the future Veenkolonien (concept of farm demonstration fields were practice ready innovations come together) and EJP Soil project PRAC2LIV. The later project develops a framework with guidelines for the development of 'decision support tools' and/or a web portal on the subjects mentioned above. For this purpose, a regional assessment of the guidelines is carried out in the Living Lab. The approach of this type of agroecological transition, i.e. crop diversity as a base for system change, and the implementation of a living lab for upscaling to the regional level, will be discussed. The expected outcome is that through co-creation of knowledge in a living lab, new and innovative connections between stakeholders will be made. Farmers get support in adopting agroecological innovations, and will be able to earn an income while taking care of the ecosystem. Question to be discussed at the poster presentation: which connections may be expected in the combination of crop diversity and a living lab?

Participatory approaches to address Water-Ecosystems-Food Nexus challenges: focus on Italian pilot case

Baratella, V[1,*], Pirelli T[2], Giordano R[3], Pagano A[3], Portoghese I[3], Bea M4, López-Moya E[4], Di Fonzo A[2], Fabiani S[2], Vanino, S[1]

[1] *Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro Agricoltura e Ambiente, Rome, Italy;*

2 Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Centro di Politiche e Bioeconomia, Rome, Italy;

3Consiglio Nazionale delle Ricerche (CNR) - Istituto di Ricerca sulle Acque (IRSA), Bari (Italy);

4 Asociación ECOADAPTA, Madrid (Spain);

** Corresponding author: valentina.baratella@crea.gov.it*

Multi-actor approaches are increasingly recognized in Nexus research as the most effective way to identify divergent interests and interdependencies between usually "siloed" management sectors, as a fundamental basis for developing effective decision support tools and innovative policy and technical strategies. In the framework of the PRIMA project LENSES (LEarning and action alliances for NexuS EnvironmentS in an uncertain future), we developed a methodological approach to implement a cross-sectoral and multi-level participatory process in the Tarquinia Plain (Italy), as part of a broader research context that included seven pilots across the Mediterranean. Systematic methodologies for stakeholders analysis and engagement, as well as mutual learning activities for knowledge sharing were applied to develop a shared understanding of local societal challenges and potential sustainable innovations in farming practices, land, and water management.

In the first phase, stakeholder analysis methodologies enabled the identification of a large and diverse range of local stakeholders across the key local Nexus domains. By assessing and visualizing their interests and power, we were able to explore potential collaborations and conflicts, making explicit the linkages between different actors and their stakes in resource use and management. The results of the stakeholder analysis were used to recommend and develop strategies for stakeholder engagement and to support the design of tools for knowledge sharing, by the establishment of a Learning and Action Alliance (LAA) in the study area. The LAA was designed as a virtual space where cross-cutting participatory tools and mutual learning activities could be developed. In the LAA environment, we established a structured visioning process through sketches, mind maps, videos, interviews, etc. to help create a shared vision towards which decision-makers can move when discussing how to address systemic Nexus challenges, or step back from to provide feedback in an iterative process. To further support cross-sectoral and multi-level stakeholder engagement, Participatory System Dynamic Modelling (PSDM) was selected in view of its proven ability to account for complex, non-linear interactions in Nexus systems and facilitate the integration of models/data and stakeholder knowledge. PSDM for collaborative learning was introduced into the LAA environment as a robust approach for the creation and analysis of scenarios with stakeholders at multiple scales, with the final aim of co-design suitable, innovative policy and technical strategies for sustainable resource management in the pilot area.

The results obtained will serve to provide decision-makers with a "Solution Selection Framework" as evidence-based tool to support the selection of management alternatives in addressing Water-Ecosystem-Food Nexus challenges at the pilot scale, with the ultimate goal of developing an effective and widely accepted roadmap for the transition to integrated, sustainable management of agri-environmental resources.

Keywords: *Stakeholder analysis and engagement; Participatory approach; WEF Nexus; Resource management innovation; Farming practices; Sustainability.*

A3 Innovation and methods for data acquisition

Session Description

Involved projects: STEROPES, ProbeField, Sensres

Conveners: Emmanuelle Vaudour (INRAE), Johanna Wetterlind (SLU), Luboš Borůvka (CZU)

The session will consider communications dealing with i) how accurate spectral approaches can be from varied observational scales: lab, field, airborne and/or spaceborne sensors, be they multispectral or hyperspectral, point or imaging measurements ; ii) to what extent a sensed soil property can be either mapped, or timely monitored or even spatially timely monitored. Special consideration will be given to soil organic carbon and stocks and in how degree to the disturbing factors (atmospheric conditions, soil moisture, texture...) intervene in such approach for diverse agroclimatic zones and agroecosystems. The session raises the accuracy that can be reached spectrally according to diverse ancillary factors, algorithms, spatial scales and time scales and the various sources of uncertainty that spectral approaches accordingly underlie. It will also consider the use of soil spectral libraries in combination or not with remotely sensed images.

Stimulating novel Technologies from Earth Remote Observation to Predict European Soil carbon - STEROPES

Emmanuelle Vaudour (INRAE)

Conventional high-detail soil maps are static and often based on obsolete data in relation to the time of use. STEROPES intends to overcome these limitations putting the use ofsatellite time series forward, to test their potential to predict cropland soil organic carbon content over various pedoclimatic conditions and cropping systems across Europe.

First, models will be constructed from the reflectance image spectra of optical satellite series, notably Sentinel-2 (ESA), based on a number of diversified areas for which soil organic carbon samples are already available.

The second phase of the project will be dedicated to analysing the influence of various factors on SOC prediction performance: soil moisture, texture, dry vegetation due to management practices, salinity.

Then, for the sites where satellite information may not enable to derive acceptable predictions, other ancillary data will be considered at a more detailed scale, using geophysical proxies to reduce the uncertainty associated with these predictions.

A novel protocol for in-field monitoring of soil carbon stock, based on proximal sensors and soil spectral libraries – ProbeField

Luboš Borůvka, CZU

Quick and simple soil analyses directly in the field through proximal sensing have the potential to substantially gear up the number of samples analysed. To meet the growing demand for fast and cheap analysis of soils, ProbeField will focus on visible and near infrared spectroscopy (vis-NIRS) as an alternative tool to expensive and time-consuming conventional methods. The vis-NIRS technique has many advantages required for field analyses of soil properties. There are, however, drawbacks to be overcome. In contrast to lab spectroscopy, variable moisture and structure in the field will hamper reliability of analyses. ProbeField will test and suggest the most optimal physical and mathematical procedures to manage these problems. A wide range of soil properties will be analysed and 3D mapping will be performed to estimate for example carbon stocks. A best practice protocol will be produced.

The presentation will introduce the objectives, structure and methodological approaches of the project. The work and achievements so far will be presented. The methods and their applications and results will be shown on example of selected fields in the Czech Republic and other participating countries. A novel tool for field spectra measurement SoilPro developed by prof. Eyal Ben Dor in Israel and preliminary results of its application will be also presented.

Apparent electrical conductivity across classes of soil drainage and survey conditions: what performance can we expect from EMI sensors' response revealing soil parameters?

Carlos Lozano Fondon[1*], Roberto Barbetti[2], Giovanni L'Abate[1], Maria Fantappiè[1]

[1] *CREA Research Centre for Agriculture and Environment, Florence, Italy*

[2] *CREA Research Centre for Forestry and Wood, Casale Monferrato, Alessandria, Italy*

** Carlos Lozano Fondon: carlos.lozanofondon@crea.gov.it*

The use of proximal soil sensors revealing apparent electrical conductivity (ECa) through electromagnetic induction (EMI) is increasingly being considered to produce high spatial resolution soil maps for precision agriculture. However, predicted values from linear regression models between ECa and main soil physical properties (i.e., clay, sand, EC, and coarse fragments) sometimes may show inconsistency. We hypothesized that different soil drainage classes (i.e., SDC) and survey season could influence the performance of EMI sensors revealing soil properties, and thus a specialized knowledge to correctly interpret the EMI output is required. The aim of this work was to study the effect of varying soil parameters and survey conditions over seven SDC on ECa data (ms m^{-1}) collected during the last fifteen years within the Italian territory (up to sixty-five soil surveys and up to one thousand soil profiles). We used a step-by-step modelling of data, starting from the classical relationships (i.e., correlations, RMSE, and R^2). First, we identified the better correlation between soil properties and ECa. Second, we scaled survey points (i.e., EMI outcome) using the Bray-Curtis distance based on SDC, using non-metric multidimensional scaling (i.e., NMDS). Then, we applied a PERMANOVA to identify which variable of those identified in the first step was influencing the more ECa. Last step was to apply a generalized additive model (i.e., GAM) using NMDS coordinates as random factor to study the spatial dependency of ECa, together with soil properties, SDC, and survey season.

Our results show that i) more variability of ECa is associated with well-drained soils and winter surveys as indicated by NMDS and PERMANOVA statistics; ii) clay content was the best correlated parameter (R^2=10%) after the soil drainage (R^2=22%), still residuals of the PERMANOVA were up to 50%; iii) unsignificant influence of physical parameters on ECa was found with the GAM (R^2=97%), which relates an important portion of variance of data with NMDS coordinates. This reveal a spatial dependence of ECa and SDC, which is influenced by the survey season and marginally by soil properties. In particular, well-drained soils surveyed in humid seasons accounted for the highest effect on ECa. Lower influence of moisture and drainage on ECa was identified in poorly drained soils due to drier survey conditions. Such fact allows the identification of better relationships with clay, sand, EC, and coarse fragments.

From such results, we infer that knowledge of hydrological characteristics of soils is mandatory to obtain a better interpretation of EMI outcomes, because ECa dependency on soil moisture and drainage would mask relationships with other soil parameters. Thus, we would recommend the use of more techniques and the measurement of auxiliary variables for surveys carried out in soils with high drainage in humid seasons.

Keywords: electromagnetic induction; performance metrics, soil properties, survey season, soil drainage

SANCHO'S THRIST, the effects of cover crops on multiple ecosystem services in woody crops of semiarid areas

Marques, Maria Jose[1*], Sastre, Blanca[2], Vaudour, Emmanuelle[3], Baghdadi Nicolas[4], Seddaiu, Giovanna [5], Fouad, Youssef [6] and Hatté, Crhistine [7]

[1] *Universidad Autónoma de Madrid, Madrid, Spain*

[2] *Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario. Alcalá de Henares, Spain*

[3] *AgroParisTech, Palaiseau, France*

[4] *French National Institute for Agriculture, Food and Environment, Montpellier, France*

[5] *University of Sassari, Sassari, Italy*

[6] *Institut Agro Rennes Angers, Rennes Cedex, France*

[7] *Silesian University of Technology, Gliwice, Poland*

**Presenting author: mariajose.marques@uam.es*

Woody crops (vineyards and olive groves, for example) are usually located in marginal areas, on poor and sloping soils. This fact, together with its intensive use, has led to degraded soils, with little organic matter and very prone to erosion. This scenario is typical of southern European countries. The current Common Agricultural Policy tries to mitigate this situation by financing agri-environmental measures or eco-schemes, for example, the use of cover crops to improve organic carbon and moisture content and prevent erosion and desertification. However, in dry areas, this type of sustainable management is not welcomed by farmers, who fear competition for water and nutrients.

In this project we want to study the effects of cover crops compared to tillage, in vineyards and olive groves, in Spain and Italy, using experimental farms and private farms (30 to 40 farms). The objectives can be grouped into large groups. The first is based on the study of the effect of cover crops, or ground covers, on the quantity and quality of organic matter, on the availability of water, and on the microorganisms involved in carbon metabolism. The second is the ability to remotely monitor the changes produced by this management, incorporating elements such as soil roughness, and the type of clay or iron oxides, which can interfere with the interpretation of satellite time series. The third is the efficiency of carbon sequestration by studying the 13C and/or 15N isotopic signature on bulk soil fraction. The fourth is the effect on productivity and costs of this management, as well as the socio-environmental aspects that are crucial to achieving acceptance by farmers. A set of ecosystem services indicators will be established for different domains: production, socio-economic and environmental aspects, and thresholds for favorable and unfavorable for each indicator will be established.

This project will try to evaluate to what extent woody crops in semiarid areas can be managed with cover crops. We will consider a wide set of pros and cons, including the production of grapes and olives, soil health, carbon sequestration, and other ecosystem services. The results will be modeled to establish future scenarios of business as usual compared to the long-term use of cover crops. We will improve the interpretation of satellite imagery to better monitor carbon sequestration in agricultural areas as spectral and spectral-spatial models will be made for soil organic carbon, with clay and iron oxides as covariates. A synthetic ecosystem service index will be calculated and compared with the tilled woody crop for each cover crop system. The final objective is the dissemination of results through small meetings with farmers, notes on social networks, and the production of a high-quality documentary that can be broadcast on television and the internet.

Keywords: ground covers; woody crops, carbon sequestration, satellite imagery

Monitoring soil salinity and using proximal sensing to map soil salinity and soil texture

Gonçalves, Maria Conceição[1*], Farzamian, Mohammad[1], Castanheira, Nádia[1], Paz, Ana[1], Ramos, Tiago[2], Alexandre, Carlos[3]

[1] *Instituto Nacional de Investigação Agrária e Veterinária, Laboratório de Solos, Oeiras, Portugal*

[2] *Instituto Superior Técnico, Centro de Ciência e Tecnologia do Ambiente e do Mar, Universidade de Lisboa, Lisboa, Portugal*

[3] *Departamento de Geociências e MED, Universidade de Évora, Évora, Portugal*

** Presenting author: maria.goncalves@iniav.pt*

Temporal series of soil salinity were obtained for ten drip-irrigated commercial orchards, located in Roxo' irrigation district, southern Portugal, from May 2019 to May 2021. Secondary salinization has long been reported in this irrigation district, due to the use of saline-prone irrigation water and the existence of poorly structured soils. The crops were almond groves, olive groves, citrus, and pomegranates, having different tolerances to soil salinity. The soils were Luvisols, Cambisols, Regosols, Planosols and Vertisols. Soil samples were taken at different depths (soil surface to a maximum of 80 cm) and the electrical conductivity of the soil saturation paste (ECe) was measured (indicator of soil salinity). Twenty campaigns were carried out. The average electrical conductivity of irrigation water was 0.72 dS/m. Soil salinity varied over time, but without reaching values of concern. In salt-sensitive crops (almond and citrus), there were occasional situations in which ECe presented values above the tolerance. At the end of the monitoring period, ECe values were very close to the initial ones. In addition to the quality of the Roxo water indicating an improvement compared to previous studies, the precipitation that occurred from 2019 to 2021 (1200 mm) also contributed to the removal of salts that eventually accumulated in the rootzone.

During the monitoring period, electromagnetic induction (EMI) surveys were conducted, to measure the apparent electrical conductivity (ECa) of the soil. The objective was to use a fast and non-invasive methodology, that allows covering large areas quickly, to map soil salinity. However, ECa does not represent the actual electric conductivity (EC) variation with depth (is a depth-weighted average conductivity measurement). Inverse modelling can be applied to ECa data to obtain 3D electromagnetic conductivity images (EMCI) of EC of soil horizons or layers. EC is influenced not only by soil salinity but also by other soil properties, such as clay content. To evaluate the potential use of EMI inversion models for mapping soil salinity and other soil properties, EC values were related to soil data collected during an extra survey at the same time as EMI measurements. Sampling locations were selected based on the observed ECa variation in each study site. Most samples were collected in the

almond, citrus, and super-intensive olive grove fields due to higher ECa values observed, suggesting potentially higher soil salinity. Soil samples were analysed for ECe and texture. Soil salinity was extremely low at the time of EMI measurement since all samples from the different locations had ECe lower than 2 dS/m (non-saline soil), and no correlation between ECe and EC was found. However, higher correlations (R2>0.60) were found between EC and sand and clay content in almond and citrus fields. In the absence of high salinity, clay content can dominate the EMI signal and be used to map soil texture. A linear regression (LR) between EC and soil texture, in Almond and Citrus fields, was established. Results showed that it is possible to establish LRs between EC and clay and sand content, allowing to convert EMCI into these texture classes and generating sand and clay 3D maps in depth.

Keywords: soil salinity, electrical conductivity, electromagnetic induction, inversion modelling, soil texture mapping

Sentinel imagery capability in digital SOC mapping in two agricultural regions in France

Urbina-Salazar Diego[1*], Vaudour Emmanuelle[1] Richer-de-Forges Anne[2] and Arrouays Dominique[2]

[1] *University of Paris-Saclay, INRAE, AgroParisTech, UMR ECOSYS, 91120, Palaiseau, France*

[2] *INRAE, Info&Sols, 45075 Orléans, France*

** Presenting author: diego.urbina-salazar@inrae.fr*

Soil organic carbon (SOC) is the target attribute with the largest number of studies in digital soil mapping in the frame of global initiatives such as *GlobalSoilMap* that aim to provide maps of key soil properties at national scales. Previous studies have considered terrain-derived variables and other soil properties such as clay to map SOC. Nowadays with the free availability of satellite imagery the mapping of SOC using remote sensing data is being more widely envisioned. However, the capability to predict SOC via satellite imagery in conjunction with soil and terrain data is still unknown in many agricultural regions. In order to map top SOC content over croplands, this study was carried out in the framework of the STEROPES project in two regions in France, Beauce (4838 km^2) and Pyrenean piedmont (22177 km^2), addressing: (i) for both areas, the use of Sentinel-2 single date images and/or soil moisture maps derived from Sentinel 1 and 2 data (ii) for Beauce only, the constructing of temporal mosaics of bare soil images, the inclusion of Gamma-ray images and terrain-derived covariates in prediction models and the map uncertainties.

In both study areas, the prediction performances were influenced according to the date of image acquisition, surface soil conditions (e.g., soil moisture and soil roughness) and the historical context. In Pyrenean piedmont based on a purely spectral method (i.e. using only spectral data from S2 images) using single date images it was possible to predict high SOC contents in specific soil types. In Beauce considering a mixed method (i.e. using S2 spectral data and terrain-derived variables as covariates in the prediction models) using S2 temporal mosaics of bare soil (S2Bsoil) it was possible to determine the most relevant variables in that area and the best periods to elaborate S2Bsoil for predicting SOC.

Keywords: Soil organic carbon; digital soil mapping; Sentinel-1/2; bare soil; map of uncertainties

Estimation of soil salinity using the electrical conductivity of the saturated soil paste from soil:water extracts in a 1:5 ratio

Castanheira, Nádia L.[1*], Paz, Ana[1], Farzamian, Mohammad[1], Ramos, Tiago[2], Alexandre, Carlos[3] and Gonçalves, Maria Conceição[1]

[1] *Instituto Nacional de Investigação Agrária e Veterinária, Laboratório de Solos, Oeiras, Portugal*

[2] *Instituto Superior Técnico, Centro de Ciência e Tecnologia do Ambiente e do Mar, Universidade de Lisboa, Lisboa, Portugal*

[3] *Departamento de Geociências e MED, Universidade de Évora, Évora, Portugal*

** Presenting author: nadia.castanheiraniav.pt*

Soil salinity mapping requires the input of soil data depending on the method used. Soil indicator-based methods are considered more demanding in the need for soil data input to provide evidence of the occurrence of salt problems in the soil. Soil salinity indicators are used to quantify the intensity of salt problems in the soil and to calibrate other methods (remote and proximal sensing) for mapping salt-affected soils.

Electrical conductivity (EC) is one of the most widely used parameters to diagnose soil salinity and estimate soil ion concentration. The determination of soil EC can be carried out in the saturation extract of a saturated soil paste (ECe) or in aqueous soil extracts with different soil:water ratios. The first method is considered ideal for estimating soil salinity and better at assessing plant response to salinity. However, it is time consuming and requires greater investment in equipment. Moreover, the dynamic nature of soil salinity due to the influence of management practices (such as irrigation) and physical factors (soil permeability, water table depths, micro-topographic conditions, water use, rainfall, and salinity of groundwater) leads to the need of repeated measurements. Soil:water extracts are less time consuming and more economical and are therefore often used to assess soil salinity. The most commonly used soil:water ratios are 1:1, 1:2.5 and 1:5. The latter extracts are also used for the measurement of soil pH (ISO 10390) thus making EC analysis more expeditious. The aim of the present study was to determine the relationships between ECe and EC1:5 of soil:water extracts of several agricultural soils of the southern region of Portugal. It is an ongoing study and preliminary data is presented. A total of 749 soil samples from 27 different sites belonging to the irrigation perimeters of Lezíria, Vigia, Campilhas and Alto Sado, Roxo and Alqueva were used for the measurement of the EC of saturated soil pastes (as developed by USDA, 1954) and soil:water extracts (m:v) in 1:5 ratio. The ECe of the soil samples varied between 0.13 and 13.53 dS m-1. The soil samples presented varied textures, with greater predominance of silty-clay and sandy-loam textures with 26 and 22%, respectively. Of the total number of soil samples, 689 were used to establish the regression and the

remaining 60 to validate the estimation of ECe from EC1:5. The results showed a linear regression between ECe and EC1:5 with R2 = 0.89. The set of 60 samples for independent validation showed that the slopes of the regressions between ECe estimated from EC1:5 measurements and direct ECe measurements were close (ME= 0.0783 dS m-1, RMSE= 0.76 dS m-1, PBIAS= 0.1085 % and R2 = 0.89), indicating that the equation found in this ongoing study can be used to reliably assess soil salinity.

Keywords: soil salinity, electrical conductivity, saturated soil paste, soil:water extracts

Block B

B1 Carbon sequestration and trade-offs

Session Description

Involved projects: INSURE, TRACE-SOILS, SOMMIT

Conveners: Felipe Bastida (CSIC), Miriam Gross (AGS), Cristina Aponte (CSIC), Eugenio Diaz-Pinés (BOKU), Tuula Larmola (LUKE)

The improvement of soil carbon (C) sequestration while reducing GHG emissions is a strategic target to mitigate climate change in agricultural lands. This can be pursued through a large range of management strategies, including minimizing soil disturbance, diversification of crop rotations, use of cover crops, incorporation of crop residues, addition of organic amendments, rewetting of organic soils, etc. Further, the increase of soil organic carbon stocks has a variety of co-benefits, beyond climate change mitigation, including improvement of soil health, fertility and water holding capacity. However, the environmental context, including biotic (biodiversity, microbial activity, crop type, etc.) and abiotic (soil physical and chemical properties, climate, etc.) factors can strongly shape the balance between C sequestration, CO2, N2O and CH4 fluxes, and N leaching. For instance, in cultivated peat soils warming is expected to intensify organic matter degradation and further reduce C-sequestration, while contributing to GHG release. In more arid environments, the application of organic amendments can improve carbon sequestration while impacting the GHG fluxes. In this session, we welcome contributions that give insights into how soil management influences C sequestration rates and non-CO2 GHG fluxes in agricultural lands. We welcome experimental, modelling or synthesis approaches addressing the causes and mechanisms of the observed trade-offs and/or synergies between GHG release and soil C sequestration. The session will be convened by scientists participating in projects within the European Joint Programme Cofund on Agricultural Soil Management.

A meta-analysis of field experiments on the effect of organic matter inputs on N_2O emissions in European arable land

Valkama Elena[1*], Tzemi Domna[2], Esparza-Robles Ulises Ramon[3], O'Toole Adam[4], Syp Alina[5]

[1] Natural Resources Institute Finland (Luke), Jokioinen, Finland

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

[3] University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

[4] Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway

[5] Institute of Soil Science and Plant Cultivation - State Research Institute (IUNG), Puławy, Poland

** Presenting author: elena.valkama@luke.fi*

Keywords: N_2O; field experiments, organic matter, arable land, meta-analysis

The focus of previous research regarding the effects of applying organic matter (OM) inputs on carbon sequestration has been mostly restricted to a simple quantification of soil organic carbon stock or CO_2 balance. However, all a more comprehensive assessment of net carbon balance should also consider non-CO_2 GHG sources and sinks across the soil-plant system. The objective of this study is to synthesize results from field experiments, which explore the effects of adding different OM inputs (crop residues, green manure, livestock manure, slurry, digestate, compost or biochar) to soil on N_2O emissions in Europe.

A comprehensive literature search was conducted using keywords in Web of Science, Agricola, Scopus, ScienceDirect, Google Scholar, and in the reference list of published reviews and meta-analyses. We included European experiments with diverse arable crops cultivated in monoculture or in crop rotations on mineral soils. Cumulative N_2O emissions were monitored in the fields that received either solely OM inputs or in combination with inorganic fertilization, and inorganic fertilization served as a control.

The entire database consists of over 50 independent studies, published in 46 peer-reviewed scientific articles between years 1993 and 2022, and in a PhD thesis and a project report. Nitrous oxide emissions were measured at each site over a period of one month to three years in 46 sites, in 15 European countries covering all European climate zones, from Alpine North to Mediterranean South. Annual rainfall and average annual temperature varied between 250 mm and 1300 mm, and between 4.5 °C and 19.6 °C, respectively. The impact of OM input in terms of quantity, nature, as well as quality was captured by C/N ratio (2.7 - 390) and amount of N (20 - 420 kg ha^{-1}). The list of potential moderators consists of soil physical and chemical properties, such as the percentage of soil organic C,

clay, silt, sand, soil texture, C/N ratio and pH for each site, and agricultural management practices, such as type and the amount of inorganic fertilization, tillage system, crop residue management and irrigation type.

The mean values of cumulative N_2O emissions for a duration, standard deviations, and sample sizes (equal to the number of replicates) for OM inputs and inorganic fertilization were extracted from tables and figures in articles. To perform a meta-analysis, logarithm response ratios as an index of effect size were calculated for each study, which were then be summarized across the studies by using weighing procedure.

For the entire database, the OM effect on N_2O emissions was highly variable, ranging from -75% to 330% compared to inorganic fertilization. A weighted summarized effect was -8%, however, statistically non-significant (95% CI -19% to 6%, n = 53). Among the different types of OM inputs, only biochar and compost significantly reduced N_2O emissions by 25-33 %, compared to inorganic fertilization. The largest risk for N_2O emission seems to be the application of slurry (23%, 95% CI -15% to 105%, n = 10), followed by digestate (16%, 95% CI -17% to 58%, n = 7).

The impact of pedo-climatic characteristics, agricultural management practices, the nature and quality of OM inputs on N_2O emissions will be also studied.

Analyzing the degree of organic matter transformation of rewetted European peatlands in the context of their greenhouse gas emission potential

Miriam Gross-Schmölders*, Jens Leifeld

Climate and Agriculture Group, Agroscope, Zurich, Switzerland
**Presenting author: Miriam.gross-schmoelders@agroscope.admin.ch*

Keyword: peatland, peat quality, transformation degree, biogeochemical indicators, greenhouse gas emissions, pyrolysis-GCMS

Peatlands are a vast and vulnerable carbon stock. Although they cover only 3% of the land area, globally the organic matter stored in peat accounts for 20% of soil carbon. In peat-rich countries, peat soils contribute much to the carbon dioxide (CO2) emissions from croplands and grasslands in the national greenhouse gas (GHG) budgets. This may seriously diminish any possible net carbon sink of the land use sector. Owing to their high emission reduction potential per area, cultivated peat soils are often considered as a very effective target for GHG mitigation measures in the agriculture and land use sector. This goal can be achieved by rewetting. Rewetting often comes with synergies such as water protection, as peat soils are also high sources of dissolved organic matter and nutrient efflux. In wet soil transformation is driven by anaerobic processes and the resulting methane emissions can be considered a tradeoff of CO2 savings by wet management. How groundwater table raise influences GHG emissions depends e.g. on peat properties, environmental conditions and site management. The goal of the EU project EJP Soil INSURE, to which our research project belongs, is to evaluate the significance of different factors regulating the GHG balance of wet cultivated peat soils at different European sites and to seek for indicators of successful GHG mitigation. We contribute to this goal by analyzing the organic matter of peat profiles. We study the molecular composition of the different peats using analytical pyrolysis GC-MS, in conjunction with organic matter stoichiometry. Our aim is to better understand the role of peat properties for the biogeochemical cycles in rewetted peatlands and their GHG balance. By using different classes of compounds, we were able to distinguish between transformed organic matter and peat that is relatively rich in undecomposed plant material. We identified marker compounds that were highly specific for fresh plants, transformed plant material or microbial abundance. For example, the abundance of undecomposed plants can be linked to levosugars, decomposed plant material is pictured by low weight polysaccharides such as 5-methyl-2-furalaldehyde and microbial matter is displayed by specific nitrogen compounds, as pyridines, pyrroles and indene's, such as 1H-indene, 3-methyl. In addition, we studied the correlation between peat stoichiometry, compound abundance and the degree of transformation. We find that for example a high C/N ratio is negatively correlated with a high amount of low weight polysaccharides and compounds indicative for microbial abundance. We conclude that our method gives a detailed insight of peat composition. Further, it enhances our knowledge of peat quality and could therefore help to gain insights into the dependency of GHG emissions on peat quality.

Greenhouse gas fluxes from a cultivated peatland, northern Norway–implications for climate friendly management

Zhao Junbin[1], Mastepanov Mikhail[2], Klutsch Cornelya[3]

[1]Department of Biogeochemistry and Soil Quality, Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Norway
[2]Department of Ecoscience - Arctic Ecosystem Ecology, Aarhus University, Denmark
[3]Department of Ecosystems in the Barents Region, Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Norway

** Presenting author: junbin.zhao@nibio.com*

Peatlands are ecosystems with great soil carbon (C) stocks, which represent one third of the global soil organic C pool. Due to the needs for human development, large areas of peatlands have been drained for, e.g., agricultural and forestry purposes. Drainage of peatlands significantly changes the ecosystem hydrology, which facilitates the release of stored C in the peat soil into the atmosphere and turns peatlands into hot spots for greenhouse gas (GHG) emissions. Various management practices have been implemented to use drained peatlands to enable biomass production while reducing GHG emissions, including restoration, cultivation, etc.. However, these mitigation measures are contentious and their effects on peatland GHG balance are largely unknown. We investigated productivity and GHG balance in response to peatland cultivation under different fertilization and hydrological scenarios and carried out an experiment on a drained peatland, under grass cultivation with 7-year rotation time in Svanhovd, northern Norway. GHG fluxes (CO_2, CH_4 and N_2O) were measured from 30 plots with 5 water levels and 2 fertilization levels (3 replicates each) at a sub-daily interval using automatic chambers during growing season 2022. Results indicate that sporadic N_2O emissions were related to fertilization and appeared higher with the more intense fertilization. CH_4 emissions were primarily affected by hydrological regimes, where high water level plots acted as sources for CH_4 and low water level plots as CH_4 neutral. On the other hand, higher water levels can constrain CO_2 emissions through heterotrophic respiration, turning the ecosystem from a source to a sink for CO_2. Our results quantify peatland GHG potentials after cultivation and have great implications for guiding peatland management in a climate friendly fashion in boreal regions.

Keywords: carbon dioxide, methane, nitrous dioxide, fertilization, water table

Assessing the Environmental and Productive Implications of Soil Management Strategies for Sustainable Agriculture: A Combined Process-Based Modelling and Fuzzy Logic-Based Index Approach

Roberta Calone[1], Joël Léonard[2], Fabien Ferchaud[2], Marco Acutis[3], Elena Valkama[4], Alessandra Lagomarsino[1], Simone Bregaglio[1]

1. CREA - Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, I-40128 Bologna, 50125 Firenze, Rome I-00184, Italy; roberta.calone@crea.gov.it; alessandra.lagomarsino@crea.gov.it; simoneugomaria.bregaglio@crea.gov.it;
2. BioEcoAgro Joint Research Unit, INRAE, Université de Liège, Université de Lille, Université de Picardie Jules Verne, 02000 Barenton-Bugny, France; joel.leonard@inrae.fr; fabien.ferchaud@inrae.fr;
3. Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy, University of Milan, 20122 Milan, Italy; marco.acutis@unimi.it;
4. Natural Resources Institute Finland (Luke), Bioeconomy and environment, Sustainability Science and Indicators. Tietotie 4, 31600 Jokioinen, Finland; elena.valkama@luke.fi;

Agriculture is a major contributor to anthropogenic greenhouse gas (GHG) emissions and one of the most vulnerable sectors to climate change. Meeting the sustainable development and food security objectives set in the UN 2030 Agenda requires adopting a Europe-wide policy approach to evaluate the impact of alternative soil management strategies (SMS) on nitrogen and carbon fluxes. The ∑ommit project, funded by the European Joint Programme SOIL, seeks to generate a robust indicator to identify the best SMS according to trade-offs and synergies between soil C sequestration, N_2O emissions, NO_3 leaching, and crop yield under variable pedo-environment conditions.

The IPCC guidelines for estimating GHG emissions from agriculture entail three tiers of increasing complexity. The Tier 1 and Tier 2 methods propose default equations and emission factors at increasing spatial resolution, leading to an independent estimate of C stock changes and N_2O emissions. Consequently, these tiers do not explicitly consider the complex interplay between soil C and N cycles and depend on general assumptions that impede the prediction of system responses under varying boundary conditions, leading to substantial uncertainty. In contrast, Tier 3 methods are the most accurate and precise, relying on process-based modelling and site-specific measurements, but their application is complex and not yet a standard.

This study applied two widely used agricultural systems models, STICS and ARMOSA, to simulate the target trade-off components. STICS simulations were compared with field experimental data from the ACBB Estrées-Mons long-term experiment, where different soil tillage options, residue managements, levels of nitrogen fertilisation and crop types are tested. ARMOSA simulations extended the evaluation to a rotation experiment performed on organic farming in Mikkeli (Finland), where virtual agronomic scenarios have been tested under current and future climate conditions. The simulated trade-off components for each case scenario (a combination of pedo-environmental conditions and management practices) were aggregated via a fuzzy logic model, whose aggregation rules can be customised according to the application context. The index ranges from 0 (bad) to 1 (good) and enables synthesising the interdependent variations within the trade-off components when transitioning from one case scenario to another, resulting in a highly sensitive measure that accurately captures changes in individual components. In addition, the aggregation procedure reduced the magnitude of the error in reproducing experimental data via simulation, leading to lower uncertainty in the composite index values compared to the individual trade-off components.

The two use cases highlighted several advantages for system evaluation with respect to estimating trade-off components from IPCC guidelines or field experiments. Indeed, the use of models has a tremendous potential to extend the index application to a wide range of in-silico experiments covering different options without the need for long-term, resource-intensive field experiments. Simulation models enable exploring continuous response curves of the input factors (e.g., N input, irrigation) affecting GHG emissions and crop yields under various pedo-environmental conditions, including future climate scenarios. This study proved that applying the ∑ommit index using model-based input data provides a time and resource-efficient method for policymakers to evaluate the environmental and productive implications of alternative land management options and make well-informed decisions for future agriculture policy actions.

Laboratory estimates obscure the patterns of GHG emissions from agricultural soils

Goberna Marta [1*], Juhanson Jaanis [2], Gómez-Gallego Tamara [3], Ros Mart [4], Feizene Dalia [5], Peixoto Leanne [6], Walder Florian [7], Jeanbille Mathilde [8], Dammie Nompumelelo [7], Aponte Cristina [1], Parasotas Irmantas [5], Kochiieru Mykola [5], Pulido-Moncada Mansonia [2], Amaleviciute-Volunge Kristina [5], Feiza Virginijus [5], Ramos Juan Luis [3], van der Heijden Marcel [7], Petersen Søren O. [6], Philippot Laurent [8], Munkholm Lars [6], Velthof Gerard [4], Hallin Sara [2] and Sánchez-Moreno Sara [1].

[1] *Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA-CSIC), Madrid, Spain*

[2] *Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden*

[3] *Estación Experimental del Zaidín (EEZ-CSIC), Granada, Spain*

[4] *Wageningen Enviromental Research, Wageningen University & Research, Wageningen, Netherlands*

[5] *Lietuvos Agrariniu Ir Misku Mokslu Centras (LAMMC), Akademija, Kedainiai, Lithuania*

[6] *Aarhus University, Aarhus, Denmark*

[7] *Agroscope, Zürich, Switzerland*

[8] *Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAe), Dijon, France*

** Presenting author: marta.goberna@inia.csic.es*

Agricultural management practices aimed at sequestering carbon (C) in soils show synergies with many agroecosystem services, but may come at the cost of increased greenhouse gas (GHG) emissions. We performed a systematic literature synthesis, followed by a meta-analysis and experimental measurements, to analyse whether C sequestration practices generate trade-offs in terms of CO_2 and N_2O emissions. We performed systematic literature searches in the Web of Science to look for articles published worldwide that experimentally assess the effect of: 1. minimising soil disturbance (reduced or no tillage), 2. diversifying agroecosystems (crop rotations, cover crops, intercropping), and/or 3. increasing organic matter inputs (crop residue retention, organic amendments) versus standard practices. We only included studies that quantified C sequestration and at least another response variable related to the synergies or trade-offs of C sequestration. We retrieved 771 publications, 537 of which were excluded based on the type of article, a focus on non-soil habitats, forests or organic soils, or experimental designs not matching our criteria. We included 234 studies that report 572 effects of sustainable practices on 228 sites located in 38 countries. Experiments averaged 10 years of monitoring and the majority reported effects of increasing organic matter inputs and minimising soil disturbance (88%) in temperate and continental climates (75%). Sustainable practices effectively sequestered more C than standard practices considering all studies together. In total, we detected 353 effects related to CO_2 and N_2O emissions, 51% of which were measured as field fluxes and 43% as laboratory fluxes. Taking both types of measurements, C sequestration increased GHG emissions, particularly CO_2. However, the response of CO_2 and N_2O

emissions (increase, neutral, decrease) of sustainable versus standard agricultural practices varied significantly depending on how emissions were measured (field or laboratory fluxes). This result was confirmed in a subsequent meta-analysis, including 71 articles that report 123 independent experiments: CO_2 and N_2O emissions increased significantly when using agricultural practices that sequester C, but the magnitude of this trade-off depended on the use of field or laboratory measurements. This pattern was remarkable for CO_2, where lab fluxes (N=48) yielded significantly larger responses than field fluxes (N=50). Finally, we quantified CO_2 emissions, both as field and laboratory fluxes, in a long-term (27 year) experiment in central Spain, comparing standard tillage (mouldboard plough 30 cm), reduced tillage (chisel plough, 15 cm) and no tillage (direct seeding). Field fluxes measured weekly for a month were significantly lower under no tillage compared to standard tillage, while laboratory fluxes under controlled conditions yielded the opposite result. Independent methodological approaches indicate that the use of laboratory fluxes, particularly to measure CO_2, might overestimate the magnitude of the trade-offs of C sequestration in terms of climate regulation services.

Keywords: agricultural management, carbon sequestration, carbon dioxide, greenhouse gas emissions, nitrous oxide

Carbon Farming Geolocation Support by Establishing a Spatial Soil Database Management System: LIFE GEOCARBON

Pascual Jose Antonio[1*], Ros Margarita[1] Triantakonstantis Dimitris[2] Bithas Kostas[3], Spyridon E. Detsikas[2], Petropoulos George P[4]., Calzolari Costanza[5], Vaccari Francesco P[5]., Guerrero Carlos[6], Panagopoulos Thomas[6]

[1]Centro de Edafología y BiologíaAplicada del Segura (CEBAS-CSIC), Campus Universitario de Espinardo - 25, 30100, Murcia, Spain

[2]Department of Soil Science of Athens, Institute of Soil and Water Resources, Hellenic Agricultural Organization HAO – DIMITRA, 1 S. Venizelou str., 14123, Lycovrisi, Attiki, Greece

[3] Institute of Urban Environment & Human Resources, Department of Economic and Regional Development, Panteion University, 14 Aristotelous St., 17671 Kallithea, Athens, Greece

[4]Department of Geography, Harokopio University of Athens, El. Venizelou 70, Kallithea, 71676, Athens, Greece

[5]Institute of BioEconomy, National Research Council (IBE CNR), Via Madonna del Piano, 10, 50019, Sesto Fiorentino (FI), Italy

[6]Universidade do Algarve, Faro, Portugal.

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

The development of a future Carbon Farming Information platform will incorporate relevant information related to monitoring, reporting, controlling, and verifying the existing and new payment solutions for maintaining or increasing environment health, that nowadays is related to the reduction of CO2 equivalent reduction. Subsidies will be linked to carbon farming, necessitating the development of operational methods for determining the farmer's carbon balance (European Parliament, 2021).

Agricultural soils globally become among some of the largest pools of carbon storage with possible potential for expansion of carbon sequestration (SC), and therefore provide a prospective way to mitigate increased CO2 concentration. It has been estimated that soils are capable of sequestering around 20 Pg in 25 years, that it is more than 10% of anthropogenic emissions. Improved agricultural practices can restore carbon sequestration by storing carbon in plant and soil biomass; fact that it contributes to reduce CO2 equivalent emissions from agriculture. However, the main gap when dealing with carbon balance from agriculture is the lack of activity data by farmers that it can only be precisely if it is provided by own farmers.

The GEOCARBON project will geo-locate a representative sample of the Mediterranean area farms (at the agricultural parcel level) and provide simulations of alternative management practices under different environmental policy scenarios. GEOCARBON crowdsourcing application will be developed under the canopy of a Community of Practice (CoP) strategy, with farmers serving as the primary nodes of the CoP network.

The first results reported in https://www.lifegeocarbon.eu collect and organize pre-existing available sources of soil and agriculture management practices databases, using contemporary Geographic Information System (GIS) web-based tools and that have been updated and harmonized. The Activity Data which have already existed in the above soil datasets are going to be enriched by the contribution of farmers obtained through a survey for farmers about soil managements, fertilization type of crops, place etc. Different workshops and conferences have been developed to bring the CoP together to learn from one another, and to have feedback of the end-users for future enhancements and modifications of the recommended tools.

Contribution of different cover crop species to soil organic matter fractions and N_2O emissions under Norwegian cereal production

Rittl, T. F.[1]; Bárcena, T. G.[2]; Farkas, E.[3]; Henriksen, T. M.[4]; Kjær, S. T.[5]; Dörsch, P.[5] and Frøseth, R. B.[4]

[1] Norwegian Centre for Organic Agriculture (NORSØK), Tingvoll, Norway
[2] Norwegian Institute of Bioeconomy Research (NIBIO), Department of Agricultural Soil Survey, NO-1431 Ås, Norway
[3]Norwegian Institute of Bioeconomy Research (NIBIO), Department of Biogeochemistry and Soil Quality, NO-1431 Ås, Norway[4]Norwegian Institute of Bioeconomy Research (NIBIO), [4]Department of Grain and Forage Seed Agronomy, NO-1431 Ås, Norway
[5]Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Resource Management, NO-1434 Ås, Norway

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

In Norway, cover crops were introduced to prevent loss of nitrogen and phosphorous from fields to waterways. Today, cover crops are also used to restore soil organic matter and improve soil health. Yet, the direction and magnitude of these effects are variable, and little is known about the persistence of the C derived from the cover crops in the soil. In the CAPTURE project, we evaluated the soil C sequestration potential from different cover crops used in the main cereal production areas in Norway. To do so, we used pulse labelling with ^{13}C (CO_2) to label four different cover crop species Italian ryegrass, phacelia, oilseed radish and summer vetch through their growing period. Cover crops were grown in a monoculture to enable the labelling. The results of the first year of the experiment show that cover crops produced 10- 14 Mg ha^{-1} above ground biomass, corresponding to 4-6 Mg C ha^{-1}. At the end of the growing season, 3-5% of cover crop C was found in the soil particulate organic matter (POM) fraction and 2-4% in the soil mineral organic matter fraction (MAOM). In the following years, the fate of C derived from the cover crops in the soil will be determined. Furthermore, the soil C sequestration of the different cover crops will be scaled to barley plots in the same experiment, to which cover crops had been undersown in spring or summer. In these plots, N_2O emissions have been measured through the whole year. The greenhouse gas trade-offs of cover crops in Norwegian cereal production will be estimated.

Keywords: ^{13}C pulse labelling, particulate organic matter, mineral associated organic matter, freeze-thaw.

TRUESOIL Project: reduced tillage effects on soil organic matter and greenhouse gas emissions under ambient and reduced rain conditions

Apostolakis Antonios[1*], Englert Paulina[1] and Meijide Ana[1]

[1] *Department of Crop Sciences, Division Agronomy, University of Göttingen, Göttingen, Germany*

** Presenting author: antonios.apostolakis@uni-goettingen.de*

The EJP-SOIL project TRUESOIL (2022-2025) studies trade-offs between different management practices aiming at sequestering soil organic carbon and greenhouse gas emissions, to determine the true climate mitigation potential of these management practices across crops, soil properties and climates. Reduced tillage is a widely applied practice often found to increase organic carbon sequestration in the topsoil. However, it is unclear how reduced tillage and the associated organic matter might affect greenhouse gas emissions, especially under a changing climate. Within the German subproject of TRUESOIL, we took advantage of a long-term trial comparing conventional and reduced tillage in central Germany. We combined this trial with a drought-simulation leading to a two-factor experiment. We monitored soil greenhouse gas emissions and soil chemical properties following a tight schedule with emphasis on fertilization and management events. In our field trial, the reduced tillage practice started in 1970 and it is located in an experimental field with Luvisol soils near Göttingen. It has 16 plots, eight under conventional tillage where tillage is performed until 30 cm and eight under reduced tillage with harrowing down to 10 cm. In February 2023, we installed rainout shelters (area =2 m × 2 m) designed to intercept 50% of the precipitation in half of the plots, while the rest remained under ambient rain conditions. At the same time, we started measuring soil CO_2 efflux and N_2O fluxes with static chambers and portable gas analysers at least three times per week following fertilization events and at least once per week otherwise. Soil nitrate, ammonium and dissolved organic carbon were measured at least weekly in the plots under ambient rain and more sparsely in the reduced rain plots due to space limitation under the shelters. In selected samples, we analysed the operational carbon pools of particulate and mineral-associated organic matter. Soil water content and temperature were recorded with a time-domain reflectometer sensor. Based on preliminary data, we found higher particulate and slightly higher mineral-associated organic matter in the topsoil under reduced than conventionally tilled plots. Plots under reduced tillage had higher soil water content than under conventional tillage. Rainfall exclusion led to slightly lower soil water contents but, presumably, the observational period was not long enough to yield significant differences. Similarly, under the wet, cold and unfertilized conditions of the first sampling events, we found no differences in soil CO_2 and N_2O emissions between tillage practices and rainfall conditions. Different results are expected later in spring due to warmer conditions and nitrogen fertilization. Within the frame of

TRUESOIL, we will monitor greenhouse gas emissions and soil organic matter pools under conventional and reduced tillage and under current and reduced rainfall for two successive years from February 2023. In the EJP-SOIL Annual Science Day 2023, we will present our existing data and updated results until the time of the meeting.

Keywords: soil carbon sequestration; greenhouse gases; agroecological practices; reduced tillage; drought

Climate smart solution for growing medium production based on paludiculture

Larmola Tuula[1*], Saarnio Sanna[2], Miettinen Antti[2], Karvonen Jaakko[3], Näkkilä Juha[4], Turunen Aimo[5] Lång Kristiina[6]

[1] *Natural Resources Institute Finland, Helsinki, Finland*

[2] *Natural Resources Institute Finland, Joensuu, Finland*

[3] *Finnish Environment Centre, Joensuu, Finland*

[4] *Natural Resources Institute Finland, Turku, Finland*

[5] *Kiteen Mato ja Multa Oy, Kitee, Finland*

[6] *Natural Resources Institute Finland, Jokioinen, Finland*

** Presenting author: tuula.larmola@luke.fi*

We examine the benefits and trade-offs of rewetting cultivated peat soils in the first field-scale paludiculture experiment in Finland. Our aim is to quantify greenhouse gas mitigation potential and water impacts of rewetting as well as to evaluate the economic effects in the production chain of peat substituting growing medium based on paludiculture and compare them to those of peat-based medium. The renewable growing medium produced from common reed and reed canary grass may provide a solution for reducing greenhouse gas emissions from both agriculture and peat production and for improving the ecological status of water bodies. This is because 1) perennial plants will be cultivated in greater proportion in peat fields, 2) groundwater levels can be raised in peat fields, 3) peat mining area will be reduced as the renewable growing media becomes more common, 4) biomass of common reed will be harvested from water courses. The project is carried out together with the farmers, growing media refiners and the greenhouse enterprises. In addition to environmental and economic impacts, we will assess the current problems in harvesting and transporting the plant material. This will help to resolve the bottlenecks in the production chain of a renewable growing medium and make profitable paludiculture possible for an increasing number of farmers and promote Finland's goal for carbon neutrality. The study is a part of Catch the Carbon Programme funded by Finnish Ministry of Agriculture and Forestry.

Keywords: reed canary grass, methane, carbon dioxide, nitrous oxide, peat

Long-term management for carbon sequestration in European croplands and its legacy effect on greenhouse gas fluxes

Ulises Ramon Esparza-Robles[1*], Eugenio Díaz-Pinés[1] and Alessandra Lagomarsino[2]

[1] *Institute of Soil Research, University of Natural Resources and Life Sciences, Vienna, Austria*

[2] *Centre of Agriculture and Environment, Council for Agricultural Research and Economics, Florence, Italy*

** Presenting author: ulises.esparza-robles@boku.ac.at*

In the frame of climate change mitigation, the effect of agricultural practices on soil organic carbon (SOC) stocks has been widely studied in different pedoclimatic conditions across Europe. Practices that have been identified as generally having a positive effect on SOC stocks include those increasing carbon inputs to the soil via external organic matter or via incorporation of crop residues. These practices also modify the soil N2O and CH4 fluxes; this is highly relevant for estimating the overall effect of management strategies on the soil greenhouse gas (GHG) balance, but so far, this aspect has not been assessed comprehensively. In this work, we make use of long-term experiments covering a large range of soil and environmental conditions in European countries. Further, the experiments were selected based on the management practices under investigation (addition of organic matter, crop residue management) and access to data on SOC stock changes as affected by management. Undisturbed soil samples were investigated for non-CO2 fluxes under controlled conditions. As research within the scope of global change, soils underwent a drying-and-rewetting cycle to study the soil response to extreme events in relation to the organic matter inputs and substrate availability. Our lab data provide relevant information on soil non-CO2 fluxes, which will be integrated with SOC stock change data, field GHG flux data and ancillary soil information. Overall, we will increase our understanding of soil processes towards identifying and promoting win-win scenarios between greenhouse gas fluxes and soil carbon storage in European croplands. Further steps include the comparison of enzymatic activity, DNA-sequencing and PLFA data to increase our understanding about microbial processes involved in the interaction of agricultural management and pedoclimatic conditions.

Keywords: nitrous oxide, methane, undisturbed soil cores, dynamic flow chambers, microbial biomass.

Towards an improved understanding of soil borne greenhouse gas and ammonia emissions in Flanders

Maenhout Peter[1*] **and Ruysschaert Greet** [1]

[1] *Flanders research institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium*

** Peter Maenhout: peter.maenhout@ilvo.vlaanderen.be*

The stimulation of soil organic carbon (SOC) sequestration and preservation of existing SOC stocks are important climate change mitigation strategies. However, soil management strategies applied to achieve this mitigation may induce the emission of non-CO_2 greenhouse gases (GHG) and negatively affect the climate change mitigation potential. Furthermore, the application of organic matter (OM) may also stimulate the emission of ammonia (NH_3) which can negatively affect biodiversity through atmospheric deposition.

Despite the strong potential effects of these greenhouse gas and ammonia emissions, detailed information to allow for an accurate emission inventory is missing in Flanders. The complex experimental set-ups and labour intensive character often create a barrier to initiate field trials. However, dedicated field experiments may strongly improve our understanding of the impact of specific soil management strategies on these emissions. Therefore, in a recent field experiment the effect of rewetting agricultural soils on the methane (CH_4) and carbon dioxide (CO_2) emissions was investigated. For this, a selection of three locations characterised by varying soil drainage classes were selected. Despite a strong local variation in CH_4 emissions that complicates the evaluation of the first results, the experiment allows for a unique insight in the effects of rewetting soils in Flanders.

Furthermore, field experiments that aim to investigate the potential trade-offs of soil carbon sequestration would provide Flanders with unique data that allow to improve both advice on carbon farming towards farmers and improve regional assessment of GHG emissions. Therefore, a field experiment evaluating the impact of compost application on the emission of GHG will be initiated in Flanders. However, for OM sources characterized by high mineral N contents also the impact on the emission of ammonia requires more in depth research to allow for a better estimation of source specific emissions.

Keywords: Greenhouse gas emissions; ammonia emissions, field trials, rewetting

Soil organic carbon under conservation agriculture in Mediterranean and humid subtropical climate: global meta-analysis

Tadiello Tommaso[1], Acutis Marco[1*], Perego Alessia[1], Schillaci Calogero[2], Valkama Elena[3]

[1]*University of Milan, Milan, Italy*

[2]*European Commission, Joint Research Centre (JRC), Ispra, Italy*

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

** Presenting author: marco.acutis@unimi.it*

Keywords: soil organic carbon; conservation agriculture; meta-analysis

Conservation agriculture (CA) is an agronomic system based on minimum soil disturbance (no-tillage, NT), permanent soil cover, and species diversification. The effects of NT on soil organic carbon (SOC) changes have been widely studied, showing somewhat inconsistent conclusions, especially in relation to the Mediterranean and humid subtropical climates. These areas are highly vulnerable and predicted climate change is expected to accentuate desertification and, for these reasons, there is a need for clear agricultural guidelines to preserve or increment SOC.

We quantitively summarized the results of 47 studies all around the world in these climates investigating the sources of variation in SOC responses to CA, such as soil characteristics, agricultural management, climate, and geography. All the screening process followed the PRISMA checklists (Page et al., 2021) for evaluating research synthesis in systematic reviews and meta-analysis. We found the articles by searching for keywords with a nested query in Web of Science and Scopus databases. Studies were located in North America (n = 19), South America (n = 9), Europe (n = 10), Asia (n = 8), and Africa (n = 1) between 23° and 36° S and 19° to 45°N of latitude. Entire database for meta-analysis is available in Zenodo (Database 1 https://zenodo.org/record/7404592).

Within the climatic area considered, the overall effect of CA on SOC accumulation in the plough layer (0–0.3 m) was 12% greater in comparison to conventional agriculture. On average, this result corresponds to a carbon increase of 0.48 Mg C ha^{-1} $year^{-1}$. However, the effect was variable depending on the SOC content under conventional agriculture: it was 20% in soils which had ≤ 40 Mg C ha^{-1}, while it was only 7% in soils that had > 40 Mg C ha^{-1}. We proved that 10 years of CA impact the most on soil with SOC ≤ 40 Mg C ha^{-1}. For soils with less than 40 Mg C ha^{-1}, increasing the proportion of crops with bigger residue biomasses in a CA rotation was a solution to increase SOC. The effect of CA on SOC depended on clay content only in soils with more than 40 Mg C ha^{-1} and become null with a SOC/clay index of 3.2. Annual rainfall (that ranged between 331–1850 mm y^{-1}) and geography had specific effects on SOC depending on its content under conventional agriculture.

In conclusion, SOC increments due to CA application can be achieved especially in agricultural soils with less than 40 Mg C ha^{-1} and located in the middle latitudes or in the dry conditions of Mediterranean and humid subtropical climates.

Drivers for carbon emissions and management alternatives on a poorly drained fen peatland

Rodriguez Andres F.[1*]**, Pullens Johannes W.M.** [1] **and Lærke Poul E.**[1]

[1] *Department of Agroecology, Aarhus University, Foulum, Denmark*

** Presenting author: afrodriguez@agro.au.dk*

Despite occupying a small global area, peatlands store approximately 21% of the global soil C stock. Due to their high organic matter and nutrient content, these organic soils have been drained mostly for agriculture making them greenhouse gas (GHG) sources. Rewetting drained organic soils is an effective way to reduce GHG emissions and attain the goals of net zero emissions by 2050. Peatland drainage in Denmark has taken place since the mid-19th Century and rewetting of these soils is part of current national strategies to reduce GHG emissions as well as pollution from excess nutrient leaching into rivers and streams. The purpose of this study is to determine whether management (combined harvest N fertilizer treatments) of reed canary grass (*Phalaris arudinacea* L.) established on a poorly drained fen peatland influence CO_2 and CH_4 emissions, and to study potential relations with soil and water chemistry. The experimental design included four plots divided into three subplots each. Subplots corresponded to harvest treatments (0, 2, and 5-cut per year) where 0-cut was unfertilised while 2-cut and 5-cut were fertilised with 200 kg N ha^{-1} y^{-1} in equal split doses for each cut. The CO_2 and CH_4 measurements were conducted biweekly between May 1st 2021 and April 30th 2022 using a transparent manual chamber connected to a GLA131-GGA Los Gatos gas analyser. Nutrient concentrations (NO_3-N, NH_4-N, total N, total dissolved N, total P, total dissolved P, total organic C, dissolved organic C, and Fe) were measured in water samples collected from piezometers installed close to each collar used for GHG measurements. Auxiliary measurements (water table depth (WTD), ratio vegetation index (RVI), vegetation height, soil and air temperature, photosynthetically active radiation, and redox potential) were taken on each campaign or continually to be used in gap filling models to obtain annual estimates of ecosystem respiration, gross primary productivity, and net ecosystem exchange (NEE). Preliminary results indicate that average WTD was -18 cm during the growing season (April 1st to September 30th) and -4 cm during the winter season (October 1st to March 31st). Results showed that NEE ranged between 5 ± 11 to 22 ± 9 Mg CO_2 ha^{-1} yr^{-1} (mean ± SD) with 5-cut as the lowest source and 0-cut as the largest source of CO_2 emissions. Annual biomass yields were 8.9 ± 2.7 Mg ha^{-1} and 8.6 ± 0.9 Mg ha^{-1} (mean ± SD) for the 2-cut and 5-cut, respectively. Potential trade off from increased CH_4 emissions appeared largest during the summer reaching average fluxes of up to 6 mg CH_4 m^{-2} hr^{-1} and lowest during winter. Nutrient concentrations in water showed highest concentrations under higher WTD and significant differences between the studied plots. Improving

the gap filling models by the use WTD and RVI data is ongoing. Findings from this study will provide insights on drivers for GHG emissions on rather wet agricultural peatland and the impact of new management alternatives to drained agricultural peatlands.

Keywords: fen peatland, greenhouse gas emissions, peatland management

Effects of different tillage regimes on soil structural characteristics along a pedoclimatic gradient

ten Damme, L.[1*], Bragazza, L.[2], Feiziene, D.[3], Goberna, M.[4], Hallin, S.[5], Ros, M.[6], Pulido-Moncada, M.[1,7], Sánchez-Moreno, S.[4], Philippot, L.[8], Munkholm, L.J.[1]

[1] *Aarhus University, Foulum, Denmark*
[2] *Agroscope, Zurich, Zwitserland*
[3] *Lithuanian Research Centre for Agriculture and Forestry, Kedainiai Distr., Lithuania*
[4] *Instituto Nacional de Investigací́on y Tecnología Agraria y Alimentaria (INIA-CSIC), Madrid, Spain*
[5] *Swedish University of Agricultural Sciences, Uppsala, Sweden*
[6] *Wageningen University and Research, Wageningen, the Netherlands*
[7] *University of Padova, Legnaro, Padova, Italy*
[8] *Université Bourgogne Franche-Comté, INRAE, Dijon, France*

** Presenting author: Loraine ten Damme ltd@agro.au.dk*

Intensive tillage regimes may cause detrimental effects on soil pore characteristics and structural stability. Conservation tillage has been suggested as an effective measure to avoid such adverse effects as well as to increase soil organic matter in soil surface layers. However, the accumulation of soil organic matter may also promote nitrous oxide emissions and nutrient losses through strong links between the carbon and nitrogen cycles. The TRACE-Soils project aims to identify mechanisms underpinning trade-offs and synergies of soil carbon sequestration, greenhouse gas emissions and nutrient losses in agricultural soils across Europe.

Soil structure is a driving factor in the transport of water and gas through soil, and influences, among others, the prevalence of oxic and anoxic soil processes. While it is common knowledge that soil structure is highly responsive to soil management practices, knowledge on the effects of different tillage strategies on soil structure in relation to trade-offs and synergies of soil carbon sequestration is still lacking. We conducted a range of laboratory measurements on intact soil cores (100-cm^3) taken from seven long-term agricultural experiments (12 years or longer) with a common experimental set-up located along a pedoclimatic gradient in Europe.

We measured oxygen diffusivity and air permeability at -100 hPa matric potential and deducted air-filled and water-filled pore space at -100, -60 and -30 hPa matric potential as well as dry bulk density from balance-measurements. The soil samples were taken from two depths – 0–0.1 m and 0.1–0.2 m – after harvest, prior to any further field operations. We tested for differences ($p < .05$) in tillage regime (inversion tillage, reduced tillage, no tillage), depth and their interaction across the long-term experiments, as well as for confounded location-effects.

Location and soil depth generally had the strongest effect on the assessed soil characteristics, while the effect of tillage practice and the interaction between tillage and depth often was much smaller or not significant. The effect of tillage practice was pronounced but generally interacted with depth. For instance, a higher water-filled pore space at -100 hPa was found for no tillage (63%) compared to inversion tillage (58%) at 0–0.1 m depth (across locations). The effect of depth and/or treatment could not be generalised to all individual long-term experiments assessed. We observed strong interaction effects between depth and experimental location. Moreover, we observed an interaction between tillage practice and experimental location on pore conductivity characteristics, except for oxygen diffusivity.

These results show that the effects of location and sampling depth generally overshadowed the long-term effect of tillage on soil structural characteristics in the topsoil when soil was sampled after the growing season. Stronger effects of tillage may have occurred if samples had been taken closer to the time of tillage.

Keywords: long-term agricultural experiments; soil tillage management; soil structure; TRACE-Soils

Soil management effects on soil organic matter properties and carbon sequestration (SOMPACS)

Weber Jerzy[1*], Leinweber Peter[2], Kuzyakov Yakov[3], Hewelke Edyta[4], Frąc Magdalena[5], Hayes Michael[6], Boguzas Vaclovas[7], Mielnik Lilla[8], Leahy James J.[6], Norton Urszula[9], Gregory Andy[10], Jerzykiewicz Maria[11], Spaccini Riccardo[12], Stępień Wojciech[4], Di Meo Vincenzo[12]

[1]*Wroclaw University of Environmental and Life Sciences, Poland (jerzyweber@gmail.com)*
[2]*University of Rostock, Germany (peter.leinweber@uni-rostock.de)*
[3]*University of Goettingen, Germany (kuzyakov@gwdg.de)*
[4]*Warsaw University of Life Sciences (SGGW), Poland (edyta_hewelke@sggw.edu.pl; Wojciech_stepien@sggwedu.pl)*
[5]*Institute of Agrophysics, Polish Academy of Sciences, Lublin (m.frac@ipan.lublin.pl)*
[6]*University of Limerick, Ireland (michael.h.hayes@ul.ie; j.j.leahy@ul.ie)*
[7]*Vytautas Magnus University, Agricultural Academy, Kaunas, Lithuania (vaclovas.boguzas@vdu.lt)*
[8]*West Pomeranian University of Technology in Szczecin, Poland (lilla.mielnik@zut.edu.pl)*
[9]*University of Wyoming, Laramie, USA (unorton@uwyo.edu)*
[10]*Rothamsted Research, Harpenden, UK (andy.gregory@rothamsted.ac.uk)*
[11]*University of Wroclaw, Poland (maria.jerzykiewicz@chem.uni.wroc.pl)*
[12]*University of Naples, Italy (riccardo.spaccini@unina.it; vincenzo.dimeo@unina.it)*

**Presenting author: Jerzy Weber* jerzyweber@gmail.com

SOMPACS is a project recommended by EJP SOIL for funding under the 1st External Call "Towards Healthy, Resilient and Sustainable Agricultural Soils". The goal of this project is to assess management practices that enrich organic matter pools that are resilient to rapid microbial decomposition. The project started in 2022 as a consortium of 12 research institutions from Poland, Germany, Ireland, Lithuania, UK, Italy and USA for a period of three years.

Soil and vegetation samples from eight long-term experiments that differ in soil management practices (i.e. conventional vs. no-tillage; mineral vs. organic fertilization; with and without catch crop; and arable land vs. undisturbed grassland) are investigated. Study sites include: 22- and 54-year long experiments in Lithuania; 26-year long experiment in Italy; 30- and 40-year long experiments in Ireland; 30- and 46- and 100-year long experiments in Poland; and 178-year long Broadbalk experiment in Great Britain. Additional experimentation includes assessing the impact of root growth promoting amendments (commercially available humic substances, biochar and biogas digestate) on stable organic matter pools. In parallel with soil sampling, plant productivity are measured in all field experiments. This investigation is couples fields studies with small-scale experimental plots and laboratory incubations under controlled conditions. In addition to assessing basic soil properties, the following state-of-the-art analyses are conducted: (1) SOM composition and stability by Py-GC-MS; (2) fractionation of aggregate size classes and C pools of increasing physicochemical protection; (3) isotopic analysis of δ13C and δ15N performed on different SOM pools; (4) microbiological properties (community-level physiological profiling, selected functional genes involved in C and N cycles, microbiome and mycobiome analyses by next-generation sequencing, genetic diversity using terminal restriction fragment length polymorphism); (5) enzymatic activity; (6) soil water retention and soil water repellency; (7)mineral composition of clay fraction; (8) soil structure stability. The most resistant SOM pool (humin) are isolated by different methods (isolation vs. extraction) and examined for chemical composition and structure, using spectrometric and spectroscopic techniques (mass spectrometry, NMR, FTIR, EPR, UV-Vis-NIR, fluorescence). The carbon stocks in the soil profile will be evaluated and the carbon extractable in cold water will be determined to assess the potential carbon leaching and microbial availability. Additionally, in-field soil carbon dioxide (CO_2) fluxes from selected experiments is monitored.

Thus far, soil samples (0-100 cm depth) were collected and the humin fraction from surface A horizon was isolated for spectroscopic studies. Crop yield and vegetation productivity was also assessed.

Keywords:; soil management; soil properties; soil organic matter fractionation; humin spectroscopic properties; carbon sequestration.

Crop residue management and N2O emissions: a 12-year experiment on arable cropping systems in northern France

Belleville Paul1*, Keuper Frida1, Bornet Frédéric1, Duval Jérôme1, Ferchaud Fabien1, Gréhan Eric1, Mary Bruno1, Vitte Guillaume1, Heinesch Bernard1,2, Dumont Benjamin1,3 and Léonard Joël1

1 BioEcoAgro Joint Research Unit, INRAE, Université de Liège, Université de Lille, Université de Picardie Jules Verne,02000, Barenton-Bugny, France

2 Liege University, Gembloux Agro-Bio Tech, AgroBioChem/TERRA, Biosystems Dynamics and Exchanges(BIODYNE), Passage des Deportes, 2, 5030, Gembloux, Belgium

3 Liege University, Gembloux Agro-Bio Tech, AgroBioChem/TERRA, Crop Science Unit, Passage des Deportes, 2,5030, Gembloux, Belgium

* Presenting author: paul.belleville@inrae.fr

Carbon storage in agricultural soils might help to reduce our current excess atmospheric carbon while simultaneously improving soil quality1. Attempts at increasing soil carbon often involve residue restitution, i.e. the return of organic matter to the soil after harvest of a cash-crop or destruction of a cover-crop. This practice might, however, lead to greater nitrous oxide (N2O) emissions2. N2O is the single greatest ozone-depleting substance4 and a greenhouse gas with a 273 times stronger global warming potential than carbon dioxide3. Understanding this trade-off is relevant when assessing the mitigation potential of carbon storage in agricultural soils. Residue management affects residue quantity, quality (C:N ratio, particle size) as well as the timing and depth of residue incorporation in the soil. All of these factors might impact on the biotic and abiotic redox reactions that lead to N2O emissions. Recent meta-analysis shows that immature residues (e.g.cover crops) stimulate N2O emissions while mature residues (e.g. straw) only have marginal effects 5,6.Further, lower N2O emissions seem to be obtained with shallow incorporation and residue C:N ratios above 30 7. Overall, however, meta-analysis shows high-unexplained variability and stresses that, little long-term data on interactions between residue management and other agricultural practices, exist. To assess the long-term impact of crop residue management on N2O emissions we use a 12-yeardataset from an ongoing experiment in Estrées-Mons (northern France). Since 2011, automatic-chambers have been used for daily N2O measurements. Eight experimental treatments reflect a range of management practices representative for regional cropping systems. They include differences in practices such as tillage (conventional, reduced), nitrogen input (rate, origin), pesticide application(organic, conventional) and residue management (quantity, quality, restitution depth). Crop successions include spring and winter cereals, rapeseed, spring pea and covercrops. Cash crop residues are either exported or incorporated into the soil by superficial tillage and/or ploughing, covercrop residues are always incorporated. The carbon to nitrogen ratio of residues varies between 11 and 83. Over the monitored period, a wide range of weather conditions was observed. The N2O fluxes are integrated over time periods defined from one residue return event to the next (length ranging from 108 to 363 days, N = 171). We associate 40 explanatory variables with each of these units (e.g. climate,soil moisture and temperature, residue quality, carbon and nitrogen availability). We use Random Forest Analysis, a machine learning tool able to deal with complex relationships, thresholds, non-linearity and the presence of optima, to analyse the driving factors of N2O emissions and to identifyand weigh the role of the different crop residue management factors.

Preliminary results indicate that long-term cumulative N2O emissions are best predicted by the amount of nitrogen input and precipitation, but that large uncertainty exists. Further, for our site-specific pedo-climatic conditions and agricultural management practices, the quantity and quality of restituted residues appears to have a significant but much smaller effect. Overall, our data suggest little risk of elevated N2O emissions offsetting the benefits of residue restitution as a means of stimulating soil carbon inputs.

Keywords: climate change; N2O emissions, residue restitution, trade-off, machine learning

1. Pellerin, S. et al. Stocker du carbone dans les sols français. Quel potentiel au regard de l'objectif 4 pour 1 000 et à quel coût ? (éditions Quae, 2021). doi:10.35690/978-2-7592-3149-2.

2. Guenet, B. et al. Can N2O emissions offset the benefits from soil organic carbon storage? Glob. Change Biol. 27, 237–256 (2021).

3. Forster, P. et al. The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Masson-Delmotte, V. et al.) 923–1054 (Cambridge University Press, 2021).

4. Ravishankara, A. R., Daniel, J. S. & Portmann, R. W. Nitrous Oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century. Science 326, 123–125 (2009).

5. Abalos, D. et al. Predicting field N2O emissions from crop residues based on their biochemicalcomposition: A meta-analytical approach. Sci. Total Environ. 812, 152532 (2022).

6. Lashermes, G. et al. N2O emissions from decomposing crop residues are strongly linked to theirinitial soluble fraction and early C mineralization. Sci. Total Environ. 806, 150883 (2022).

7. Abalos, D. et al. A review and meta-analysis of mitigation measures for nitrous oxide emissions fromcrop residues. Sci. Total Environ. 828, 154388 (2022).

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.

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.

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 ($p \le 0.05$ 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

B3 Indicators for soil ecosystem services

Session Description

Involved projects: SERENA, MINOTAUR, ARTEMIS

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

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

Soil Biological Quality index effectiveness at different reference scale

Ungaro Fabrizio[1], Maienza Anita[1], Lorenzetti Romina*[1], and Calzolari Costanza[1]

[1] *CNR - National Research Council of Italy, Institute of BioEconomy, Florence, Italy*

** Presenting author: romina.lorenzetti@ibe.cnr.it*

The Soil Biological Quality index (QBS-ar) is a method associating the mesofauna community diversity to the degree of adaptation to edaphic life. So far, most applications of the QBS-ar index are aimed at assessing soil quality at farm or local scale in relation to different crop management practices, or different level of disturbance from natural soils to urban soils. In more than 20 years of application, the QBS-ar index resulted a user-friendly, rapid and low-cost method sensible to catch soil quality changes even in the short-term. In the framework of EJP Soil, and in particular within the MINOTAUR project, the index is investigated as a possible mesofauna biodiversity indicator to be estimated/predicted in modelling and mapping. However, for spatial modelling of QBS-ar knowledge gaps must be filled in order to improve our knowledge about the main environmental drivers behind QBS-ar, and how they could change at the different reference scales.

This contribution presents the results of different studies undertaken at different scales in the Emilia Romagna Region (N Italy). At a local scale, the trend of the QBS-ar index as affected by different levels of disturbance has been analysed, showing a significant negative correlation with anthropic pressure and vegetation degradation status, and a good correspondence with soil biological parameters. At regional scale, a tentative DSM approach was used to infer the QBS-ar index spatial distribution. Machine learning algorithms were used which highlighted the relevance of vegetation spectral indexes from remote sensing as predictors of QBS-ar, providing a provisional map which could represent a basis for validating hypothesis on the mechanisms driving biodiversity indicator patterns at regional scale.

Keywords: QBS; soil biodiversity; biodiversity environmental drivers; spatial modelling; machine learning

How to use soil threats bundles to assess the effects of climate change and land use changes at EU scale

Coblinski João[1*], Reyes-Rojas Jessica[2], Pindral Sylwia[3], Antón Rodrigo[1], Cousin Isabelle[1], Boruvka Lubos[2], Piccini Chiara[5], Saby Nicolas[1] and Cornu Sophie[6]

[1]*INRAE, Info&Soils, 45075 Orléans, France*

[2]*Department of Soil Science and Soil Protection, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, 16500 Prague-Suchdol, Czech Republic*

[3]*IUNG-PIB, Czartoryskich 8, 24-100 Puławy, Poland*

[5]*Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, via della Navicella 2–4, 00184 Rome, Italy*

[6]*Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France*

** Presenting author: Email address presenting author*

The identification and assessment of bundles of both soil-based ecosystem services and soil threats (ST) represent a key point in soil health monitoring, where the definition of reference thresholds constitutes the major challenge. In particular, ST bundles assessment may allow to evaluate the effects of multiple stressors on soil multifunctionality. The objective of this work is to evaluate the effects of different scenarios, such as climate change and land use changes, on the evolution of ST bundles at European scale. To achieve this objective, we propose the assessment of a ST bundle consisting of soil erosion and soil organic carbon (SOC) losses, drivers of soil degradation, under different future scenarios that consider plausible climate and land use changes.

In this work we evaluated the two individuals ST using the following indicators: potential of soil losses by water erosion and SOC losses. The revised universal loss equation (RUSLE) was used to estimate the potential soil losses due to water erosion as RUSLE is able to process large-scale input data. This equation considers 5 factors: cover management factor, support practice factor, slope length factor and slope steepness, soil erodibility factor and rainfall-runoff erosivity factor. To assess SOC losses, a digital soil mapping approach using Quantile Regression Forests (QRF) was used. SOC content data were extracted from current date SoilGrids predictions to project to 2050. To fit the DSM model, SOC content was extracted across a grid of points 100 km apart for calibration of the projection model for SOC, totaling about 40,000 observations. Climate change and land use scenarios projected to the year 2050 were used. For climate change data an average composite of 3 Global Climate Models (GCMs) from the WorldClim dataset of Inter-comparison Model Projects Coupled (CMIP6) into two Shared Socio-economic Pathways (SSPs) was used: 126 and 585. Concerning to land use change, we use the projections provided by the LUISA (Land Use-based Integrated Sustainability Assessment) modeling platform. ST bundles were finally assessed using clustering approaches including k-means and model-based algorithms.

In this research, we discuss the different steps of the soil threats mapping approach. We present the method of spatial distribution of bundles as a possible solution to indicate the co-occurrence of soil threats that can reduce the cultivated areas decreasing the soil health. The presented approach allows indicating hotspots where soil threats deteriorate soil health influenced by climate and land use changes. Therefore, the proposed approach is one of the solutions that can help achieve the goals of the Green Deal and the Soil Strategy for 2050.

Keywords: Soil threats; bundles, climate change, land use change, scenarios

Microbial diversity promotes primary productivity across contrasting land uses in European soils

Romero Ferran[1*], Labouyrie Maëva[1,2,3], Orgiazzi Alberto[2], Panagos Panos[2], Jones Arwyn[2], Tedersoo Leho[4], Bahram Mohammad[5,6], Tóth Gergely[7,8], Hermann Tamás[8], Ballabio Cristiano[2], Lugato Emanuele[2], Delgado-Baquerizo Manuel[9], van der Heijden Marcel[1,3]

[1] *Plant-Soil Interactions group, Agroscope, Zurich, Switzerland*

[2] *Department of Plant and Microbial Biology, University of Zurich, Zurich, Switzerland*

[3] *European Commission, Joint Research Centre Ispra, Ispra, Italy*

[4] *Mycology and Microbiology Center, University of Tartu, Tartu, Estonia*

[5] *Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu, Tartu, Estonia*

[6] *Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden*

[7] *Centre for Agricultural Research, Institute for Soil Sciences, Budapest, Hungary*

[8] *Institute of Advanced Studies, Köszeg, Hungary*

[9] *Departamento de Sistemas Físicos, Químicos y Naturales, Universidad Pablo de Olavide, Seville, Spain*

** Presenting author: Dr. Ferran Romero (ferran.romeroblanch@agroscope.admin.ch)*

Soils provide critical services for terrestrial ecosystems and life on Earth, such as plant productivity. However, it is still not fully resolved how belowground biodiversity drives plant productivity and other ecosystem services. Here we used an extensive soil database to establish biodiversity-plant productivity relationships at the European scale. Specifically, we selected 602 sampling locations distributed along the European continent and for which both soil biodiversity and plant productivity information were available. Soil biodiversity included the richness of fungal and bacterial operational taxonomic units (OTUs), as well as microbial community composition. Plant productivity was modelled from the spatially explicit model SoilProd and validated through normalized difference vegetation index (NDVI). These sampling locations spanned contrasting land uses (woodlands, grasslands, and croplands). Our results show that soil bacterial diversity (OTU richness) and community composition correlate with plant productivity. However, only fungal community composition, and not fungal richness was found to explain plant productivity. Among the different taxonomic groups, strongest correlations with plant productivity were found for Acidobacteria, Proteobacteria, Verrucomicrobia, and Ascomycota. Random forest analyses at the OTU level demonstrated that microbial predictors of plant productivity depended on land use: many beneficial taxa drove plant productivity in woodlands (e.g., mycorrhizal fungi), but plant pathogens appeared as major drivers in croplands (i.e., *Alternaria*,

Fusarium). This study contributes to the development and implementation of policies aiming at preserving soil biodiversity and associated services at the European scale.

Keywords: microbial diversity; primary productivity, European scale

What is a “good” soil organic carbon content?

Christopher Poeplau* and Axel Don

Thuenen Institute of Climate-Smart Agriculture, Braunschweig, Germany

** Presenting author: Christopher.poeplau@thuenen.de*

Soil is a precious and non-renewable resource under increasing pressure. The development of soil health or quality indicators to monitor its state is pivotal and part of the EU soil strategy. Soil organic carbon (SOC) is important for key physical, chemical and biological soil properties and thus a central indicator. SOC content is driven by many pedo-climatic factors, which complicates the search for appropriate threshold values to differentiate between healthy from less healthy soils. Clay content is acknowledged as a strong driver of SOC content, so the SOC:clay ratio has been introduced as a normalised SOC level metric. In this metric, classes range from *degraded* (SOC:clay < 1:13) to *very good* (> 1:8). Here we applied the ratio to 2,958 topsoils (0-30 cm) of the German Agricultural Soil Inventory and showed that it is not a suitable indicator. It is strongly clay-biased, which can be misleading and result in many soils that are insensitive to SOC changes. We propose an alternative clay-normalisation of SOC: the ratio between actual and expected SOC content ($SOC:SOC_{exp}$), in which the expected SOC content is derived from a regression between SOC and clay content. This ratio allows a simple but unbiased estimate of the clay-normalised SOC level. We derived the classes *degraded*, *moderate*, *good* and *very good* that help to judge on the soil health status of different soils. These classes were clearly linked to soil´s porosity as an important structural parameter, which was however not the case for classes based on the SOC:clay ratio. Therefore, the ratio between actual and expected SOC is proposed as a metric that could be easily used in a soil health monitoring of smaller spatial units, such as EU member states, to follow and judge upon SOC levels over time.

Keywords: soil health indicator, SOC:clay, soil quality, soi functions

Assessment of management practices to prevent soil degradation threats on Lithuanian acid soils

Mockevičienė Ieva*, Feiza Virginijus, Feizienė Dalia, Kadžiulienė Žydrė, Stulpinaitė Urtė, Antanaitis Šarūnas

Lithuanian Research Centre for Agriculture and Forestry, Kėdainiai District, Lithuania

** Presenting author: ieva.mockeviciene@lammc.lt*

Sustainable use of soil is essential to maintain crop productivity and environmental quality. The intensification of agriculture as well as poor management accelerates the rate of land degradation. Land use and management is one of the most noticeable indicators of human activities that either contribute to soil degradation or soil improvement. These problems are further compounded by intensive agricultural usage and largely attributed to soil degradation in respect of decline in soil organic content, soil erosion, water contamination and loss of biodiversity. It is needed to evaluate and monitor quality and degradation of the soils. Therefore, assessment of soil characteristics pertaining to their suitability for agricultural use in general is necessary to reverse the decaling trend of soil quality and to ensure sustainable agriculture. Recently, identification of appropriate soil quality and degradation indices for assessing sustainable use of soil has received increased attention. The aim of this study was (1) to determine the soil quality, degradation, and resistance indices under different agricultural management practices and (2) to find out whether management-induced changes are large enough to have the potential to reduce soil degradation.

The study was based on comparing physicochemical indicators data from 3 long-term experiments, conducted in Western part of Lithuania. Changes in soil properties during the last 20 years (1999-2019) were identified. The most common measures applied in Lithuania such as soil liming, manuring, residue maintenance and tillage, have been selected to analyse. Soil quality, degradation and resistance indices were computed and compared. The results indicate that the lowest soil quality, degradation, and resistance values were observed in acid soil (pH 4.2), where the liming was applied, that results the greater sensitivity to degradation. The soil quality indices of studied agricultural practices ranked as: manuring > residue management > reduced tillage > liming). The lowest soil resistance indices values were obtained for low level of nutrients (N and P), organic carbon, pH, and Zn, showing that these properties, compared with the others, are more sensitive to applied agricultural practices. All these findings provide information for promoting better soil management, soil protection, land use planning, and in planning remedial measures, especially in the most afflicted areas.

Keywords: soil quality 1; degradation 2, agricultural practices 3, soil threats 4, soil 5

Assessing on-farm soil health indicators under Norwegian conditions

Pommeresche, Reidun [1] **and Rittl, Tatiana F.**[1*]

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

** Presenting author: tatiana.rittl@norsok.no*

Farmers and advisors seek simple methods to monitor soil health. Here, we assessed the performance of different soil health tests on the top soil (0-10 cm) of different agricultural "habitats", from an organically managed grassland to a conventional potato production in Norway. In each production system, grassland and potato, we selected different areas where variations on soil health were expected. In the grassland, a gradient from cultivated to permanent pasture was selected. In the conventional potato field, plots that received different organic materials (biochar, digestate, farmyard manure) two years prior to the soil assessment, were selected. The tests were performed in early summer 2021 (June) for the grassland, and in summer 2021 (July) after the harvest of early potatoes in the potato field. The tests comprised different aspects of soil health: soil organic matter content (ignition loss), labile soil carbon fractions (Active C), soil biology (microbiology and mesofauna) and soil biological activity (soil respiration and feeding activity) and soil aggregate stability. Test results were used to compare the systems and the areas within the systems. Overall, the tests significantly differentiate between organically managed pasture and conventional potato field, with the first showing better values for soil health. However, the tests did not significantly differentiate between areas/treatments within the production systems. Yet, in the organically managed grassland, permanent pasture showed a trend of better soil health than cultivated areas. In the conventional potato field, selected soil health tests were not sensitive to capture the residual effects of the organic amendments, and untreated and treated soil showed very similar values. To be able to visualize the results together, we normalized the data by diving single values by the maximum value observed for each soil indicator within each system. By doing so, we obtained an overall soil health diagram that can be easily interpreted by farmers and advisors. The use of several simple tests together showed to be valuable also to inform about soil health within the to two production systems. Yet, a visual evaluation of the topsoil and chemical nutrient analysis is recommended to complement these tests. Furthermore, we need more field data to obtain "reference levels" for these tests, that would help with the interpretation of their results in the future.

The main funder of these projects is Norwegian Agriculture Agency, 2021-2023.

Keywords: Soil biology, soil carbon, soil organic matter, grassland, potato production

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

Martelli Andrea[1*], Klimkowicz-Pawlas Agnieszka[2], Jandl Robert[3], Cousin Isabelle[4] and Altobelli Filiberto[1]

[1] *CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy.*

[2] *Institute of Soil Science and Plant Cultivation- State Research Institute (IUNG), Pulawy, Poland*

[3] *Bundesforschungszentrum für Wald (BFW), Vienna, Austria*

[4] *INRAE, Unité de Recherche Info&Sols, Orléans, France*

** Presenting author: andrea.martelli@crea.gov.it*

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

In the policy analysis process, the next pre-determined step will be stakeholder consultation to agree on a list of suggested indicators for policy implementation.

References

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

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

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

<u>Seidel Felix</u>[1*]; Don Axel[1], Seitz Daria[1], Kätterer Tomas[2], Leifeld Jens[3], Martin Manuel[4], Pelerin Sylvain[4], Chenu Claire[4].

[1] *Thünen Insitute, Braunschweig, Germany*

[2] *SLU, Uppsala ,Sweden*

[3] *Agroscope, Zürich, Switzerland*

[4]*INRAE, Paris, France*

** Presenting author: felix.seidel@thuenen.de*

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

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

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

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

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

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

Pavlů Lenka*, Penížek Vít, Vašát Radim, Borůvka Luboš

Czech University of Life Sciences Prague, Prague, Czech Republic

** Presenting author: pavlu@af.czu.cz*

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

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

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

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

Statistical assessment of the usability of SOC sequestration indicators

Pindral Sylwia[1*], Coblinski João Augusto[2], Saby Nicolas[2] and Smreczak Bożena[1]

[1] *IUNG-PIB, Czartoryskich 8, 24-100 Puławy, Poland*

[2] *INRAE, Info&Soils, 45075 Orléans, France*

** Presenting author: spindral@iung.pulawy.pl*

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

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

The applied method allows for a combination of the most suitable indicators for the assessment of SOC sequestration potential in agricultural soils and identifies areas requiring special soil conservation and carbon management practices. In the light of presented findings and the results obtained, it should be concluded that the proposed method has a high application value and can be used for the assessment of other soil ecosystem services indicators and the analysis of the soilscapes' spatial structure.

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

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

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

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

Ungaro Fabrizio[1], Gardin Lorenzo[1], Lorenzetti Romina[1], Medina Eduardo[1] and Calzolari Costanza*[1]

[1] *CNR - National Research Council of Italy, Institute of BioEconomy, Florence, Italy*

** Presenting author: costanza.calzolari@ibe.cnr.it*

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

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

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

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

De Haan, Janjo[1*], Fenny van Egmond[1]

[1] *Wageningen University & Research, Wageningen/Lelystad*

** Presenting author: janjo.dehaan@wur.nl*

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

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

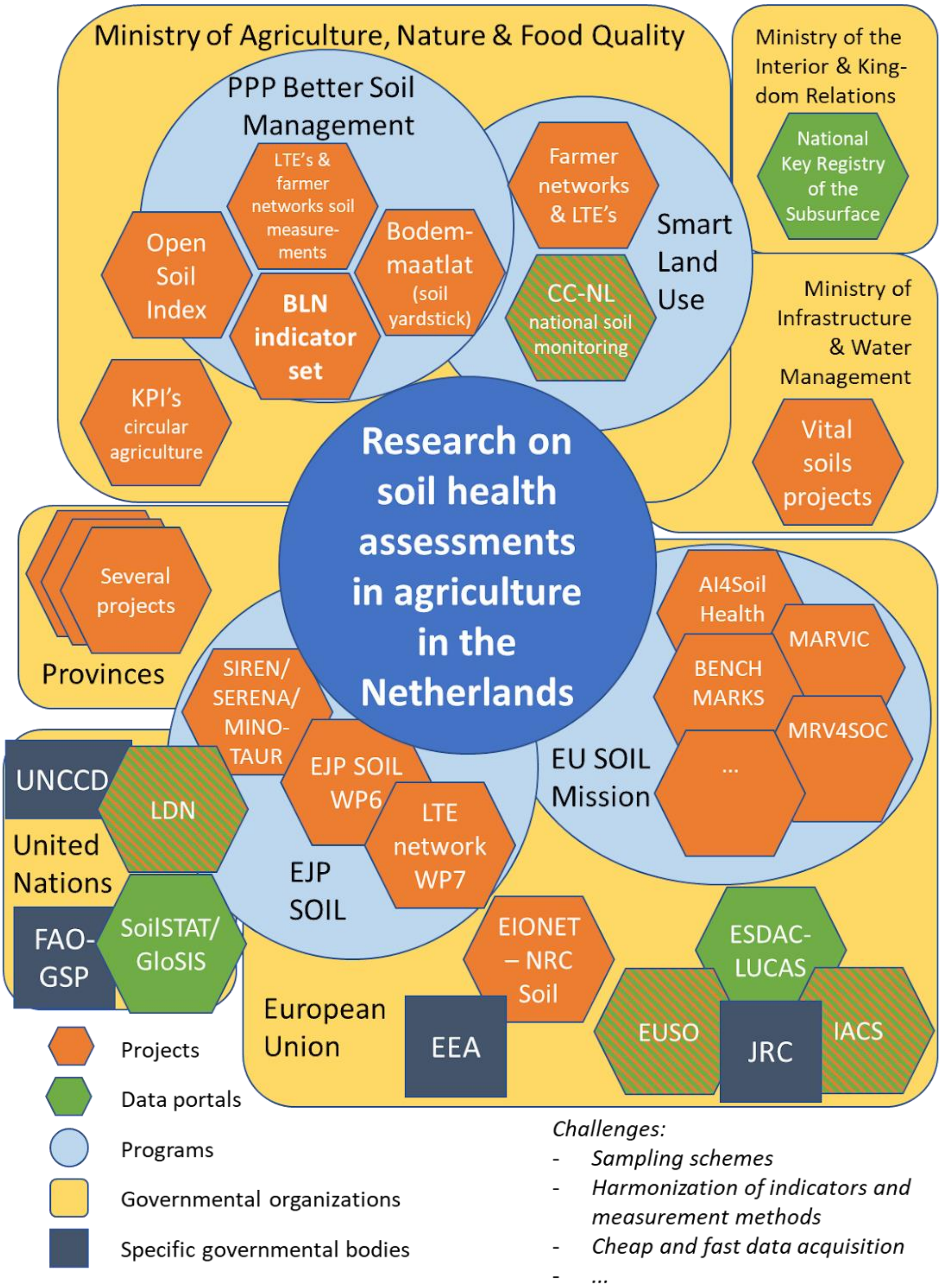
Apart from within the EJP SOIL community, this debate takes place in the wider international research community: e.g. other EU-projects (BENCHMARKS, AI4SoilHealth) and within the FAO-GSP of the United Nations. And besides research, across a large range of policy levels around the EU Soil Health Law development,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

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

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

Keywords: soil health assessment; soil indicator, soil monitoring

Landscape on soil health assessments in the Netherlands



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

Sara Del Duca[1], Roberta Pastorelli[1], Markéta Mareckova[2] and Stefano Mocali*[1]

[1] *CREA – Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, Florence, Italy*

[2] *Czech University of Life Science, Department of Microbiology, Nutrition and Dietetics, Prague, Czechia*

** Presenting author: stefano.mocali@crea.gov.it*

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

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

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

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

Towards a harmonized system for the monitoring of soil microbial biodiversity

Sara Del Duca*[1], Francesco Vitali[1], Elena Tondini[1], Erica Lumini[2], Ialina Vinci[3], Adriano Garlato[3], Stefano Brenna[4], Elisa Tagliaferri[4], Alberto Orgiazzi[5], Arwyn Jones[5], Maria Fantappiè[1], Stefano Mocali[1]

[1] *Research Centre for Agriculture and Environment, Council for Agricultural Research and Economics (CREA), Florence, Italy*

[2] *Institute for Sustainable Plant Protection (IPSP) - National Research Council (CNR), Turin, Italy*

[3] *Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (ARPAV), Centro Veneto Suolo e Bonifiche, Treviso, Italy*

[4] *Ente Regionale per i Servizi all'Agricoltura e alle Foreste (ERSAF), Milan, Italy*

[5] *European Commission Joint Research Centre (JRC) - Sustainable Resources Directorate, Land Resources Unit, Ispra, Italy*

** Presenting author: sara.delduca@crea.gov.it*

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

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

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

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

Keywords: microbial communities; soil biodiversity; soil health

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

Bragato Gilberto[1*], Fornasier Flavio[1] and Lozano Fondón Carlos[2]

[1] *CREA – Viticulture and Enology, Gorizia, Italy*

[2] *CREA – Agriculture and Environment, Firenze, Italy*

** gilberto.bragato@crea.gov.it*

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

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

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

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

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

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

What can accelerate hemp residues mineralization?

Urtė Stulpinaitė[1*] **and Vita Tilvikienė** [1]

[1] *Lithuania Research Centre for Agriculture and Forestry*

** urte.stulpinaite@lammc.lt*

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

Keywords: Hemp, residues, mineralization.

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

Cristina Aponte[1], Stefano Mocali [2], Roberta Pastorelli [2], Lorenzo D´avino [2], Roberta Pastorelli [2], Elena Tondini[2], Francesco Vitali[2], Marketa Sagova-Mareckova[3], Felipe Bastida [4], Jose Luis Siles [4], Jose Luis Moreno[4], Carmen Trasar-Cepeda [5], Ángeles Prieto-Fernández [5], Marcel van der Heijden [6], Raphael Wittwer [6], Rajasekaran Murugan [7], Johann Zaller [8], Sharjeel Ashfaq[9], Maria Viketoft [1]0, Mohammad Bahram [1]0, Marjetka Suhadolc [11], Anton Govednik [11], Rok Mihelic [11], Anna Maria Bevivino[12], Federico Sbarra[12], Filippo Sevi [12], Federico Sbarra[13], Erica Lumini [14], Jack Faber [15], Gerard Korthals [15], Jaap Bloem [15], Joeke Postma[15], Tess van de Voorde [15], Mickael Hedde [16], Marc Roucaute [16], Lou Lerner[17], Issaga Dialo [17], Guenola Peres [17].

1 Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA-CSIC), Madrid, Spain
2 Research Center for Agriculture and Environment -CREA , Florence, Italy.
3 Czech Univerisity of Life Science, Department of Microbiology, Nutrition and Dietetics, Prague, Czechia
4 Centro de Edafologia y Biología Aplicada del Segura (CEBAS-CSIC) , Murcia, Spain
5 Misión Biológica de Galicia sede Santiago (MBG SCQ-CSIC), Santiago, Spain
6 Agroscope, Zürich, Switzerland
7 Institute of Soil Research, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
8 Institute of Zoology, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
9 Soil Research & Institute of Zoology, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
10 Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden
11 University of Ljubljana · Agronomy Department, Center for Soil Sci. and Environment, Ljubljana, Slovenia
12 Italian National Agency for New Technologies, Energy and Sustainable Economic Development ENEA, Italy
12 Italian National Agency for New Technologies, Energy and Sustainable Economic Development ENEA, Italy
13 University of Turin, Turin, Italy
14 Italian National Research Council - CNR- · Institute for Sustainable Plant Protection, Torino, Italy
15 Wageningen Enviromental Research, Wageningen University & Research, Wageningen, Netherlands
15 Wageningen University & Research, Wageningen Plant Research, Wageningen, the Netherlands
16 Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (INRAe), Versailles, France
17 Institut Agro, Rennes Cedex, France

** Presenting author: Cristina.aponte@inia.csic.es*

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

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

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

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

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

Jarosch Klaus[1*], di Bene Claudia[2] and the EJP SOIL ARTEMIS team

[1] Agroscope, Agroecology and Environment, Zurich, Switzerland

[2] CREA, Council for Agricultural Research and Economics, Rome, Italy

** Presenting author: klaus.jarosch@agroscope.admin.ch*

Soils provide a multitude of ecosystem services that can contribute to both, the mitigation as well as the adaptation to climate change. Land management practices have a large effect on the ability of soils to provide these services. Within the ARTEMIS project we aim to determine how specific agro-ecological (AE) land management practices affect soil ecosystem services. This will be done in a four-pillar approach:

i) Buy conducting a scientific literature meta-analysis the available knowledge on the effect of AE practices (in particular organic farming) on crop yield stability will be synthesized on a European level. To determine the effect of these AE practices to climate change mitigation the effect on N_2O emissions will be looked at in particular.

ii) Buy statistically analysing data of long-term field experiments we aim to demonstrate how AE practices (reduced tillage, organic matter management, …) are affecting crop yield stability and how this stability is reacting in specific years with climatic extreme events. We further want to determine the soil-related drivers of a potentially different yield stability in specific AE system compared to a conventional control.

iii) Buy numerical modelling (ARMOSA) we will determine how specific changes in land management practices may affect crop yield stability in both current but also future climate conditions. This will potentially allow to predict which AE practices will show higher crop yield stability in combination with fewer detrimental environmental effects (e.g., nutrient losses, SOC losses, …) in the future.

iv) By developing and testing a framework for an on-farm monitoring network on the impacts of AE practices on soil related ecosystem services we want to determine the possibilities but also limits to determine these indicators in the field by practitioners.

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

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

Block C

C1 Carbon sequestration, roots and amendments

Session Description

Involved projects: MIXROOT-C, MaxRoot C

Conveners: Rebecca Hood-Nowotny (BIOS-BOKU), Isabelle Bertrand (INRAE), Anna Wawra (BIOS-AGES)

To reduce the effect of climate change carbon sequestration and or the implementation of negative emission technologies are essential. Sequestering carbon in soils through increased belowground sequestration, specifically increasing root carbon inputs from cropping systems could play a major role in reaching the 4 per mil targets. The most viable yet to date neglected option is through increased and deeper root production of both main and cover crops in both extensive and intensive cropping systems. In MIX and MaxRoot-C we are developing assessment methods to estimate root C inputs of both staple and novel crops in cropland, grassland and agroforestry systems across Europe. In this session we seek contributions which cover topics such as: measuring root traits, root biomass, root stoichiometry, root architecture, isotope labelling and rhizodeposition, in conjunction with E-environmental- factors, such as soil type, strength and fertility, to predict the effect of root systems on SOC stocks. We would also like to see results from the ongoing projects that might be of interest to the root community and the initial data or approaches from those working on modelling. In this session we hope to go beyond current knowledge, to evaluate the potential impact of promising C sequestering management interventions, such as: cover cropping, targetedbreeding, and soil management in these diverse agricultural production systems aiming at widespread adoption of more sustainable carbon sequestering and soil restorative practices.

Environmental conditions are ten times more important than wheat variety for arbuscular mycorrhizal fungi

A. Versuliene[1]*, J. Hirte[2], F. Ciulla[2,3], M. Toleikiene[1], M. Camenzind[4], K. Yu[4], A. Hund[3], M. da Silva-Lopes[5], F. Durand-Maniclas[2], H. Heinemann[6], F. Seidel[6], A. Don[6], M. Visse-Mansiaux[7], J. Herrera[7], F. Bender[2]

[1] *Lithuanian Research Centre for Agriculture and Forestry, Institute of Agriculture, Lithuania*
[2] *Agroscope, Agroecology and Environment*
[3] *ETH Zurich, Institute of Agricultural Sciences, Switzerland*
[4] *Technical University Munich, School of Life Sciences, Precision Agriculture Lab, Germany*
[5] *Institute of Agrifood Research and Technology, Sustainable Field Crops Program, Spain*
[6] *Thünen Institute, Institute of Climate-Smart Agriculture, Germany*
[7] *Agroscope, Plant Production Systems, Cultivation Techniques and Varieties in Arable Farming*
** Presenting author: agne.versuliene@lammc.lt*

Arbuscular mycorrhizal fungi (AMF) are an important component of the soil biota in most agroecosystems. The mutualistic symbiosis of plant roots and AMF allows plants to explore larger volumes of soil to acquire more water and nutrients and plays an outstanding role in root carbon allocation to soil. Wheat is one of the most important cereal crops worldwide. It is, however, not well understood, to what extent different wheat varieties associate with AMF and how this relationship is affected by environmental conditions. This knowledge could offer potential pathways towards a more sustainable use of water and nutrient resources in wheat production and increased soil C allocation. Within the EJP Soil project MaxRoot-C and in close cooperation with the H2020 project INVITE, we (i) compared the abundance of mycorrhizal structures in winter wheat roots between different varieties, (ii) evaluated the relative importance of variety and environment for the variability in root colonization by AMF, and (iii) tested the relation between mycorrhizal abundance and grain yield.

The study was conducted in the field season of 2021/2022 on ten modern winter wheat (*Triticum Aestivum*) varieties at four different European sites: Dotnuva LT, Eschikon CH, Freising DE, and Lleida ES, in three replicates each. The ten varieties had a high commercial relevance for the partner countries and differed strongly in yield based on experiments in the previous year. Roots were taken at the crop flowering (BBCH 63–65) stage from 0–15 cm soil depth, washed, stained and assessed for mycorrhizal root colonization by microscopy (McGonigle et al., 1990). We analyzed the data using generalized linear mixed models for binomial data and variance decomposition (LMG scores; Lindeman et al., 1980).

Arbuscular, hyphal, and vesicular abundance ranged from 10-59%, 20-91%, and 0-3%, respectively, across all samples. Averaged across sites, the varieties varied by 8% and 18% in arbuscular and hyphal abundance, respectively. Three varieties each at the lower and upper end of the abundance ranges differed significantly from other varieties, whereas four varieties were intermediate. The LMG scores for site and variety, respectively, were 5 and 51% for arbuscular abundance and 7 and 69% for hyphal abundance, indicating that site was 10 times more important for AMF than variety. In the next steps, we will further look into the site: variety interaction and test the relation between mycorrhizal abundance and grain yield.

Our findings show for the first time the response of mycorrhizal structures to different crop varieties and environmental conditions in arable settings across Europe.

Keywords: wheat genotype, arbuscules, vesicles, hyphae, environmental factors.

McGonigle, T. P., Miller, M. H., Evans, D. G., Fairchild, G. L., Swan, J. A. (1990). A new method which gives an objective–measure of colonization of roots by vesiculas arbuscular mycorrhizal fungi. New phytologist, 115: 495-501.

Lindeman, R. H., Merenda, P. F., Gold, R. Z. (1980). Introduction to Bivariate and Multivariate Analysis. Scott, Foresman, Glenview, IL

Soil intrinsic limits for carbon sequestration due to C saturation

Don Axel[1*], Begill Neha[1], Heinemann Henrike[1] and Christopher Poeplau[1]

[1] *Thünen institute, Braunschweig, Germany*

** Presenting author: axel.don@thuenen.de*

Carbon (C) sequestration in soils has been discussed as important climate mitigation option with the potential to generate negative emissions. Agriculture requires such negative emissions since some of their greenhouse gas emissions are unavoidable and require compensation to achieve net zero. Expectation of soils contribution to climate mitigation need to come down from theoretical assumptions to realistic estimates. In order to do so the limitations for soil C sequestration need to be analysed and discussed. Here we present case studies looking at limitations that are intrinsic due to the soils´ ability to stabilize SOC on mineral surfaces (C saturation) and the current state of knowledge. More root C input for soil C sequestration maybe hampered by soils reaching C saturation. For the start of this analysis we used data of the first German Agricultural Soil Inventory comprising more than 3000 sites and fractionated a subset into particulate organic carbon (POC) and mineral associated organic carbon (MAOC). The dataset covered a range up to 12% C_{org} but we could not detect a limitation of soils to stabilise C as MAOC. Moreover, we investigated three long-term field experiments with different additions of organic amendments. We found a linear relation between C input to the soil and soil carbon stocks. The sand sized fraction reacted most to C additions and the silt and clay fraction showed significant increases with C addition in two experiments, likely due to the slow turnover in this fraction. C saturation was frequently discussed as reason for preventing further built up of stabilised SOC in C-rich soils. However, based on data from long-term field experiments and the national soil inventory we challenge the perception that C saturation is a limiting factor for soil C sequestration in our soils but consider available biomass as the key limiting factor for large scale C sequestration. Thus, more root-C input can increase soil carbon no matter what the soil´s initial C status is.

Keywords: Carbon sequestration; C addition to soils, agricultural management

The root shoot database. What can the available literature tell us about the effect of management on the root shoot ratio (RSR)

Weldon Simon[1*], Rasse Daniel[1], de Barcena Teresa-Gomez [1] and Moni Christophe[1]

[1] *Norwegian Institute for Bioeconomy Research, Ås, Norway*

** Presenting author: simon.weldon@nibio.no*

The contribution of plant roots to persistent carbon stores in soil is significant. Understanding how it might be possible to optimise root biomass production through species choice and crop management is therefore an important step towards identifying agricultural policies that increase soil carbon inputs. The root shoot ratio (RSR) is the ratio between the above and below ground biomass and is used as an index for the plant biomass allocation. The RSR is a dynamic ratio influenced by biotic factors, such as plant age and species as well as abiotic factors such as climate, soil texture, nutrient, and water availability. The Root Shoot database was developed within EJP soil project Carboseq to gather all the available data on RSRs from literature and direct communication with data holders. The goal of this data set was to identify allometric relationships that might be used to improve models of soil carbon input via crop roots as a tool for policy makers. This data set was also of value to the Maxroot project where the goal is to understand specific management practices that may result in larger RSRs thereby maximising belowground inputs. To this end we present some initial results from our time working with and developing the database. We discuss the extent to which the available data can be used to increase our understanding of this critical theme as well as approach some of the limitations of the data.

Keywords: Root shoot ratio; Soil carbon, Crop management, Maxroot, Carboseq

Root system architecture traits of winter wheat in a genotype x environment network across a European pedoclimatic gradient

F. Durand-Maniclas[1*], F. Ciulla[1,2], F. Seidel[3], H. Heinemann[3], A. Don[3], M. Camenzind[4], Z. Csűrös[5], Zs. Czakó[5], C. Flamm[6], J. M. Herrera[7], A. Hund[2], F. Platz[6], B. Poós[5], M. da Silva-Lopes[8], M. Toleikiene[9], A. Versuliene[9], M. Visse-Mansiaux[7], K. Yu[4], J. Hirte[1]

[1] Agroscope, Agroecology and Environment, Switzerland
[2] ETH Zurich, Institute of Agricultural Sciences, Switzerland
[3] Thünen Institute, Institute of Climate-Smart Agriculture, Germany
[4] Technical University Munich, School of Life Sciences, Precision Agriculture Lab, Germany
[5] National Food Chain Safety Office, Agricultural Genetic Resources Directorate, Hungary
[6] Austrian Agency for Health and Food Safety, Austria
[7]Agroscope, Plant Production Systems, Switzerland
[8] Institute of Agrifood Research and Technology, Sustainable Field Crops Program, Spain
[9] Lithuanian Research Center for Agriculture and Forestry, Institute of Agriculture, Lithuania

** Presenting author: fabien.durand@agroscope.admin.ch*

Roots are a main source of organic carbon in agricultural soils and root system architecture (RSA) traits substantially govern water and nutrient acquisition from soils. Hence, selecting varieties of main crops with improved root system architecture has been proposed as both climate change mitigation and adaptation measures in arable farming. Up to date, only little is known about the variability in root parameters of modern, commercially relevant crop varieties. Moreover, there is a lack of data on the impact of different pedoclimatic conditions across Europe on root parameters that would allow active root and, with this, soil carbon management in agriculture via variety selection.

Within the EJP Soil project MaxRoot-C and in close cooperation with H2020 INVITE, we compared a set of 10 modern winter wheat varieties for their belowground performance on 11 sites with three replicates per site. The sites spanned the major European bioclimatic regions from the Mediterranean to the Nemoral and from the Atlantic to the Pannonian zone. In the present study, we will present results of seven of the 11 sites. We sampled roots after harvest by collecting all crown roots from 0.25 x 0.25 x 0.15 m soil monoliths and by taking soil cores to 1 m soil depth. The roots were thoroughly washed, weighted and scanned and seven RSA traits (*total length, surface area, volume, diameter, orientation, length density, number of tips*) were measured using the image analysis software RhizoVision Explorer (Seethepalli et al., 2021). Additionally, the 10 winter wheat varieties were genotyped using a 25k SNP chip to further compare the relatedness of the varieties and describe genome x environment interactions in root traits. We tested differences in RSA traits between varieties using simple linear and linear mixed effects models and performed a heritability analysis on the same RSA traits.

The variability in RSA traits of the crown roots was 2.4 to 3.2 times greater among sites than among wheat varieties and all studied RSA traits differed significantly between sites. While only root surface area of the crown roots differed significantly between varieties, we found significant interactions between site and variety for the majority of RSA traits. Based on the preliminary analysis of the genetic relatedness, two out of the 10 wheat varieties were considerably different from the other eight and also from each other. In addition, we will present RSA traits of the root samples retrieved from the soil cores, with a particular focus on deep roots, and results from integrated data analyses of genome and root data.

Our preliminary findings on the crown roots imply that modern, commercially relevant wheat varieties show little variability in RSA traits and that breeding programs opting for a change in root parameters might need to consider introgression of historical accessions. However, all varieties showed substantial plasticity in RSA traits depending on the environmental conditions, indicating that root management needs to take pedoclimatic boundaries into account in order to increase carbon inputs to agricultural soils.

Keywords: root system architecture, wheat, genome x environment, deep soil, variety choice

Seethepalli, A., Dhakal, K., Griffiths, M., Guo, H., Freschet, G. T., & York, L. M. (2021). RhizoVision Explorer: open-source software for root image analysis and measurement standardization. *AoB Plants*, *13*(6), plab056. https://doi.org/10.1093/aobpla/plab056

Increasing root-derived soil carbon input to agricultural soils by genotype selection

Heinemann Henrike [1*], Seidel Felix [1], Don Axel [1] and Hirte Juliane[2]

[1] *Thünen Institute of Climate-Smart Agriculture, Bundesallee 65, 38116 Braunschweig, Germany* [2] *Agroscope, Reckenholzstrasse 191, 8046 Zürich, Switzerland*
** Presenting author: henrike.heinemann@thuenen.de*

Climate change mitigation and adaptation is a major challenge of modern agriculture. In general, atmospheric carbon (C) can be taken up by plants via photosynthesis and incorporated into their biomass. When the plant gets harvested, the remaining above and below-ground biomass supplies the soil with organic C. The increased incorporation of atmospheric C into soils is a promising agricultural management tool for mitigating climate change. In order to build up soil organic carbon stocks in agricultural soils or even maintaining them under the pressure of climate change, increased organic C inputs are needed. In agricultural soils, crop roots are the major source of organic C and of great importance for long-term C storage in soils as their turnover is 2 to 3 times slower than that of above ground biomass. This suggests, that genotype selection towards increased root biomass may enhance root C inputs and could therefore be a promising, easy-to-implement agricultural management option for increasing C stocks and possibly allow for additional C sequestration.

We compiled data from 13 global studies with field experiments in order to estimate the potential of optimized genotype selection to enhance root biomass without compromising yield for winter wheat, spring wheat, silage maize, winter rapeseed and sunflower. A median root C increase of 6.7 % for spring wheat, 6.8 % for winter rapeseed, 12.2% for silage maize, 21.6 % for winter wheat and 26.4 % for sunflower would be possible without yield reduction. This approach suggested a genotypic variation of root biomass but could not depict whether biomass allocation is also affected by genotype x environment interaction. To quantify this variation on the example of winter wheat, we assessed root biomass, vertical root distribution to 1 m soil depth and root: shoot ratios in a set of 10 different genotypes grown at 11 experimental sites, covering a large European climatic gradient. Preliminary results show a broad intra-specific variation in biomass production and its allocation between roots and shoots amongst the varieties. It seems possible to simultaneously select genotypes with higher grain yield and higher root biomass production meeting the needs for both food production and increased SOC build up. Additionally, increased root biomass due to deeper roots may stabilise yields under future climate change conditions where increased frequency of drought

events during vegetation periods are expected and may therefore be a climate change adaptation measure that increases the crops resilience towards changing environmental conditions.

Keywords: root biomass, root carbon inputs, root to shoot ratio, climate change mitigation, carbon sequestration

Carbon sequestration potential of legume-cereal intercropping

Martins, Juliana Trindade[1*]; Liang, Zhi[1]; Enggrob, Kirsten[1] and Rasmussen, Jim[1]

[1] *Department of Agroecology, Aarhus University, Blichers Allé 20, DK-8830, Tjele, Denmark*

** jtm@agro.au.dk*

Under Danish conditions, grain legumes play a crucial role in enhancing soil carbon (C) sequestration and nutrient cycling. Therefore, optimization of cultivation of grain legumes is highly important. Intercropping is believed to provide higher environmental benefits compared to monocrops. The benefits include a wide range of ecosystem services, such as a more diverse array of plant species in the field which can provide root interactions, greater above and below ground biomass, and thus increased carbon storage. However, there is a lack of comprehensive studies on the intercropping effect on legume-cereal C inputs via phyllo- and rhizodeposition (ClvPR). A field experiment with $^{13}CO_2$ enriched atmosphere labeling-cylinders was conducted with pea, spring barley and intercropped pea and spring barley to investigate how plant C inputs into the soil in deep layers (1 m) are affected in relation to the selected species monocrop x intercropping. Results will include how the selected species differ in C allocation, and how grain legume contribute to the quantity of C input into the soil through phyllo- and rhizodeposition (qClvPR) compared to spring barley monocrop. We expect complementary effects of intercropped pea and spring barley to increase C inputs, due to better resource utilization and increased biomass in relation to plant diversity. In addition, it is expected that intercropping will have greater rooting depth soil exploration in terms of root diversity. We will report the aboveground and belowground biomass of legume and cereal monocrop which are expected to have lower densities when compared to intercropping, due to higher diversity of intercropping species allowing for the presence of a more diverse range of plant interactions.

Keywords: Crop diversification; Phyllodeposition; Rhizodeposition; leguminous

Main crop effect on biodiversity expression in spontaneous flora and C input from cover crop mixtures

Bloch, Nadja Fuglkjær[1*], Martins, Juliana Trindade[1], Liang, Zhi[1,2], Enggrob, Kirsten Lønne [1] and Rasmussen, Jim[1]

[1] *Department of Agroecology, Aarhus University, Blichers Allé 20, 8830, Tjele, Denmark*

[2] *iCLIMATE, Aarhus University Interdisciplinary Centre for Climate Change, Blichers Allé 20, 8830 Tjele, Denmark*

** Presenting author: nfb@agro.au.dk*

Cover crop (CC) mixtures are believed to provide a better and wider range of ecosystem services in agroecosystems, compared to CC in pure stand. These services include increased biodiversity through increased plant diversity and carbon (C) storage through cover crop biomass and phyllo- and rhizodeposition. However, little to no information exists about how the C storage capabilities of CC mixtures are affected by the previous crops in the rotation, or how CC mixtures interact with biotic factors, such as spontaneous flora (SF), in an agroecosystem.
A field experiment using isotopic labelling with $^{13}CO_2$ was conducted to examine the impact of two different types of CC treatments (pure stand versus mixture) and preceding main crops (Pea, Barley, Pea: Barley, and Faba bean) on the input of C into the soil to 1 meter depth, with the goal of determining whether the use of diverse crops in time and space could enhance the storage of soil C in agroecosystems. Additionally, the relationship between diversified CC and SF diversity was investigated in treatments without CC, and with CC in pure or mixed stands.
Results will be presented on how mixed CC contribute to the quantity of C input to the soil through phyllo- and rhizodeposition (qClvPR) and biomass compared to CC in pure stand. We expect complementary effects of different CC species in mixed stand to increase C inputs, due to better resource utilization and increased biomass. Due to complementarity, mixed CC are also expected to have higher total biomass production and greater rooting depths. Generally, CC grown after a leguminous main crop, are expected to have higher aboveground and belowground biomass. A deeper root growth is also expected, due to the N_2 fixing abilities of legumes which increase nutrient availability for CC growth. Cover crops following a leguminous main crop are expected to have lower relative net C inputs to the soil via phyllo- and rhizodeposition (%ClvPR) compared to CC grown after a non-leguminous crop, due to higher microbial activity in the fertile soil of leguminous crops. We will report how mixed CC affects densities of SF compared to no CC or CC in pure stand, where we expect mixed CC species to better capture resources and thereby suppressing SF, but at the same time supporting a higher

diversity of SF compared to CC in pure stand as they decrease the dominance of a few SF species, allowing for the presence of a more diverse range of species.

Keywords: Mixed cover crops, phyllo- and rhizodeposition, carbon storage, biodiversity, spontaneous flora

In situ ^{13}C isotope labelling of winter wheat to determine net belowground carbon inputs

Celia Fernández-Balado[1], Elisabeth Ziss[1], Rebecca Hood-Nowotny[1]

[1]*Institute of Soil Research, Department of Forest and Soil Sciences, University of Natural Resources and Life Sciences, Tulln, Austria*

Promoting cropping systems with higher soil carbon sequestration is indispensable to reduce the effect of climate change. Plant photosynthesis and carbon allocation belowground is the primary pathway for C to enter the soil. However, little is still known about the distribution of roots and the amount of rhizodeposits for different crop varieties. Selecting varieties with increased belowground plant carbon (root and rhizodeposition) can be a viable option to maximize carbon input to the soil to enhance soil organic carbon (SOC). This study aims to determine the carbon allocation from shoots to roots and the carbon loss from these two pools to the soil in four winter wheat (WW) varieties under field and different pedoclimatic conditions in Europe.

In a replicated pan European experiment, cylinders were inserted at a depth of 25 cm before the tillering stage to confine the root system of the selected WW varieties and to control the spread of the ^{13}C tracer. Currently, we are labelling the selected varieties by ^{13}C multiple pulse labeling throughout the active growth period. After ripening, aboveground biomass will be harvested, the cylinders will be excavated, and soil samples will be taken at a depth of 1 meter. The carbon content and the ^{13}C in soil, roots, aboveground biomass, and microbial pools will be assessed by Elemental Analyzer Isotope Ratio Mass Spectrometer (EA-IRMS) and will allow us to determine net rhizodeposition. Furthermore, we are interested in determining the contribution of belowground carbon inputs to SOM by studying its molecular structure as well as in investigating the recalcitrance of this inputs through SOM fractionation.

C2 Soil biodiversity and ecosystem services

Session Description

Involved projects: AGROEcoSeqC, EnergyLink

Conveners: Alessandra Trinchera (CREA), Sebastien Fontaine (INRAE)

The concept of soil health is unavoidably connected to its multifunctionality, strongly dependent on soil biodiversity. The recently changed and still evolving environmental conditions call for management practices able to increase biodiversity and the functional redundancy of soil biological communities to ensure adequate ecosystem resilience, contemporary optimizing the synchronization of nutrients plant demand and availability in soils. This breakout session will focus on the importance of soil biodiversity and related ecosystem services: contributions describing labelling methods, molecular markers, assessment of plant diversity, geno- and phenotypic profiling of soil microbial community, enzymatic activities, soil soluble C pools, plant-microbial symbiosis, greenhouse gas emission, and indicators of ecosystem services observed in long-term experiments from crop- and grasslands, as well as application of modelling and multivariate approaches, are welcome.

Sculpting the soil microbiota: role of soil management and plant-diversity based farming practices

Trinchera Alessandra[1*]

[1]*Council for Agricultural research and Economics (CREA), Rome, Italy*

** Presenting author: alessandra.trinchera@crea.gov.it*

Soil microbial community is one of the main regulators of fundamental ecosystem processes. Its composition, diversity and functional may support the long-term soil productivity and the resilience to climatic and environmental stress. However, the application of impacting agronomic practices, such as deep soil disturbance, monocropping, or use of herbicides, provoke deep changes in microbial community affecting its composition and functional diversity, generating a cascade of negative effects on C sequestration and soil-plant nutrient balance.

The adoption of agroecological practices, based on reduction of soil disturbance, increase of plant diversity by introducing service crops, or promotion of plant-microbial symbioses in field, is an effective tool able to ensure an efficient energy and nutrients complementation and exploitation by plants and soil microbiota, thus increasing ecosystems production and resilience.

For example, tillage and crop rotation change the distribution pattern of soil fungi. In ploughed soils, the fungal species are evenly distributed, while a higher spatial variability is found in no tilled ones, being fungal taxa distributed according to a small-scale pattern, corresponding to undisturbed and heterogeneously distributed micro-niches. The increase of mycorrhizal fungi abundance in no-tilled soils is due to fungi species selection, due to higher soil compaction and lower pore aeration, which increases the physical resistance to hyphal development and penetration.

With reference to plant diversity in field, the intercropping of legume with organic tomato increases soil-P availability when compared to monocropping, due to potentiation of rhizobia–mycorrhiza mycorrhiza association, especially in presence of organic fertilization.

In different EU vegetable systems, it was observed that multi-cropping increases soil microbial biomass amount and shape microbial community toward a predominance of some bacteria or fungi phyla, in the function of soil nutrient availability. The increased *Bacteroidetes* and decreased *Mortierellomycota* relative abundance in rhizosphere soil of intercropped crops are sensitive ecological indicators of an improved agro-system functionality: the *Bacterioidetes*, as evidence of low impact agricultural practice introduction, and the *Mortierellomycota* as undirect indicator of the reduced pressure made by pathogens in intercropping systems.

Finally, an overall highest plant diversity in field also improves mycorrhizal colonization of coexisting species, by developing a root-connecting external hyphal mycelial network with a positive effect on cropping system productivity in long term.

Keywords: Soil microbial diversity, mycorrhiza, no tillage, crop rotation, intercropping

Designing sustainable agrosystems by copying the biogeochemical organization of natural ecosystems

[*1]Sébastien Fontaine, [2]Luc Abbadie, [3]Michaël Aubert, [2]Sébastien Barot, [1]Juliette M.G. Bloor, [4]Delphine Derrien, [5]Olivier Duchene, [1]Nicolas Gross, [3]Ludovic Henneron, [6]Xavier Le Roux, [2]Nicolas Loeuille, [7]Jennifer Michel,[8]Sylvie Recous, [9]Daniel Wipf, [1]Gaël Alvarez

[1]Université Clermont Auvergne, INRAE, VetAgro Sup, UMR Ecosystème Prairial, 63000 Clermont-Ferrand, France

[2]Sorbonne Université, UPEC, CNRS, IRD, INRAE, Institut d'écologie et des sciences de l'environnement, IEES, 75005 Paris, France

[3]Normandie Univ, UNIROUEN, INRAE, ECODIV-Rouen, 76000 Rouen, France

[4]INRAE, BEF, 54000 Nancy, France

[5]ISARA, Research Unit Agroecology and Environment, 23 Rue Jean Baldassini, 69364 Lyon, France

[6]INRAE UMR 1418, CNRS UMR 55557, Université de Lyon, VetAgroSup, Microbial Ecology Centre LEM, 69622 Villeurbanne, France

[7]Plant Sciences, TERRA teaching and research centre, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

[8]Université de Reims Champagne-Ardenne, INRAE, FARE, UMR A 614, 51100 Reims, France

[9]Agroécologie, AgroSup Dijon, CNRS, Université de Bourgogne, INRAE, Université de Bourgogne Franche-Comté, Dijon, France

** Presenting author: sebastien.fontaine@inrae.fr*

Redesigning agrosystems by incorporating more ecological regulations has been suggested as a solution to feed a growing world population while preserving soil assets for future productivity and reducing environmental impacts such as eutrophication and greenhouse gas emissions. However, guidelines for redesigning cropping systems from natural systems remain limited. Reviewing the last knowledge of ecosystem functioning, we outlined four ecological systems synchronizing the supply of soluble nutrients by soil biota to fluctuating plant nutrient demand. This synchrony limits deficiencies and excesses of soluble nutrient, which usually penalize both production and regulating services of agrosystems such as nutrient retention and soil carbon storage. We explain why fertility should no longer be viewed as an intrinsic property of soils but as an emerging property of soil-plant interactions. We also describe how ecological systems promoting synchrony can be installed in agrosystems to improve their sustainability and reduce the use of mineral fertilizers.

Keywords: carbon and nutrient cycling, plant-soil interactions, agroecology, biodiversity and ecosystem functioning, synchrony, nutrient ecosystem economy

Will cover crops alter microbial carbon use efficiency? - First results from the Wageningen Clever Cover Cropping site

Schroeder Julia[1*] and the EnergyLink consortium

[1] *Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany*

** Presenting author: julia.schroeder@thuenen.de*

The aim of EnergyLink is to unravel how crop diversity affects the microbial processing of organic carbon (C) in agricultural soils. Despite microbial respiration causing CO2 losses from soil organic matter decomposition, the microbial transformation of plant-derived C inputs is assumed to foster C stabilisation in soils: microbial-derived compounds likely associate to mineral surfaces which prevents further decomposition. The ratio of metabolised C being shared between microbial growth and respiration, i.e. microbial C use efficiency (CUE) is thought to be a key control determining the fate of organic C in soil. The microbial CUE depends amongst others on the substrate stoichiometry and chemical composition, and therefore on the C inputs entering the soil. We hypothesised that crop diversification leads to the diversification of plant-derived C inputs, which ultimately affects CUE, C processing and potentially C stabilisation.

At the project's core site, the long-term Clever Cover Cropping experiment in Wageningen, cover crops and mixtures of different cover crops are introduced into the crop rotation, representing different levels of crop diversification. The site includes eight treatments in five replicates, resulting in a total of 40 plots. Treatments are bare fallow, cover crops planted as single species (i.e. oats, radish, vetch) and full-factorial mixtures of two and three cover crops. Topsoil samples were taken in August 2022 (close to maize harvest) and December 2022 (cover crops established) to examine if potential effects of crop diversification persist during seasons without direct diversified plant C inputs. Microbial CUE was determined by the 18O-labelling method. First results on microbial CUE, growth, respiration and microbial biomass C will be presented.

Keywords: crop diversification, cover crops, microbial carbon pump, carbon stabilisation, isotopic labelling

Modelling microbial and plant diversity in multi-species agroecosystems: the DIMIVEA project

Rodríguez Antonio[1], Buée Marc[2], Cavalli Daniele[3], Cébron Aurélie[4], Fontaine Sébastien[1], Maron Pierre-Alain[5], Martin Raphaël[1], Trinchera Alessandra[6], Warren Raffa Dylan[6] and Bellocchi Gianni[1*]

[1] UCA, INRAE, VetAgro Sup, Unité Mixte de Recherche sur Écosystème Prairial (UREP), Clermont-Ferrand, France
[2] Université de Lorraine, INRAE, UMR 1136 Interactions Arbres-Microorganismes, Champenoux, France
[3] Council for Agricultural Research and Economics - Research Centre for Animal Production and Aquaculture, Lodi, Italy
[4] Université de Lorraine, CNRS, LIEC, Nancy, France
[5] INRAE/Université de Bourgogne/AgroSup Dijon, UMR 1347 Agroécologie, Dijon, France
[6] Council for Agricultural Research and Economics-Research Centre for Agriculture and Environment, Rome, Italy

** Presenting author: gianni.bellocchi@inrae.fr*

Biogeochemical modelling is used to assess the impact of agricultural activities and climate on ecosystem carbon (C) and nutrient cycles and associated services or disservices, such as biomass production, C emissions/storage and nutrient retention. From an agroecosystem perspective, DIMIVEA is interested in the characterization and dynamic simulation of: i) the physico-chemical and biochemical properties of soils, ii) the functional diversity of plant and soil microbial communities, and iii) their role in the provision of ecosystem services. The simulation of multi-species systems (grasslands, forests, multi-species cropping systems) ensures a detailed representation of the coupled C-N cycles, but the models used remain simplified insofar as biological diversity is reduced to simplistic patterns of interactions with the environment. The creation of simulators based on the information provided by diversity attempts to overcome the paradigm of condensing biological diversity into constant parameters. This opens up new avenues of research to be explored to explain the synchronisation of nutrient demand and supply in multi-species systems by modelling some plant and microbial diversity. By focusing on the characteristics of plant and microbial communities in mixed vegetation canopies, the consortium aims to provide a conceptual framework for extending the potential of models towards a reliable estimation of the ecological processes that support the ecosystem services provided by these vegetal communities. Moving towards the creation of explicit, dynamic and integrated simulators of microbial and plant diversity, DIMIVEA represents a new paradigm that implies that related aspects of biological diversity cannot be ignored in agroecosystem modelling studies.

DIMIVEA integrates different experiences and knowledge in an attempt to model the ecological organisations that enable natural ecosystems and certain agro-systems to be productive, multifunctional (ensuring C storage, purification of drainage water, improvement of soil quality) and low-input. The aim is also to identify the ecological organisations to be favoured according to local soil and climate contexts, and to propose agricultural practices likely to favour them in agro-systems.

For its reflections and conceptualisations, the consortium relies on the aggregate microbial modelling (i.e. stocking/de-stocking microbes) and the experimental devices of the AGROECOseqC project of the European Joint Programme Cofund on Agricultural Soil Management (EJP SOIL). The partnership is committed to organising and leading dedicated workshops within the framework of scientific events such as international conferences and study days, and to progressing towards the writing of a synthesis and positioning article, envisaged as the horizon of a collective reflection in addition to the production of model prototypes.

Keywords: dynamic modelling; plant diversity; microbial diversity; multispecies land covers

Influence of saltwater irrigation on crops and soil microorganisms under a salinity gradient

Anais Chanson[1], Iain J. Gould[2], Nadia Castanheira[3], Ana Marta Paz[3], Asgeir R. Almas[4], Matthew R. Goddard[1]

1. School of Life Sciences, University of Lincoln, Lincoln LN6 7DL, UK
2. Lincoln Institute for Agri-Food Technology, University of Lincoln, Lincoln LN6 7DL, UK
3. Instituto Nacional de Investigação Agrária e Veterinária (INIAV)
4. Norwegian University of Life Science, Faculty of Environmental Sciences and Natural Resource Management, Ås, 1432, Norway

Saltwater contamination is a major contributor to agricultural soil degradation. With rising sea levels and increasing dry periods due to climate change, ground water in temperate coastal areas is becoming increasingly brackish, forcing growers to use part-saline ground water to irrigate their crops in summer. In arid areas, saltwater contamination has been reported to decrease crop yields, but the short- and long-term effects of saltwater contamination in temperate areas have not yet been thoroughly investigated, especially its effects on the soil microbial communities. Our hypotheses are that soil microbial communities will be impacted by saltwater irrigation, and that microbial communities exposed to saltwater irrigation over a long period of time will become increasingly more tolerant to salt. To test these hypotheses, we designed a 3-year experiment using a salinity gradient to irrigate crops. During these 3 years, we will monitor the crop health and yield, as well as study the soil microbial community of each crop. This experiment started last summer, and I will be presenting the crop yield and microbial communities results we have obtained from the first year of this experiment.

Keywords: soil, salinity, microorganism, bacteria, crop, salinity gradient, microbe, irrigation, saltwater

A guideline for appropriate estimates of carbon use efficiency with the ^{18}O method

Rodríguez, Antonio[1*] and Fontaine, Sébastien[1]

[1] *UCA, INRAE, VetAgro Sup, Unité Mixte de Recherche sur Écosystème Prairial (UREP), Clermont-Ferrand, France*

** Presenting author: antonio.rodriguez-hernandez@inrae.fr*

The carbon utilization efficiency (CUE) of soil microorganisms is the fraction of absorbed carbon that is allocated to microbial growth, with the remainder being released as CO_2. The CUE provides information on the carbon metabolism of soil microorganisms, but also on the carbon storage function of soils, since the microbial biomass contribute to soil organic matter building. One of the aims of the AgroecoseqC project is to estimate CUE in soils under a gradient of agroecological intensification to determine if they act as source or sink of carbon during the low and high plant nutrient demand periods. Nowadays there are multiple methods to estimate CUE. In the AgroecoseqC project, we will use the ^{18}O method, which measures microbial gross growth in short periods of time. Unlike the methods based on C substrate addition, with this method we avoid bias in CUE estimation due to the stimulation many new microbial populations that were previously dormant. The main assumption of this method is that all the oxygen in DNA of soil microorganisms comes from water. Hence, the method consists on the addition of ^{18}O labelled and to trace the incorporation of 18O in DNA in order to estimate microbial growth. Meanwhile, microbial respiration is measured by gas chromatography. Then these measures are used to feed a series of equations for estimating CUE. At the time of testing these methods for its application in AgroecoseqC, we have identified some points that are not clear in the published bibliography, being potential sources of uncertainty in the final CUE estimates. These are related with the quantity of oxygen and the impurity levels in the DNA extractions, the needed of spiking those samples with salmon DNA (to reach the minimum oxygen levels measurable by the mass spectrophotometer), and the use of different equations for estimating CUE from the measurements obtained. Here we propose a synthesis of the method, and a guideline to help future users to take the right decisions depending on the situation.

Keywords: carbon cycle; stable isotopes; soil microbials; plant/soil interactions, nutrient cycling

Early detection of microbial carbon stabilization by biomarker-SIP

Rasmussen, Jim[1*], Peixoto, Leanne[1] and Enggrob, Kirsten Lønne[1]

[1] *Department of Agroecology, Aarhus University, Blichers Allé 20, DK-8830, Tjele, Denmark*

** jim.rasmussen@agro.au.dk*

Soil organic matter (SOM) consists of two overall pools: particulate organic matter (POM) - primarily of plant origin – and mineral associated organic matter (MAOM) – primarily of microbial origin. These two pools each constitute about half the C in SOM in cultivated soil, but differ in their residence time with MAOM staying considerably longer than POM. We therefore have an interest in understanding how plant species, management and pedoclimatic conditions drive the microbial formation of this SOM pool. Studies of SOM pool changes require long-term treatments as the background SOM level often is high. In order to estimate the effect plants and management on C stabilization over shorter time spans the use of isotopes is a strong tool – especially when combined with microbial biomarkers. We here will report findings of a novel biomarker stable isotope probing (SIP) based methodology, which allow short-term evaluation of potential microbial C stabilization. The method is based on compound specific isotope analysis of PLFAs – indicating living microbial biomass – and of amino sugars – indicating living and dead microbial biomass. We applied this method in a field study with a perennial wheatgrass and lucerne and found that the legume induced a greater potential for microbial C stabilization within the upper meter of the soil profile. Using amino acid stable isotope fingerprinting and functional gene expression we identified a higher exudation of organic N compounds under lucerne to be a likely explanation for the higher microbial C use efficiency.

Keywords: Plant traits, Microbial C stabilization, Stable isotope probing, Biomarkers.

Validation of microbial community-level physiological profiles (CLPP) analysis in LAMMC and MBG Santiago-CSIC

Skaidrė Supronienė[1*], Renata Žvirdauskienė[1], Ángeles Prieto Fernández[2], Carmen Trasar Cepeda[2], Simona Pranaitienė[1], Arman Shamshitov[1], Modupe Doyeni[1], Ona Auškalnienė[1] and Gražina Kadžienė[1]

[1] *Lithuanian Research Centre for Agriculture and Forestry (LAMMC), Instituto al. 1, Akademija, LT-58344, Kedainiai distr., Lithuania*

[2] *Misión Biológica de Galicia sede Santiago-CSIC (MBG SC-CSIC), Apartado 122, 15780 Santiago de Compostela, Spain*

** Presenting author: skaidre.suproniene@lammc.lt*

A rapid community-level approach to assess sole carbon source utilization in mixed microbial samples may be used to study metabolic potential of microbial community. The method involves direct inoculation of environmental samples into a Biolog Ecoplates and uses color formation by reduction of a tetrazole dye to assess the utilization of 31 carbon sources over a few days of incubation period. Current studies were carried out to validate the microbial community-level physiological profiles (CLPP) analysis in LAMMC and MBG Santiago-CSIC laboratories and subsequently evaluate the influence of the sustainable agricultural practices on the metabolic potential of the soil microbial communities at the moment of maximum nutrient plant uptake by cover plants (i.e., when the soil functions as a C source). Soil samples (total 12) were collected from LAMMC long-term soil tillage experiment. Selected treatments included: ploughing without cover crops, no-tillage without cover crops, and no-tillage with cover crops. A harmonized and unified assay protocol was used in both laboratories. The absorbance data every 24 hours (until 144 hours) obtained in both labs were compared. The values at 72 h or 96 h were considered as the most representative, because degradation of some substrates (e.g., cellobiose, lactose, phenylalanine, glycyl glutamic) could be detected only after incubation of 3 or 4 days. In general, there was an agreement between the results of the two laboratories, although for some substrates the differences were more pronounced. The degradation of these substrates might be affected by the storage during the trip to MBG Santiago-CSIC. The analysis of the data suggests that the substrates more affected are those with lower degradation or with degradation patterns with higher variability. Among the tested treatments, highest metabolic activity was detected in no-tillage treatment with cover crops following by no-tillage without cover crops. The study suggests that the usage of sustainable agricultural practices, such us no-tillage and cover cropping, may positively influence the metabolic potential of soil microbial community.

Keywords: CLPP, metabolic potential, soil microbial community, validation

Variation in soil bacterial community structure under different tillage intensity

Vilkienė Monika[1*], Mockeviciene Ieva[1] and Karcauskiene Danute[1]

[1]Vezaiciai Branch, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Vezaiciai, 96216, Lithuania.

** Presenting author: monika.vilkiene@lammc.lt*

Soil bacterial community structure is the key player identifying the strengthening of ecosystem stability. The biodiversity of soil bacteria and other functional groups can affect a row of soil properties, as well as chemical processes, physical parameters, and indirectly, through previously mentioned aspects - crop yield. Because of methodological difficulties of microbial researched there is still lack of information about variation and functional responses of bacterial communities to different tillage. The aim of the present study was to identify bacterial community composition and diversity under different soil tillage. *Dystric Glossic Retisol* was analysed, geographical coordinates 55º43'38″N, 21º27'43″E. We assessed soil bacterial communities in two different management regimes - deep ploughed and more environmentally friendly - shallow ploughless tillage. Composition and diversity of soil bacterial communities were assessed by sequencing of 16S rRNA genes. All sequences were classified below phylum level. Results show that, two types of bacteria are dominant: *Actinobacteria* and *Proteobacteria.* Their relative abundance ranges about 33% and 28% respectively. The most widespread family was *Micrococcaceae*, and *Hyphomicrobiaceae,* which accounts for 6% and 3% respectively. The number of taxonomic units in different agroecosystems shows the abundance of organisms but does not allow for the estimation of biodiversity; therefore, five different biodiversity indices were calculated. Shannon and Simpson biodiversity indices found that 10 most abundant species were the same in tested soils, just relative abundance various. The ACE, Chao1, and JackKnife biodiversity indices varied in the analysed soils – the highest indices calculated for shallow ploughless soil. This leads us to the assumption that mentioned type of soil management contribute to the protection of soil functions.

Keywords: stakeholders, criterion, framework and model, engagement, values and practices.

REHABILITATION OF SOILS CONTAINING HIGH SALT LEVELS WITH BENEFICIAL FUNGI

Turkolmez Sahimerdan[1], Un Akin[1*], Dervis Sibel[2] and Dikilitas Murat[3]

[1] *GAP Agricultural Research Institution, Sanliurfa, Turkey.*
[2]*Mardin Artuklu University, Kızıltepe High School, Department of Crop and Animal Production, Mardin, Turkey*
[3] *Harran University, Faculty of Agriculture, Department of Plant Protection, Şanlıurfa, Turkey*
** Presenting author:* akin.un@tarimorman.gov.tr

Soil salinity not only reduces the quality of the soil, but also causes ionic imbalance in the plant, competition in the nutrient uptake and toxic effects at high concentration. Combating salinity, which has become a greater stress factor due to impact of drought and high temperatures, is of great importance. In this study, 3 kg soil in pots, adjusted to 12 mS/m EC, under four different treatments (3 different fungi species and control) were compared in a laboratory environment. The experiment was designed with three replications for each subject and one plant in each pot. Fungi species (*Clononotachys rosea*, *Trichoderma* sp., *Taloromyces funiculosus*) were used as soil inoculant to reduce soil salinity. The soil electrical conductivity (EC) was between 9.25 and 9.95 mS/m within 1 month in tomato cultivated soils, while the EC of the plant-free medium was between 10.4 and 11.4 mS/m: thus, the salt content did not differ statistically. EC values of the saline soils was decreased by 21-, 17-, 29 %, respectively, when *Trichoderma* sp., *Taloromyces funiculosus*, *Clononotachys rosea* were applied to tomato plant growing soils. These fungi also decreased the soil EC values by 15-, 16-, 25 %, respectively, in the plant-free environment. The chlorophyll SPAD value of tomato plants grown in saline soils decreased from 22.65 to 0, however, the SPAD values of tomato plants grown in soils with Clononotachys rosea, Trichoderma sp., Taloromyces funiculosus were increased from 22.4-, 25.6-, 24.1 to 29.3-, 50.2-, and 24.5. Similar findings were also observed for the increase in the chlorophyll content of the tomato plant. The fungi mentioned above also contributed to the increase of soil macro (Ca, Mg, K, P) and micro (Fe, Cu, Zn, Mn) element contents, and to the improvement of soil available phosphorus amount (P2O5) with the increase in soil phosphorus content. Fungi inocula induced a statistically significant increase of soil micronutrient concentrations ($p>0.05$). Sodium (Na) concentration in saline soils did not change in inoculated-non-inoculated soils. These findings were interpreted as fungi inocula were not able to assimilate the salt from the soil, but they instead contributed to the release of macro and micro elements that were unavailable under saline conditions, possibly due to their metabolic activities. According to the results of soil analysis at the end of the experiment, it was revealed that the pH value was 7.72 in the control pots and 3.28 in the pots treated with Taloromyces funiculosus, and the EC value was 12.34 and 9.74 mS/m, respectively. Among the

fungi studied, *Taloromyces funiculosus* was found to be more effective than other two fungi on decreasing soil salinity and increasing micronutrient availability to plants.

Keywords: *Trichoderma sp., Taloromyces funiculosus, Clononotachys rosea*, salinity, tomato.

On-farm regeneration of microbiology for healthy agricultural soil

Huber Sabine[1], Rosinger Christoph[1,2], Bieber Magdalena2, Scharf Bernhard1, Sae-Tun Orracha1,2, Bodner Gernot1 and Keiblinger Katharina [1,*]

[1] *Institute of Agronomy, Department of Crop Sciences, University of Natural Resources and Life SciencesVienna (BOKU), Vienna, Austria*

[2] *Institute of Soil Research, Department of Forest- and Soil Sciences, University of Natural Resources and Life Sciences Vienna (BOKU), Vienna, Austria*

** Presenting author: katharina.keiblinger@boku.ac.at*

Agriculture is bearing the full brunt of pressures, related to rising demands of food and fiber higher energy costs and climate change. Promoting soil organic carbon (SOC) sequestration has gained immediate concern for maintaining and restoring soil health in order to ensure continuous soil fertility and functioning. Despite extensive research effort for farming practices that promote soil health applicable measures from farms are still scarce.

In the present study we followed an on-farm approach comprising 21 sites in North-Eastern Austria to compare two farming systems (an innovative 'pioneer' and a standard system) and semi-natural field margins as a reference. Soils from pioneer farms have been managed according to soil health-oriented principles combining multiple measures such as: conservational tillage, diverse crop rotations, intensive cover cropping and organic amendments to improve soil biology. While the `standard" system represents the current state-of-the-art conventional practice on neighbouring fields with the same soil type. The study focused on available nutrients, microbial biomass C, nitrogen (N) and phosphorus (P), ergosterol, potential activities of C-, N- and P-acquiring enzymes as proxies for microbial functioning, and amino sugar concentrations as proxies for microbial necromass. Beside management effects, we also investigated whether differences in soil texture and soil depth (0-5, 5-20, 20-35 cm) affect microbial biomarkers.

Our results indicate that microbial parameters, especially microbial biomass and necromass C, are significantly enhanced in soils of pioneer farming systems. Yet, pioneer cultivation did not reach the levels prevailing in the semi-natural reference system. Likewise, differences between systems were most pronounced in the topsoil and declined with soil depth. Soil texture had a serious leverage on management effects. Significant management predictors were observed for extractable organic C contents, which is an important pathway for microbial-mediated SOC sequestration. Our on-farm approach provides significant knowledge on how farming systems can be changed towards more sustainability and higher C sequestration.

Keywords: conservation agriculture, microbial indicators, SOC sequestration, microbial carbon pump

Influence of agricultural management on soil biodiversity of Mediterranean soils. SOILBIO

Ros Margarita[1*], Alguacil Maria del Mar[1], Delgado Baquerizo Manuel[2], Medrano Luna[2], Alejandre J[3], Ochoa R[4], Sanchez A. R[5], Sacrista D[6], Pascual Jose Antonio[1]

[1]Centro de Edafología y BiologíaAplicada del Segura (CEBAS-CSIC), Campus Universitario de Espinardo - 25, 30100, Murcia, Spain

[2]Instituto de Recursos Naturales y Agrobiología de Sevilla (IRNAS), CSIC, Av. Reina Mercedes 10, E-41012, Sevilla, Spain.

[3]Unión de Pequeños Agricultores y Ganaderos (UPA) C/ Agustín de Betancourt, 17. 3º 28003 Madrid, Spain

[4]Universidad de Cádiz, Departamento de Biología. Cádiz, Spain

[5]Universidad de Córdoba, Unidad de Edafología. Córdoba, Spain

[6]Universidad de Valencia, Unidad de Edafología, Valencia, Spain.

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

Soil biodiversity, including edaphic fauna and microorganisms, are key to the functioning and health of agroecosystems. These organisms interact with each other and with plants and biota of the ecosystem, forming a complex system of biological activity. Soil organisms provide a series of essential services for the sustainability of all ecosystems. These services are a fundamental resource for a sustainable management of agricultural systems. These organisms are primary agents for driving the nutrient cycle, regulating the dynamics of matter soil organic matter, carbon sequestration in the soil and greenhouse gas emissions, modifying the physical structure of the soil and water storage, increasing the amount and availability of nutrients for vegetation and increasing plant health. Soil biodiversity and agricultural production is endangered by challenges as important as climate change and intensive agricultural management, which is leading to soil degradation. Approximately 88% of agricultural soils in Spain have a high risk of degradation.

However, considering that the soil is one of the main C reservoirs, it is necessary to promote management strategies that allow enhancing carbon sequestration in agricultural soils and maintain soil biodiversity (EU Biodiversity Strategy 2030; Farm to Fork Strategy-Green Deal).

The lack of standardized experimental designs in Spain to evaluate the loss of biodiversity and organic carbon within the context of existing climate change, as well as the influence of existing agricultural practices, has led to carrying out the project that is presented.

The Goal of the project that will be develop during 2022-2025 is to evaluate the effect of agricultural practices (conventional, ecological and conservation) on extensive herbaceous crops (wheat, Triticum), through different indicators of biodiversity (microorganisms, meso- and macro-fauna), together with chemical parameters and microbial activity and functionality, allow to evaluate the areas of greatest biodiversity and soil health and C stocks within a context of global change.

Keywords: Biodiversity, Ecosystem, Global change, Indicators, agricultural soils

Soil proteins as biochemical indicators of the plant-soil-microorganism system as a whole

Delporte Fabienne[1*], Vanwindekens Frédéric[1], Abras Morgan[1], Arlotti Donatienne[1,2], Reuter Véronique[1], Leroy Christophe[1], Huyghebaert Bruno[1] and Mesplou Sylvain[3]

[1] *Walloon Agricultural Research Centre, Gembloux, Belgium*

[2] *Interprofession Fruits et Légumes de Wallonie, Gembloux, Belgium*

[3] *Bordeaux Sciences Agro, Bordeaux, France*

** Presenting author: f.delporte@cra.wallonie.be*

Soil macromolecules have been considered with a view to developing indicators of the functionality of the plant–soil-microorganism system, considered as a whole (Mesplou Sylvain, 2022).

Soil proteins, including glomalin thought to be produced (or partially) by mycorrhizal fungi, are attractive candidates to consider as products of the overall soil biological activity, involving both below- and above-ground organisms, as well as inputs of organic matter from dead material. In addition to reflecting biological quality, soil macromolecules have a role in aggregation and carbon storage properties.

Although extensively studied for years, the diversity of extraction protocols and methods for designating the glomalin protein family, the complexity of specific assays and the use of non-specific methods such as Bradford for quantification, have led to some ambiguities and confusions. This study proposes a biochemical indicator of soil quality and fertility based on the non-specific dosage of the total compartment of extractable proteins. After improving the extraction and assay protocols, this model was compared to the one based on glomalin according to the most commonly used published protocol.

Total proteins, in addition to being able to discriminate culture modalities and systems, showed excellent correlations with the amount of microbial DNA, carbon, nitrogen, phosphorus and structural stability. In this comparative study, it was found that total proteins better discriminated cultural practices than glomalins alone. This indicator could potentially be useful in routine analyses.

Keywords: *Proteins, Glomalin, Soil, Indicator*

Linking soil microbial carbon sequestration to cover crop diversification in agricultural soil systems across Europe

***Alexander König*[1]*, Christoph Rosinger*[1]*, Katharina Keiblinger*[1]*, Sophie Zechmeister-Boltenstern*[1]*, Anke Herrmann*[2]*, Erich Inselsbacher*[1]**

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

[2] *University of Agricultural Sciences, Uppsala, Sweden*

** Presenting author: alexander.koenig@boku.ac.at*

Sequestering atmospheric CO_2 into soil organic matter through changes in agricultural practices is an appealing idea to improve soil ecosystem services and to mitigate global change. The old view of carbon (C) stability in soil, based on the intrinsic properties of the organic matter inputs (e.g. lignin content), would lead policy towards greater percentages of recalcitrant organic matter content in crops. Recent research suggests otherwise and that managing how the soil microbiome process C inputs is a more fruitful approach (Sokol et al., 2019, Poeplau et al., 2019). It is therefore to decipher and evaluate the link between the aboveground plant community and the complex belowground diversity of the microbiome and their metabolic processes that mediate C sequestration. Lehmann et al. (2020) proposed a theoretical framework in which the persistence of C in soil can be understood as the outcome of interactions between the molecular variability of organic matter input and spatio-temporal microbial heterogeneities of the soil system.

Within the EnergyLink framework we therefore investigate various microbial markers to illuminate possible physiological changes across several European agricultural field sites with different cover crop management types. Specifically, for detecting shifts in microbial necromass composition and quantity we target amino-sugars (galactosamin, gluctosamine, mannosamine and muramic acid), for evaluating effects on growth rates we measure ^{14}C incorporation into ergosterol for fungi and ^{14}C-leucine incorporation for bacteria and to grasp changes in uptake strategies we test extra cellular enzyme activities for different nutrient classes. Additionally, we determine C:N:P ratio for bulk soil, microbial biomass and above ground plant biomass to estimate stoichiometric imbalances. Here we present preliminary results from our first sampling campaign and discuss implications of diversified cover crops on soil carbon properties on a European scale.

Keywords: cover cropping, soil microbiome, necromass, exoenzymes, microbial growth

On-farm evaluation of microbial physiology and carbon-use efficiency on innovative pioneer farming systems

Rosinger Christoph[1,2*], Forer Valentina[3], Sandén Hans[3], Bodner Gernot[2], Bernardini Luca Giuliano[2], Bieber Magdalena[1], Huber Sabine[2], Sae-Tun Orracha[1,2], Mentler Axel[1], Keiblinger Katharina[1]

[1] *Institute of Soil Research, Department of Forest and Soil Sciences, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria*

[2] *Institute of Agronomy, Department of Crop Sciences, University of Natural Resources and Life Sciences (BOKU), Tulln an der Donau, Austria*

[3] *Institute of Forest Ecology, Department of Forest and Soil Sciences, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria*

** Presenting author: christoph.rosinger@boku.ac.at*

Increasing pressure on arable land related to climate change as well as recent policy frameworks have generated widespread interest on the effect of sustainable management practices on soil organic carbon (SOC) sequestration into arable soils. As soil microorganisms and their functioning are the key drivers of long-term SOC accrual, we require a better understanding of the underlying microbial physiological mechanisms governing SOC sequestration into arable soils. In this regard, the efficiency of soil microorganisms to utilize carbon (CUE) has recently been suggested as a key leverage factor for the sequestration of SOC; however, on-farm studies investigating the effect of conservation management practices are scarce.

Here, we present results from a 21-site on-farm study in North-Eastern Austria, where we evaluate soil bacterial and fungal growth rates, respiration and CUE at innovative 'pioneer' farming systems, adjacent conventional farming systems and undisturbed reference soils (i.e., field margins) across a wide range of arable soil types at three soil depths (0-5, 5-20 and 20-35 cm). These pioneer farming systems have the operational target of increasing SOC and biological activity by differently combining measures such as high rotation diversity, multi-species cover crop mixtures, minimum tillage and organic fertilization.

We show that bacterial growth rates were lowest in the conventional farming systems and highest in the reference systems; fungal growth rates on the contrary showed the opposite trend. Moreover, we observed significant effects of site and soil depth on the physiology of soil microorganisms: growth rates tended to be higher in light-textured soils and decrease with soil depth. Against our expectations, CUE was highest in the conventional farming systems and lowest in the reference soil systems. Moreover, CUE increased with soil depth. These results suggest a complex interplay between site and microbial physiology characteristics and a potential link between the relative C limitation of soil microorganisms and their CUE: with higher labile C inputs (through e.g. cover cropping or organic fertilization in the pioneer farming systems or through the permanent plant cover in the undisturbed reference systems), C limitation might be released relative to other nutrients, thus reducing CUE. This implies that other nutrients such as phosphorus or nitrogen might become more important drivers of microbial metabolism and physiology.

Our results challenge the current perception of the role of microbial CUE for the sequestration of SOC through conservation agriculture practices, and we suggest that other parameters such as bacterial and fungal biomass turnover might be more promising predictors of SOC accrual. Clearly, more studies are required to decipher the key aspects of microbial-driven SOC sequestration in agroecosystems.

Keywords: agroecosystems; carbon-use efficiency; conservation agriculture practices; microbial growth rates; on-farm approach

Benchmarking soil biodiversity through eDNA metabarcoding

Lambrechts Sam[1*], De Vos Bruno[1]

[1] *Research Institute for Nature and Forest, Geraardsbergen, Belgium*

** Presenting author: sam.lambrechts@inbo.be*

Critical knowledge gaps about soil health in relation to specific land-use practices hinder the design and implementation of policies that could protect soil functions and ecosystem services. A current specific area of weakness is characterising, quantifying, and monitoring soil biodiversity. In light of new policy priorities (e.g. EU Biodiversity Strategy for 2030) on biodiversity conservation and bio-resource management, there is a need for reliable indicators to facilitate the impact assessment of policy decisions. Due to the enormous diversity of life in soil, the development of indicators with high relevance for impact assessment studies, policy design and biodiversity monitoring, necessitates a broad coverage of the soil biome, from microorganisms to meso- and macrofauna. To acquire such coverage within a reasonable amount of time, the emerging technique of eDNA metabarcoding might be a viable option to recover as much as possible of the biodiversity present. Genetics can be used to develop indicators for each land use type (e.g. grassland, cropland), specific soil functions (e.g. organic matter and nutrient turnovers, water infiltration) or soil threats (e.g. soil contamination, salinisation, compaction). Additionally, the presence of organisms of interest from a functional point of view (e.g. plant symbionts and pathogens, decomposers, bioremediators) could be evaluated. Sufficient coverage is however dependent on the specific biodiversity recovered, which is in turn highly dependent on the sampling protocols and protocols for DNA analysis used. Therefore, the aim of this research is to evaluate the sampling and molecular protocols used for the 2018 and 2022 LUCAS Soil biodiversity component. As part of EJP-SOIL WP6, we performed double sampling of 11 biopoints in Belgium from the 2022 LUCAS Soil survey to analyse the taxonomical and functional diversity recovered when comparing LUCAS and newly developed national protocols by means of eDNA metabarcoding. For the 2018 LUCAS Soil biodiversity campaign, one DNA-extraction method and four primer sets were chosen to cover the broadest possible spectrum of soil organisms. We evaluate whether the extraction of DNA from a larger amount of soil, mixing more subsamples, analysing an additional deeper soil layer, and the amplification of DNA with an additional three primer sets is beneficial to increase the biodiversity detected. This might especially be important for soil organisms other than prokaryotes and microbial eukaryotes, for which the methodology is less well established. The inclusion of sampling protocols, DNA-extraction methods and primer sets that target functional groups (e.g. Arthropoda and Annelida) which might have been partially overlooked by the

methodology used for the 2018 LUCAS Soil biodiversity component, could contribute towards capturing a better picture of the status of the European soil biomes.

Keywords: Soil biodiversity; eDNA metabarcoding, LUCAS, monitoring, indicators

Wheat roots can modulate soil microbiome to increase sustainability and efficiency of nitrogen fertilizer inputs.

Hernandez-Soriano Maria C.[1*], Warren Fred J.[2], Wingen Luzie U.[1], Urbina Ifigenia[1], Acedo Alberto[1], Griffiths Simon[1], and Miller Tony[1]

[1] *John Innes Centre, Norwich, UK*

[2] *Quadram, Norwich, UK*

[3] *Biome Makers Inc., Valladolid, Spain*

** Presenting author: maria.hernandez-soriano@jic.ac.uk*

Wheat is the most widely grown crop in agricultural system and is the staple crop for 35% of the world population, providing 20% of daily protein and food calories. To meet the sustainable development goal of 'food security' it is necessary to maintain healthy soils and to restore degraded agricultural land. Effective strategies require identifying, and targeting, the parameters that define a healthy soil but also the effectors. The WISH-ROOTS project (Wheat Improving Soil Health through Root traits) addresses key marker of soil health: the capacity to provide essential nutrients to plants and soil organisms while maintaining an optimum balance, focusing on nitrogen (N) cycling and impact of root architecture in soil structure.

Application of N fertilisers to agricultural soils supports half of the world's food production. However, approximately 50% of this N is lost worldwide to the environment by leaching/gaseous emissions due to rapid transformation by soil bacterial nitrifying communities shortly after fertilizer application. Biological nitrification inhibitors (BNIs) exuded from the roots of certain varieties of plants can reduce loss of N-fertilizer by delaying N transformation. Particularly, some historic landraces of bread wheat (*Triticum aestivum L.)* have shown evidence of BNI activity in their root exudates. Introducing this agronomic trait into modern cultivars could improve the efficiency of use of N-fertilizer by crops while reducing N loses to the environment.

Performing 16S sequencing analysis for rhizosphere soil from modern wheat varieties and historic landraces with BNI capacity has revealed a significant segregation in rhizosphere microbiome composition between elite and historic cultivars, with significant differences in the abundances of guilds involved in the transformation of N in soil (*Nitrospiraceae, Nitrosomonadaceae* and *Nitrosococcaceae*). The prediction of the functions of these communities using PICRUSt2 and shotgun sequencing has confirmed differences for several associated ecological functions related to N transformation between moder and historic cultivars, including aerobic ammonia oxidation and nitrification.

Wheat cultivars with contrasting BNI capacity were grown in the field under three regimes of N-fertilizer application (none, one and two applications of 48 kg N/ha). Six plots were established for each cultivar and N dose. Roots and rhizosphere soil were sampled at tillering, flowering and immediately after harvest. Root architecture and rhizosphere nitrifying communities were examined.

Root image analysis revealed a significant increase in number of root tips, root length and depth with increasing N-fertilizer for both cultivars. Rhizosphere soil DNA extraction and amplification of the 16S rRNA hypervariable V3-V4 region (Illumina) revealed significant differences in rhizosphere microbiome composition for both cultivars and for the N dose, particularly at flowering. Significant differences in *Nitrososphaerales* abundance were consistent with the contrasting BNI capacity of the wheat cultivars. Increasing N dose resulted in a significantly greater *Nitrososphaerales* abundance in the rhizosphere of the elite wheat cultivar, while *Nitrososphaerales* was significantly reduced in the rhizosphere of the wheat landrace.

Control of N-cycling using the BNI trait identified in historic wheat cultivars provides a sustainable strategy to optimize N-fertilization in wheat crop systems.

Keywords: Rhizosphere microbiome; Nitrogen cycling, Wheat rhizosphere, Wheat root architecture

Influence of long-term application of different tillage system with cover crop and glyphosate management practices on greenhouse gas emissions

Shamshitov Arman *, Doyeni Modupe, Suproniene Skaidre, Versuliene Agne, Pranaitiene Simona, Auskalniene Ona and Kadziene Grazina

Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Instituto al. 1, Akademija, LT-58344 Kedainiai, Lithuania

** Presenting author: arman.shamshitov@lammc.lt*

Tillage is an important agricultural practice used to prepare land for crop production by ploughing, cultivating, and levelling the soil. However, these activities can significantly impact soil organic matter content, nutrient availability, microbial activity, and associated greenhouse gas (GHG) emissions. Arable lands are one of the sources of GHG that are influenced by the chemical and physical properties of the soil and are an important contributor to climate change. Accordingly, different tillage practices can impact GHG emissions in different ways. Therefore, this study aimed to evaluate the long-term management of agricultural practices such as different tillage systems along with cover crops and glyphosate on GHG emissions. Field trials were a long-term study consisting of three tillage systems (no-till, conventional and reduced), cover crops (white clover and no cover crops), and glyphosate with the cultivation of soil seed rape. Field trials was consisting of three tillage systems (conventional tillage, reduced tillage, and no-tillage), cover crops (with and without cover crops), and glyphosate (with and without glyphosate) with the cultivation of oil seed rape in 2022 in the crop rotation of 5 sequences. 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. By studying these management techniques, the soil physicochemical properties being a critical factor in GHG emissions were also monitored for the period under consideration. The study results showed that N2O emissions were significantly higher in reduced and conventional tillage treatments in combination with glyphosate and cover crops treatment respectively. For CH_4, reduced tillage and cover crop treatments had higher emissions while CO_2 emissions varied across all treatments under study. Interestingly, GHG emissions flattened out in all the treatments after the harvest (end of the cultivation period) signifying that the maximum uptake of nutrients by the main plants during the cultivation period impacted on the GHG fluxes. Additionally, GHG emissions were weakly correlated to water filled pore spaces (WFPS), soil moisture and soil temperature. These initial results suggested that reduced and conventional tillage could negatively impact on plants function in association with their nutrient release/uptake especially as it related with the temperate climatic conditions in Lithuania.

Keywords: soil, greenhouse gas emission, tillage, glyphosate, cover crops

C3 Sustainable soil management

Session Description

Involved projects: SoilCompaC, SCALE, SoilX

Conveners: Lisbeth Johannsen (BAW), Lorena Chagas (SLU), Loraine ten Damme (SoilX)

Sustainable soil management requires consideration of the multifunctionality of agricultural landscapes, in which the management of natural resources may be in conflict with environmental and socio-economic demands. The need for efficient, climate-smart and environmentally-friendly production of safe, high-quality agricultural products that benefit the social and economic conditions of the farmers and local communities, places high demands on soil functions and soil management. Furthermore, the challenges presented by climate change with projected increases in the occurrence and severity of extreme events, add complexity to achieving sustainable soil management. The multiple land uses and involvement of multiple stakeholders require an integrated approach between policy and practice to maintain or improve sustainable soil management. Strategies for sustainable soil management aim at, among others, the prevention and mitigation of soil compaction, minimisation of soil erosion and improvement of soil water retention and infiltration capacity. While measures to achieve these strategic goals are generally known, a deeper understanding is needed on extents of sustainability gains as well as possible trade-offs with different sustainability targets in regional European contexts. The already acute threat of soil compaction is expected to worsen in the future due to the continued trend towards heavier machinery and effects of climate change. Despite the well-documented negative consequences of compaction on key soil functions, there is limited data of the spatial extent, distribution and severity of soil compaction. Moreover, detailed information on the risk of soil compaction, as well as its impacts on key soil functions such as productivity, climate regulation and water cycling in a context of climate change is lacking. Therefore, obtaining a better knowledge of these questions is crucial for a better guidance of sustainable soil management and alleviation of soil compaction today and in future climate. In the context of soil erosion, on-site soil management of agricultural fields also has potential off-site impacts. Water and sediment transport from agricultural fields to other landscape elements such as water courses or infrastructure depends both on soil management and the connectivity within the landscape. Additional knowledge of surface processes at multiple scales and across landscape elements is needed. Through modelling of soil erosion processes and the implementation of mitigation measures, the effects of soil erosion by water can be mitigated by increasing the focus on water and sediment connectivity in the landscape. Measures such as cover cropping, organic amendments and reduced tillage are expected to benefit soil water retention and thus mitigate drought stress in cropping systems. Evidence of these benefits however is very limited. Furthermore, it is largely unknown to what extent such measures could mitigate future drought and precipitation extremes. Even when some measures may be more effective than others, they may not be equally acceptable for farmers. To enable transitions towards more sustainable soil management, possible inhibitors need to be identified and addressed through adjustments in governance. In this session, we focus on sustainable soil management, especially in regard to these three themes and we kindly invite interested parties to submit an abstract with results of their novel research.

SCALE – Managing Sediment Connectivity in Agricultural Landscapes for reducing water Erosion impacts

Lisbeth L. Johannsen[1*], **Elmar Schmaltz**[1] **and the SCALE team**[2]

[1] *Federal Agency for Water Management, Institute for Land and Water Management Research, Petzenkirchen, Austria*

[2]*Partners at AIS, AU, BFW, CREA, CSIC, INRAE, IUNG, LUKE, SupAgro, ULBF, UNIPA and VPO*

** Presenting author: lisbeth.johannsen@baw.at*

In the SCALE project we intend to improve the knowledge of sediment connectivity and how to model it at different scales and locations, to enhance our understanding of soil erosion by water, sediment transport and landscape connectivity. This will help to advance the efficient implementation of mitigation measures, which account for regional differences in erosion damages supported by erosion modelling at different scales. We present the current state and results of the project, which contribute to an enhanced knowledge on soil erosion processes, modelling, the implementation of mitigation measures and policy adaptation across landscapes in Europe. These include a survey on soil erosion modelling approaches across Europe, which revealed the use of a wide range of different models, datasets and parameters to produce soil erosion maps and a lack of focus on connectivity for the implementation of mitigation measures. Further, we collected information on mitigation measures, with the purpose of building a comprehensive inventory of the measures in use to mitigate runoff induced erosion across Europe. A dataset of 14 agricultural catchments from 8 European countries, which have different types of erosion problems, was gathered to investigate the implementation of mitigation measures against on-site and off-site impacts of water erosion. The local costs of implementing erosion mitigation measures have also been investigated, as well as local stakeholders' perception of soil erosion and the implementation of mitigation measures aided by modelled risk assessment. Guidelines on the current and improved implementation of erosion measures and connectivity elements depending on scale and modelling approach are being developed through modelling scenarios in several of the described catchments. This so far resulted in two scientific papers analysing the use of the model RUSLE for country-wide erosion prediction and the first large-scale sediment connectivity analysis in the agricultural lands of Finland.

Keywords: soil erosion, sediment connectivity, mitigation measures, sustainable soil management

Mapping and alleviating soil compaction in a climate change context (SoilCompaC)

Chagas Torres Lorena[1*], Tommy D'Hose[2], Elmar Schmaltz[3], Owen Fenton[4], Thomas Keller[1,5], Florian Schneider[6], and Mathieu Lamandé[7]

[1] *Swedish University of Agricultural Sciences, Uppsala, Sweden*

[2] *Flanders Research Institute for Agriculture, Fisheries and Food, Merelbeke, Belgium*

[3] *Federal Agency of Water Management, Vienna, Austria*

[4] *Agriculture and Food Research Organisation, Carlow, Ireland*

[5] *Agroscope, Zürich, Switzerland*

[6] *Thünen Institute, Braunschweig, Germany*

[7] *Aarhus University, Tjele, Denmark*

** Presenting author: lorena.chagas.torre@slu.se*

Soil compaction is a major threat to soil productivity and ecological and hydrological soil functioning. Although adverse impacts of compaction on soil properties and functions are relatively well documented, there is little data of the spatial extent, distribution and severity of soil compaction. Furthermore, our understanding of how compaction affects the carbon cycle is limited, and we lack information on the compaction risks for different pedo-climatic zones and cropping systems in Europe, as well as how these risks may evolve due to climate change. The SoilCompaC project directly addresses these knowledge gaps. SoilCompaC will quantify interactions between soil compaction and climate, and present information on how to assess, detect, recover and minimize soil compaction, thereby providing a basis for sustainable soil management in Europe. SoilCompaC will realize this by: exploring novel technologies such as remote sensing and data-driven, reciprocal modelling to quantify the extent and severity of the soil compaction for different pedo-climatic conditions in Europe; conducting an extensive literature review on the recovery of compacted soils; using modelling approaches to predict current and future compaction risks; and applying a modelling framework combining a compaction, root growth and soil-crop model in combination with field measurements to quantify impacts of soil compaction on soil key functions, focusing on carbon storage but considering also crop productivity and water balance. The activities in SoilCompaC will improve our understanding of compaction impacts on key soil functions and how this is affected by climate change, to synthesize information and identify novel methods for detection and alleviation of compaction, as well as to provide a solid basis for estimation of compaction risks to guide sustainable soil management today and under future climate.

Keywords: soil compaction; recovery; soil carbon; sustainable soil management

Soil management to mitigate climate change-related precipitation eXtremes (SoilX)

Holzkämper, Annelie,[1*], Pullens, Jeroen W.M.[2], ten Damme, Loraine[2*], D'Hose, Tommy[3], Mehdi, Bano[4], Leonhardt, Heidi[4], Höckert, Jenny[5], and the SoilX team[6]

[1] Agroscope, Zürich, Switzerland

[2] *Aarhus University, Foulum, Denmark*

[3] *Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Ghent, Belgium*

[4] *University of Natural Resources and Life Sciences (BOKU), Vienna, Austria*

[5] *Swedish University of Agricultural Sciences (SLU), Skara, Sweden*

[6] *Partners at AGSC, AU, ILVO, BOKU, SLU, INIA-CSIC and CZU*

** Presenting author: ltd@agro.au.dk*

With climate change, both drought and heavy precipitation are becoming more frequent. SoilX investigates the possibilities to mitigate impacts of such extremes on crop productivity and other ecosystem services (i.e. soil protection, nutrient cycling, carbon sequestration) through improved soil management practices. We are conducting a harmonized field sampling campaign across Europe to measure the impacts of soil management improvements on soil hydraulic characteristics. Based on existing and new measurements from this project, we will evaluate possible benefits and drawbacks of soil management changes with regard to productivity gains and other ecosystem services under current and future climate conditions. This work involves the use of several biophysical models to evaluate the robustness of impact estimates towards structural model uncertainties. Socio-economic factors that hinder or enable the adoption of improved soil management practices are identified through farmer interviews. The synthesis of the project findings will ultimately improve the knowledge base for advising farmers and policy makers at the European and regional levels and thus contribute to the successful implementation of soil structural improvement measures in Europe.

Start date: 1 November 2022 (24 Months)

Keywords: Climate adaptation; Farmer behaviour; Soil hydrology; Soil management; Soil/crop systems modelling

Effect of soil tillage, cover crop and wheel load on track depth, soil penetration resistance and maize yield in the Pannonian basin in 2022

Gerhard Moitzi[1], Mathieu Lamandé[2], Helmut Wagentristl[1]

[1] Experimental Farm Groß-Enzersdorf, Department of Crop Sciences, University of Natural Resources and Life Sciences, Vienna, Schloßhofer Straße 31, A-2301 Groß-Enzersdorf, Austria

[2] Department of Agroecology, Aarhus University, Blichers Allé 20, PB 50, DK-8830 Tjele, Denmark

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

In the context of the SoilCompaC project (EJP SOIL), a three-factorial field experiment at the Experimental Farm Groß-Enzersdorf (AT) was established to investigate the effect of the load of a tractor slurry tanker combination (high, medium, low), soil tillage for cover crop (ploughing, cultivating, no-tillage) and cover crop mixture (deep rooted, shallow rooted, without cover crop) on soil physical and agronomic parameters.

The soil (0–30 cm) is a silty loam with 19.9% clay, 44.1% silt, and 36.1% sand with soil organic carbon of 16.3 g kg^{-1} and is classified as Calcaric Chernozem. The year 2022 was very dry with a mean annual precipitation of 392 mm and temperature of 11.9 °C. In the three-factorial design, cover crop mixture and load were nested in tillage of the cover crop. The plot size for a tillage treatment was 30 m x 27 m and for cover crop within tillage of the cover crop 30 m x 9 m. The total field trial size was 7290 m^2, with three replicates for each factor.

Wheeling with a tractor-slurry tanker combination (10 m^3, pendulum tandem axle) was done on 21st April 2022 in three load levels: high load: 19540 kg total weight, 30 kN max. wheel load; medium load: 14825 kg total weight, 22 kN max. wheel load, low load: 10030 kg total weight, 22 kN max. wheel load. Tire inflation pressure was fixed for the tractor wheels with 300 kPa and for the slurry tanker wheels with 400 kPa. The average soil moisture content was 24.4%. After passing the plots, the track depth as a vertical distance between the middle tire print and the horizontal rigid slat was measured with a ruler. Maize (cv. P9610, FAO 370) was seeded (without tillage before!) directly on 2nd May 2022 in tracks (generated by the tractor slurry tanker combination) and on the area with no tracks using a precision seeder in a row distance of 75 cm. Maize harvest was done on 21st September 2022 in each plot by cutting the maize plants of 2 m rows manually.

Soil penetration resistance was measured three times (spring – 21th April, summer – 1st June, autumn – 18th October) in the tracks generated by wheeling of the tractor-slurry combination and in the unwheeled area with a a cone penetrometer (Eijkelkamp, The Netherlands; 60° cone and 1 cm^2) to a depth of 40 cm. For each plot, five/seven cone penetrations were recorded. The mean track depth was highest at 5.69 cm in the total-filled slurry tanker followed by the half-filled slurry tanker (4.79 cm) and empty slurry tanker (4.07 cm.). Soil penetration resistance was significant affected by tillage, cover crop and load in all three dates. Results for the 1st soil penetration measurement for tillage: ploughing>no-tillage>cultivating; for cover crop: without cover crop = shallow cover crop > deep rooted cover crop; for wheel load: high load > medium load > low load > un-wheeled. Overall the mean grain of maize yield was reduced by 37% through soil compaction generated by high wheel load.

Keywords: cover crop, wheel load, track depth, soil penetration resistance, crop yield

Acknowledgement: The field trial is part of the EJP SoilCompaC project. The research is also Danish-funded DFF RESCUE.

Policies for sustainable soil management – ambitions, knowledge gaps and incoherencies

***Martin Hvarregaard Thorsøe*[1*] and Morten Graversgaard[1]**

[1] *Department of Agroecology, Aarhus University, Tjele, Denmark*

** Presenting author: martinh.thorsoe@agro.au.dk*

In the EU Soil Strategy, sustainable soil management is emphasized as the way to prevent degradation and restore unhealthy soils. Sustainable soil management encompass a set of practices that is able to maintain the soil in, or restore it to, a healthy condition yielding multiple benefits, including for water and air. These practices increase soil biodiversity, fertility and resilience which are needed for the vitality of rural areas. However, soil management is complex, since a series of soil physical, biological and chemical processes have to be taken into account. Furthermore, soil management is connected with a range of aspects like different land-uses, multiple public policies and socio-cultural values. Based on research carried out in the context of several EJP SOIL projects (EJP SOIL WP2, Scale, and Road4Schemes), this presentation will discuss the ambitions, knowledge gaps and policy incoherencies of sustainable soil management. Focusing on case studies regarding certification of carbon removals and erosion mitigation, particular attention will be given to the way in which institutional arrangements can be used to enable a transition to sustainable soil management. We argue that achieving sustainable soil management requires a systemic reorganization of the agri-food system and the support mechanisms under the CAP.

Keywords: EU soil strategy; Systemic intervention, policy incoherencies, sustainable soil management

The Importance of Data Resolution in Regional Scale Modelling for Erosion Prediction and Soil Indicators

Callewaert Seth[1*], Deproost Petra[1], Oorts Katrien[1], Luts Dries[1] and Swerts Martien[1]

[1] Department of Environment & Spatial Development, Government of Flanders, Koning Albert II-laan 20 bus 8, 1000 Brussels, Belgium

** Presenting author: seth.callewaert@vlaanderen.be*

Erosion is a significant environmental issue in Europe, with over 20% of the continent's land area affected by soil erosion. The impacts of erosion on European ecosystems include soil degradation, loss of biodiversity, and water pollution, among other environmental problems. Erosion models have been developed to simulate erosion processes and evaluate the impacts of erosion on European ecosystems. However, the spatial resolution of the data used in these models is an important factor that needs to be investigated to improve the accuracy of the models and provide more effective erosion control and mitigation strategies.

At present, many erosion models in Europe use low-resolution data, such as data obtained on European and/or global scale, which may not capture the complex interactions between different environmental factors and erosion processes. High-resolution data, such as local remote sensing data, national soil maps, national geodatabases and high-resolution topographic data, can provide more detailed information on the landscape characteristics, vegetation cover, soil properties, and land use practices, which are critical factors influencing erosion rates.

In Flanders, a lot of high-resolution datasets are available and are being used in regional erosion modelling. However, at European scale, these high-resolution data are not being used which leads to divergent values in both model outputs. These uncertainties could potentially lead to conflicts between the different stakeholders and can often lead to distrust in the use of models for policymaking.

In this study the effect of the difference in resolution of the input data for the model has been evaluated. By upscaling the high-resolution dataset and running the same model, the impact of the resolution on the output has been assessed. Different set-ups were tested, where the data resampling takes place at different moments in the modelling process to better understand how the resolution affects modelled outputs.

Despite the fact that this study was only carried out for erosion modelling, it poses a relevant question for all soil indicators. In many cases, spatial models must rely on interpolations and up- and downscaling techniques in order to create a comprehensive overview of the modelled characteristics for a chosen resolution, and therefore they always deal with large uncertainty and a significant number of errors. By using the highest resolution of available data these errors can be reduced, however, this can possibly increase computing time, or this could lead to the emergence of other types of error.

In conclusion, this study evaluates the importance of considering spatial resolution in erosion models to improve the accuracy of the results and provide effective erosion control and mitigation strategies. By using high-resolution data and comprehensive guidelines for the model, the errors and uncertainties associated with spatial models can be reduced, enabling policymakers to make informed decisions. The impact of the spatial resolution on the model output should be considered in policymaking at regional scale and should always be kept in mind in decision making.

Keywords: Erosion Modelling, Spatial Resolution, High-Resolution Data, Soil Indicators

Assessment of potential compaction risk of arable soils in Switzerland

Weiss Lena[1*], Petter Gunnar[4], Kuhwald Michael[2,3], Keller Armin[4] and Keller Thomas[1,5]

[1] *Agroscope, Zürich, Switzerland*

[2] *Kiel University, Kiel, Germany*

[3] *Aarhus University, Aarhus, Denmark*

[4] *Kompetenzzentrum Boden, Zollikofen, Switzerland*

[5] *Swedish University of Agricultural Science, Uppsala, Sweden*

** Presenting author: lena.weiss@agroscope.admin.ch*

It is well known that soil compaction has negative effects on soil productivity and soil functioning. With a continuing trend to larger and heavier agricultural machinery, the risk of soil compaction due to agricultural traffic is likely increasing. Soil compaction risk assessments at national scales could help identify susceptible areas and critical field operations, which could guide towards more sustainable arable cropping. However, such data are currently missing in most countries. The aim of this work is to assess the potential compaction risk of arable soils in Switzerland for different major arable crops and critical field operations such as harvest during autumn.

The overall approach is based on a previously established modelling framework that combines simulations of soil moisture using a soil-crop-atmosphere model with estimates of soil stress and soil strength for different combinations of machinery, soils and weather conditions. We collect typical machinery data (wheel loads, tyres, *etc*.) for each field operation, which is used to calculate soil stress based on analytical equations for stress propagation. Soil strength is calculated by means of pedotransfer functions, using simulated soil moisture and basic soil information.

We performed simulations with climate norm weather data from the last 30 years to quantify compaction risk probabilities for the time windows of typical field operations. We focused on subsoil compactions, and therefore, calculations were made for 40 cm soil depth. Results are visualized as risk maps that indicate which areas of Switzerland are prone to a risk of soil compaction for the different field operations. Additionally, we computed the maximal wheel load carrying capacity (i.e., maximal wheel load where soil stress ≤ soil strength). Comparing the maximal wheel load to typical wheel loads used for different machinery gives some insights about the seasonal dynamics and patterns of soil compaction risks.

At the Annual Science Days, we will present soil compaction risk maps and maximal wheel load carrying capacity dynamics for different crops in Switzerland.

Keywords: soil compaction; risk map; wheel load carrying capacity; sustainable arable cropping

Subsoiling and bio-subsoilers to alleviate subsoil compaction in three maize-based cropping systems on a sandy loam soil

D'Hose Tommy[1*], Vanderhasselt Adriaan[1,2] and Cornelis Wim[2]

[1] *Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium*

[2] *Department of Environment—Soil Physics Unit, Ghent University, Ghent, Belgium*

** tommy.dhose@ilvo.vlaanderen.be*

The past few decades have seen an increased strain on the subsoils' capacity to fulfil several ecological and agricultural services. The use of ever heavier farming machinery and the increased frequency of field traffic under wet, and thus weaker soil conditions have seriously increased the risk of compaction of deeper soil layers. These more compacted subsoils constrain water infiltration and storage and increase the mechanical impedance to deeper root growth. While a compacted topsoil can more easily be remediated by natural processes (e.g. swelling-shrinking, freezing-thawing) and by regular tillage operations, compacted subsoils will be much harder to handle. Although deep tillage operations, like subsoiling have been shown to quicky and effectively loosen up compacted subsoil layers in a wide variety of soil types, effects on crop production are variable and the risk of recompaction is high. On the other hand, some deep rooting plant species such as alfalfa have the capacity to penetrate compacted subsoil layers and create stable biopores (bio-susoilers). While the effects of bio-subsoilers are considered to be more sustainable, alleviation of compaction occurs rather slow. Therefore, a multi-year field experiment was set up on a sandy loam soil to assess short and medium term effects of both subsoiling and two deep rooting (cover) crops (i.e. alfalfa and fodder radish) in three maize-based cropping systems. The study site showed the presence of a highly compacted layer at the interface between topsoil and subsoil (30-50 cm; >6 MPa). The combination of both subsoiling and deep rooting (cover) crops was included to evaluate the potential role of the latter in protecting the mechanically loosened subsoil from recompaction. This experiment demonstrated that subsoiling is an effective remediation measure to deal with subsoil compaction (i.e. lowering both bulk density and penetration resistance). The crop response was however highly variable and was only positive (+8%) when root exploration of the newly made accessible subsoil was advantageous (i.e., drought). Besides its inconsistency, the effects also proved to be very short-lived under a standard monoculture of forage maize. Adjusting the crop rotation and including deep rooting (cover) crops, like fodder radish and alfalfa, helped to partially stabilize the disrupted subsoil and reduce recompaction. The difference between both crops was limited. Despite alfalfa's longer growing period and the limit of tillage during its cultivation, the quicker growing fodder radish had a slightly better effect in this respect. While both fodder radish and alfalfa succeeded in penetrating the compacted subsoil without previous disruption by subsoiling, no significant improvements of the measured soil physical parameters were observed.

Keywords: Deep tillage, bio-subsoiler, maize-based cropping system, subsoil compaction, alleviation

Soil physical parameters and winter wheat productivity on headlands: field scale analyses in Lithuania

Karcauskiene Danute*, Kadziene Gražina[2] and Agne Versuliene[2]

[1]*Vezaiciai Branch, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Vezaiciai, 96216, Lithuania.*

[2]*Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Akademija, 58344, Lithuania.*

** Presenting author: danute.karcauskiene@lammc.lt*

Headlands are subjects to greater machinery trafficking than in mid-field area so physical soil degradation occurs in this zone which increases over time. These traffic areas can be compacted and may cause considerable yield loss. The investigations of such areas are very important for the alleviation of soil compaction and sustainable use. The aim of this study was to evaluate soil physical parameters: penetration resistance (PR), bulk density (BD), amount of water stable aggregates (WSA) and productivity of winter wheat (yield and thousand kernel weight (TKW)) in the headlands occurred during long-term intensive agriculture. Two field experiments were initiated at the Lithuanian Research Centre for Agriculture and Forestry in spring of 2022 in soils differing in genesis on two geographical sites. One of them was established on *Endocalcari-Epihypogleyic Cambisol* (55°24'38.4"N 23°51'00.1"E, Central Lithuania) and the other field experiment was set up on *Bathygleyic Dystric Glossic Retisol* (55°43'26.1"N 21°30'15.8"E) (Western Lithuania). The experiments were carried out in winter wheat in two field zones: in the headland and in the mid-field area. Each experiment was performed in 5 replications of 36 m^2 size plots placed in a row. The results obtained in both studied soils showed that the values of the physical parameters describing the soil condition were essentially worse in the headland than in the mid-field. Soil BD (at a depth of 15-30 cm) reached the critical values 1.54-1.70 Mgm^{-3}, at which plant growth is limited or even stopped. Soil PR in headland exceeded critical limit of 2MPa at 10 cm depth in *Cambisol* and at 4 cm depth in *Retisol,* while in the mid-field this limit reached in deeper layers. Lower amount of WSA was also obtained in compacted headlands than in mid-field in both examined soils. Winter wheat grain yield in compacted (headland) soils was by 13.2% and 12.3% lower compared with non-compacted soil. A similar tendency was determined with TKW. These data contribute to the development of sustainable technologies for reducing soil degradation in headlands.

Keywords: headland, soil bulk density, water stable aggregates, grain yield.

The effect of different cover crops on soil properties, soil compaction and yields of winter wheat

Fér Miroslav[1*], Kučírek Marek[1], Klement Aleš[1], Nikodem Antonín[1] and Kodešová Radka[1]

[1] *University of Life Sciences Prague, Prague, Czech Republic*

** Presenting author: mfer@af.czu.cz*

The aim of this work is to describe effect of different cover crops sown before winter wheat (W) in dry region of Czech Republic. The selected cover crops were as follow: wheat (WW) (Triticum aestivum L.), pea (PW) (Pisum sativum L.) and rape (RW) (Brasica napus L.). Soil type in study location was determined according to WRB as Pachic Chernozem Clayic (soil with higher amount of soil organic carbon in first 50 cm). The field measurement of unsaturated hydraulic conductivity, soil water repellency and soil compaction was carried out four times in different phenological phases (October 2021, March 2022, May 2022 and July 2022 after the harvest). Soil samples were taken from top soil and also from the subsoil (25 cm). Grab soil samples were used for determination of basic soil properties soil texture, particle density, soil organic matter, active and potential soil reaction, electric conductivity, cation exchange capacity, carbonates and nutrients content. Aggregate stability (WSA index) was also determined. Undisturbed soil samples (100 cm^3) were taken for determination of bulk density, total porosity and soil water retention curves. Next computed tomography (CT) was used for determination of soil microporosity. For description of cover crops effect on yields parameters the thousand-grain weight (TGW) and total yields were determined. It should be noted that the sampling in May was marked by severe drought (associated with a high occurrence of cracks in the soil). The first surprising results came from measured soil organic matter (SOM), where the highest SOM content was obtained in WW than in PW and RW. The nutrient content (P, K) was higher in RW variant. Surprisingly the hypothesis that using pea or rape as cover crop will affect negatively bulk density and enhanced soil porosity due to decay of the root system, was not confirmed. The highest bulk density and the lowest total porosity was observed in RW. These findings correspond with the results of aggregate stability and soil compaction (the highest WSA index and penetration resistance) measured also in RW. Unsaturated hydraulic conductivity determined in October 2021 was higher WW, but in other three sampling (March, May and July) the highest unsaturated hydraulic conductivity was detected in PW. Soil repellency was higher in winter wheat after pea and also after rape. The results of TGW show statistical significantly higher values in winter wheat after rape (42 g) compare to winter wheat after pea (40 g) or wheat (38 g). The same trend occurred also in total yields: RW: 8.64 t/ha, PW 7.83 t/ha and WW 7.64 t/ha. We can conclude that use of rape as a cover crop in drier locality compare to pea or wheat lead to change of almost all measured soil properties both negatively (SOM,

bulk density or porosity) and positively (nutrient content). The highest yields of winter wheat were mainly due to the use of rape as a cover crop.

Authors acknowledge the financial support from the European Structural and Investment Funds, projects NutRisk (No. CZ.02.1.01/0.0/0.0/16_019/0000845).

Keywords: cover crops, soil compaction, winter wheat, unsaturated hydraulic conductivity

Long-term effects of soil compaction on soil carbon stocks and nitrous oxide emissions

Romero-Ruiz Alejandro[1*], and Keller Thomas [1]

[1] *Soil Quality and Soil Use, Agroscope, Zürich, Switzerland*

** Presenting author: Alejandro.romero@agroscope.admin.ch*

Soil compaction in agricultural lands results from the usage of heavy machinery, producing soil deformation and changes in soil structure. It impacts soil mechanical and hydraulic properties that control key soil processes such as water flow, plant growth, carbon and nitrogen cycling. By modifying soil structure, soil compaction often creates soil conditions that are linked to reduced productivity, reduction of carbon inputs, and increases in nitrous oxide emissions. Short-term (hours to weeks) changes in soil structure and soil functioning due to compaction are relatively well understood, but long-term (years to decades) effects remain challenging to understand and evaluate. This disparity on the time length of soil processes affected by compaction limits experimental design and data availability for integrative understanding of short and long-term effects of soil compaction on soil functioning. Assessing such impacts is further challenging due to the poor understanding of soil structure dynamics, and soil compaction recovery. In this work, we address this challenge by reviewing empirical evidence of effects of soil compaction on carbon dynamics and nitrous oxide emissions under different climates, soil types and compaction conditions. To complement this, we modelled selected experiments using an agro-ecosystem modelling framework that explicitly considers changes in soil structure dynamics produced by compaction. Using this approach allows to systematically evaluate different management scenarios involving diverse compacting stresses (e.g., by vehicle wheeling or animal trampling), soil types, soil covers and climates. Depending on the compacting stress, the soil compaction model simulates changes in bulk density (increases up to 20%) and hydraulic conductivity (decreases of up to 95%) that are consistent with literature values. These changes led to modelled relative increases in N2O emissions from the compacted soils of up to 200% and a related decrease in yield of up to 15%, and changes in carbon stocks of 13%, which is in agreement with ranges reported in the literature. The proposed framework systematically evaluates the impacts of soil management on soil properties and functions and has the potential for evaluating long-term effects of soil compaction in soil functioning and developing strategies for ameliorating it, and guide experimental design for measuring this.

Keywords: soil compaction, soil carbon, nitrous oxide, agroecosystem modelling

AGROECOLOGICAL TRANSITION FOR SUISTANABLE AGRICULTURE AND SAFE FOOD PRODUCTION

Un Akin[1] , Asins Sabina[2], Bal Abdulkadir[1], Buttafuoco Gabriele[3], Kalkan Saddam[1], Di Lonardo Sara[3,4], Lasorella M.Valentina[5], Maienza Anita[3], Lumini Erica[3], Nikodemus Oļģerts[6]

[1] *GAP Agricultural Research Institute-TAGEM, Sanliurfa, Turkiye*

[2]*Centro de Investigaciones sobre Desertificación-CIDE (CSIC, UV, Generalitat Valenciana), Valencia, Spain*

[3]*National Research Council of Italy*

[4]*National Biodiversity Future Center (NBFC), Palermo, Italy*

[5] *CREA Research Centre for Agricultural Policies and Bioeconomy, Rome, Italy*

[6] *University of Latvia, Riga, Latvia*

** Presenting author: Akin UN*

In a world with growing population, agriculture is facing two challenges which are apparently contrasting: enhancing safe food production and promoting environmental sustainability. Therefore, one of the most fundamental problems to be solved is the matching of agricultural production and food demand in a condition of decreasing area for agricultural production. The decrease in cropland is due to several causes, desertification and soil degradation in the context of climate change being the major ones. Sustainable agriculture needs to produce healthier food and fibre to feed a growing population in harmony with nature. The development of technology, to satisfy the food needs of the growing human population, has generated commercial competition without ignoring the interest in increasing economic margins. As a result, food security has taken a backseat because of the extreme focus on high yield. Unfortunately, this situation causes the production and consumption of food that is far from maintaining the minimum quality of ecosystems. In this context, Agroecology, a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems, seems to be one of the most viable approaches in order to leave a healthy environment, a quality life and a clean world to future generations. A key component of the agroecological perspective is delineating agricultural lands according to their potential characteristics in the scope of sustainable and safe food production. The laws and regulations applied at the state level and the follow-up of the implementation will support rural development. In this context,

the Into-DIALOGUE project aims to contribute to rural development along with sustainable and safe food production based on the agroecological approach. The latter will consider field types (in terms of field size, soil type, product pattern, ownership types, etc.). In addition, agroecological systems will help to reduce greenhouse gas emissions from farmland, prevent soil contamination by chemicals, loss of organic matter, soil erosion and decline in soil biodiversity. Finally, the loss of soil biodiversity might also be prevented.

Keywords: Sustainability, Agroecology, Safe food, Environment

Towards a soil quality field test kit guide of soil indicators for end-land users: a litterature approach

Jerzy Grabiński[1], **Sara Di Lonardo**[2], **Sabina Asins**[3], **Akin Un**[4]

[1]*Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland*

[2]*Research Institute on Terrestrial Ecosystems-National Research Council and National Biodiversity Future Center*

[3]*Centro de Investigaciones sobre Desertificación-CIDE (CSIC, UV, Generalitat Valenciana), Valencia, Spain*

[4]*GAP Agricultural Research Institute-TAGEM, Sanliurfa, Turkiye*

The most important goal of the activities of each agricultural producer is to achieve a sufficiently high yield, of the desired quality for consumption, storage or processing. Among the many factors determining success in achieving such goals, are the physical, chemical and biological properties of the soils on which the production is conducting. These properties, on the one hand, determine the level of soil fertility, i.e. the ability to meet the nutritional needs of plants at an appropriate level throughout the growing season, and, on the other hand, determine its role in shaping the natural environment or climate. The role of soil in shaping the natural environment or climate change is currently not perceived strongly enough by producers. It is therefore justified to carry out activities that will introduce some changes in this respect. Taking this into account, the Into-Dialogue project provides for the development of a soil guide, the aim of which will be, among other things, to make producers aware of the role they can play in shaping soil quality parameters, with particular emphasis on those effects that have not been the object of their special concern so far. The research shows that the treatments that most strongly shape the quality of the soil environment include: proper crop rotation with considering the use of catch crops, proper tillage (in particular not plow), fertilization (especially organic), liming, but also the correct selection of other agrotechnical factors. This is proven by numerous scientific studies determining the role of the above-mentioned agrotechnical factors or their interactions in shaping the quality of the soil. This quality of soil is determined in the research using various indicators that will be included in the guide. One of the most widely described indicator in the soil guide will be the the content of organic carbon, which can even be significantly increased (or maintained at a sufficiently high level), but also, through improper actions, cause its rapid reduction, associated with the release of large amounts of carbon dioxide into the atmosphere.

Keywords: soil, indicators of soil quality, soil guide, farmers

Comparison of LUCAS and national Soil Information Monitoring System (SIMS) datasets – Exploring the technical possibilities to support the development of an EU harmonized monitoring system

Claire Froger[1*], Quentin Styc[1], Nicolas Saby[1], Christopher Poeplau[2], Maria Fantappiè[3], Fenny van Egmond[4], András Benő[5], Brigitta Tóth[5], Zsofie Bakacsi[5] and Antonio Bispo[1]

[1]INRAE, Info&Sols, F-45000, Orléans, France

[2]Thünen Institute of Climate-Smart Agriculture, Bundesallee 68, 38116 Braunschweig, Germany

[3]Council for Agricultural Research and Economics, Research Center for Agriculture and Environment, Via di Lanciola 12/A, 50125 - FIRENZE (Italy)

[4]Wageningen Environmental Research, Droevendaalsesteeg 3, 6708PB Wageningen

[5]Institute for Soil Sciences, Centre for Agricultural Research – Hungary

** claire.froger@inrae.fr*

Soil is crucial for life as it provides us food and fibre, regulates water and climate, and hosts thousands of organisms. A recent assessment states that 60-70% of soils in Europe can be considered as unhealthy due to different soil degradation processes. Soil monitoring is needed to determine the current soil properties, assess the soil status and detect soil changes over time.

Many EU member states implemented Soil Information Monitoring Systems (SIMS) that are quite heterogeneous (sampling scheme, resolution, measurement methods, …). In 2009, to develop a homogeneous dataset for EU, the European Commission extended the periodic Land Use/Land Cover Area Frame Survey (LUCAS) to sample and analyse the main properties of topsoil in EU. This survey was repeated several times since 2009 and offers a consistent spatial database.

Recently the EU Soil strategy for 2030 called for the implementation of an EU Soil Observatory (EUSO) that should become a dynamic and inclusive platform aiming to support policymaking by providing the Commission Services and the broader soil user community with the soil knowledge and data flows needed to safeguard soils. An attractive solution would be to pool all available data at all scales (local, national, European), including monitoring (SIMS, LUCAS) and other data in EUSO to provide a clear

and up to date picture of soil status in Europe. This induces the question how to assemble these data from different monitoring systems, developed with different purposes? The first step is a compatibility study to determine whether or not different SIMS could be used together to provide meaningful national statistics and maps.

Within EJP SOIL WP 6, we developed a comparison protocol between LUCAS and SIMS, where we propose a framework to localize the differences between the two datasets. A next step is to produce transfer functions to commonly used LUCAS and SIMS datasets regarding different sampling strategies and measurement methods.

Keywords: soil monitoring, dataset, LUCAS Soil, EUSO

A review of existing soil monitoring systems to pave the way for the EU Soil Observatory

Antonio Bispo[1], Zsofia Bakacsi[2], Fenny van Egmond[3], Bozena Smerczak[4], Grzegorz Siebelec[4], Johanna Wetterlind¬[5], Rudi Hessel[6], Arwin Jones[7] and Maria Fantappiè[8]

[1] INRAE, Unité de Recherche Info&Sols, 2163, avenue de la Pomme de Pin, CS 40001 Ardon, 45075 ORLEANS cedex 2, France, antonio.bispo@inrae.fr
[2] Centre for Agricultural Research, Institute for Soil Sciences, Department of Soil and Water Management, 1022 Budapest, Herman Ottó str. 15. Hungary, bakacsi.zsofia@atk.hu
[3] Wageningen Environmental Research (WENR) and ISRIC, Postbus 47, 6700 AA, Droevendaalsesteeg 3, 6708 PB, Wageningen, Netherlands, fenny.vanegmond@wur.nl
[4] Institute of Soil Science and Plant Cultivation (IUNG), ul. Czartoryskich 8, 24-100 Pulawy, Poland, bozenas@iung.pulawy.pl
[4] Institute of Soil Science and Plant Cultivation (IUNG), ul. Czartoryskich 8, 24-100 Pulawy, Poland, gs@iung.pulawy.pl
[5] SLU, Department of Soil and Environment, Inst f mark och miljö, precisionsodling, Box 234, 53223 SKARA, Sweden, johanna.wetterlind@slu.se
[6] Wageningen Environmental Research (WENR), Postbus 47, 6700 AA, Droevendaalsesteeg 3, 6708 PB, Wageningen, Netherlands, rudi.hessel@wur.nl
[7] European Commission – Joint Research Centre, Via Enrico Fermi, 2749, 21027 Ispra (VA), Italy, Arwyn.JONES@ec.europa.eu
[8] CREA, Via di Lanciola 12/A, 50125, Firenze, Italy, maria.fantappie@crea.gov.it

** antonio.bispo@inrae.fr*

Soils are constantly evolving due to natural factors as climate and living organisms (pedogenesis), but also due to external pressures linked mainly to human activities (e.g. urbanization, management practices, diffuse inputs of nutrients or contaminants through atmospheric deposits or waste spreading). The evolution of soils makes it necessary to set up monitoring programmes.

Designing and implementing a Soil Monitoring System (SMS) requires at least to choose: the statistical sampling design, the field sampling strategy in time and space, the entity that is sampled (i.e. pedogenic horizons or fixed depths) and how (e.g pits, augering, spade), the total thickness over which soil is sampled, the way the samples are managed (e.g. composite sample), prepared and analysed and the metadata is to be collected and stored (data about the sampling itself, its location and surroundings) to interpret the results. All those choices represent possible variations that enable the results to be compared.

Since 20 years, several projects and initiatives underlined the existing difficulties to compare and share data from national SMS, either due to technical issues (e.g. sampling designs and protocols, analytical

methods, data format) but also on motivations (e.g. why to share the data, for what purpose) and legal requirements (e.g. are we allowed to share the data). With the objective of overcoming this blockage a questionnaire was designed and circulated within EJP SOIL. Its analysis allows to identify the main technical issues (e.g. major differences between SMS) and possible ways of harmonization/collaboration in the frame of the EU Soil Observatory.

Keywords: soil monitoring, LUCAS Soil, EUSO

Collecting, harmonizing and compiling data on soil biodiversity, from European agricultural plots

Imbert Camille[1], Murugan Rajasekaran[2], Adam Mario[3], Ashfaq Sharjeel[2], Aponte Cristina[4], Aprea Giuseppe[5], Bevivino Annamaria[5], Bragato Gilberto[6], Brennan Fiona[7], Costanzo Manuela[5], d'Avino Lorenzo[8], Di Gregorio Luciana[5], Sara Di Lonardo[9] [10], Faber Jack[11], Fantappie Maria[8], Fiore Alessia[5], Geneste Christophe[3], Hedde Mickael[12], Jacomini Carlo[13], L'Abate Giovanni[8], Latini Arianna[5], Le-Bas Christine[1], Lumini Erica[14], Maienza Anita[15], Manici Luisa Maria[16], Mocali Stefano[17], Nobili Chiara[18], Pérès Guénola[3], Sevi Filippo[19], Schellenberger Antoine[1], Suhadolc Marjetka[20], Tondini Elena[21], Viketoft Maria[22], Vitali Francesco[8], Yayende-Guedoka Vivianne-Judith[1], Zaller Johann[2], Zechmeister-Boltenstern Sophie[2] and Bispo Antonio[1]*

[1] INRAE Info&Sols, Orléans, France

[2] Department of Forest and Soil Sciences, Institute of Soil Research, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria.

3 UMR SAS INRAe Institut Agro Rennes-Angers, Rennes, France

4. Department of Environment and Agronomy, Centro Nacional Instituto de Investigación y Tecnología Agraria y Alimentaria, INIA-CSIC, Madrid, Spain

5. Italian National Agency for New technologies, Energy and Sustainable Economic Development (ENEA), Roma, Italy

6. Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment (CREA-AA), Gorizia, Italy

7. Department of Environment, Soils andLanduse, Teagasc, Wexford, Ireland

8. CREA—Research Centre for Agriculture and Environment, Florence, Italy

9. Research Institute on Terrestrial Ecosystems, National Research Council (CNR-IRET), Florence, Italy

10. National Biodiversity Future Center (NBFC), Palermo, Italy

10. Wageningen Environmental Research (Alterra), Wageningen, The Netherlands

11. Eco&Sols, INRAE – IRD – CIRAD – Institut Agro, Montpellier, France

12. ISPRA, Italian National Institute for Environmental Protection and Research, Rome, Italy

13. Institute for Sustainable Plant Protection (IPSP), National Research Council (CNR), Torino, Italy

14. Institute of Bioeconomy – National Research Council, Florence, Italy

15. Research Center for Agriculture and Environment, Council for Agricultural Research and Economics (CREA–AA), Bologna, Italy

16. Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, Cascine del Riccio, Italy

17. Department for Sustainability, ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Casaccia Research Center, Roma, Italy

18. Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA), Centro Ricerche "Casaccia", Laboratorio Biotecnologie, Rome, Italy

19. University of Ljubljana, Ljubljana, Slovenia

20. Center of Plant Sciences, Scuola Superiore Sant'Anna, Pisa, Italy

21. Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden

** Presenting author: antonio.bispo@inrae.fr*

We all depend for our food and our health, for climate mitigation and water resource, of soil functions provided by soil biodiversity. The objective of the program MINOTAUR (Modelling and mapping soil biodiversity patterns and functions across Europe), is to increase the knowledge about soil biodiversity status and trends, with agricultural practices and climate change, at different scales in Europe. Within this program, the task of the Work Package 2 are 1) to inventory existing datasets, 2) to harmonize them and 3) to compile them into a database. We identified 52 datasets across Europe, using questionnaire and bibliographic search. After several meetings, the WP2 members defined the database template. It gathers biological data about micro, meso and macrofauna and metadata about sampling methodology, agricultural practices, soil properties and project information. Regarding the database, we chose to use OpenADOM solutions (Open source Application for Data Organization & Management) with a file configuration in YAML (Yet Another Markup Language). With this tool, the database is flexible and easy to use for scientists. Indeed, the database is accessible by a web interface and the data user can require a first data visualization and filter the data. This work is still on going and the next steps are to finish establishing the database structure and to collect the inventoried data.

Keywords: Fungi, Bacteria, Nematods, Mesofauna, Macrofauna, Relational database

Enabling Soil data exchange and INSPIRE data sharing in Flanders: Database underground Flanders (Regional Soil Information System)

Luts Dries[1*], Oorts Katrien[1], Swerts Martine[1] and Van Damme Marleen[1]

[1] *Departement Omgeving, Brussel, Belgium*

** Presenting author: dries.luts@vlaanderen.be*

Database Underground Flanders or DOV is an example of how a regional soil information system (SIS) can support the goals of WP6 concerning data exchange, data publication, soil monitoring and soil mapping making data accessible to a wide range of end users like scientists, citizens, companies and policy makers. As part of our participation in EJP SOIL WP6, we have been improving and strengthening the capabilities of DOV to enable the exchange of soil data within Flanders, and with other countries and Europe. DOV's data model is derived from the INSPIRE data model. The database includes the Belgian Soil Map, profile pits, boreholes, profile descriptions, physical, chemical, and biological soil properties, data on soil erosion, soil monitoring data, data from archaeological surveys and sensor data.

DOV offers several pathways for data exchange, from manual to fully automated. The last two years, a lot of effort was put into fully automating the exchange of data originating from the new Flemish Soil Carbon Monitoring network (Cmon). This required a process of data harmonisation, data centralisation and optimalisation of the infrastructure of each Cmon-partner. The result of this process enables

integrated data-analysis and INSPIRE conform open data publication of the Cmon data. DOV also enabled the exchange of sensor data from a citizen science project using IOT-devices and soil data from archaeological surveys. All this was made possible using a data model and exchange format derived from the INSPIRE data model.

The data in DOV is published as open data, complying with internationalstandards and guidelines such as the PSI- and INSPIRE-directives. This facilitates European and international data exchange, easy understanding of the data structure and integration of the data in other projects. Besides WMS and WFS services, DOV also provides data through WCS, other API's and a python library facilitating data science.

The user interfaces are an important part of DOV, making data available through a geoportal, specific applications, and informative webpages. Examples of specific applications are an informative pop-up illustrating the digital soil map and the 'virtual soil analysis' based on Digital Soil Mapping. This DSM was only possible due to the harmonisation and exchange of soil data supported by DOV and will support a wide range of environment modelling exercises and the development of soil health indicators.

Soil erosion is an important theme in DOV. Soil erosion and sediment transport modelling in Flanders result in yearly maps of parcel scale potential soil erosion to support the CAP, an erosion risk indicator and a thematic explorer. This is enabled by bringing together data from several INSPIRE themes.

DOV is the result of a 20-year cooperation between several government institutions working on soil and Subsoil bringing together soil, geological, geotechnical and groundwater data. This enables cross domain collaboration and integration with themes between and beyond soil and subsoil. The aim of DOV is to be a network organisation, not only enabling data exchange in Flanders but also actively fostering cooperation within the soil and underground community in Flanders.

Keywords: WP6; Regional Soil Information System, Data harmonisation, Data exchange and Soil indicators.

The regional soil organic carbon monitoring network in Flanders (Belgium)

Oorts Katrien[1], Luts Dries[1*], De Vos Bruno[2], Fien Amery[3], Lettens Suzanna[2], D'Hose Tommy[3], Swerts Martine[1], Salomez Joost[1]

[1] *Departement Omgeving, Vlaams Planbureau voor Omgeving (VPO), Belgium*

[2] *Instituut Natuur- en Bosonderzoek (INBO), Belgium*

[3] In*stituut voor Landbouw-, Visserij- en Voedingsonderzoek (ILVO), Belgium*

* *Presenting author: dries.luts@vlaanderen.be*

In 2020, a regional soil organic carbon monitoring network has been set up in Flanders. The purpose of this network is to measure, depending on land use, both the size and the evolution of soil organic carbon stocks till a depth of 1m. Although only recently started, the intention is to work with a 10-year return period. During a 10-year cycle, samples will be taken at 2594 sampling plots. These plots, 10 m by 10 m, are located on five different land uses: cropland, grassland, forest, nature and residential area (gardens, parcs, recreational areas and verges).

Both sampling plots and 16 sampling locations within the plots are selected using a generalized random tessellation stratified (GRTS) algorithm. At first, plot features are documented. If present and before sampling the mineral soil layers, the litter or the felt layer are collected. Sampling is done with a gouge auger at 4 fixed depth intervals: 0-10, 10-10, 30-60 and 60-100 cm. For the 0-10 and 10-30 cm layers, all 16 sampling locations are sampled, while for the 30-60 and 60-100 cm layers only 7 sampling locations are sampled within the plot. All subsamples are pooled per layer, resulting in one disturbed composite sample. Finally, to get an idea of the bulk density 4 undisturbed soil samples are taken per depth interval.

In the laboratory, the disturbed composite samples are analysed for total C, inorganic C, total N, pH-KCl and texture (laser diffraction). In addition, each soil sample is scanned to obtain near infrared spectra. For the litter and felt samples, dry mass, total C and total N are determined.

The errors associated with the sampling, sample preparation and lab analyses are quantified by resampling of 5% of the plots by a different sampling team.

The comprehensive sampling scheme and all measurements are related to the aim to significantly detect small soil organic carbon stock changes. From the start of the second 10-year sampling cycle we will already be able to calculate how much carbon is lost from or additionally stored in soils under different land uses. Additional field observations and lab analyses will help to explain the variation in and the evolution of the soil organic carbon stocks in Flanders.

Keywords: Regional Soil Monitoring System, Sampling scheme, Soil organic carbon, EJP SOIL WP6.