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BOOK OF ABSTRACTS

Block A

A1 Carbon sequestration at national and European scale and effects of policy and socio-economic factors

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Block A

A1 Carbon sequestration at national and European scale and effects of policy and socio-economic factors

Session Description

Involved projects: CarboSeq, SIMPLE

Conveners: Muhammad Mehran Anjum (Agroscope), Felix Seidel (Thuenen)

Soil carbon sequestration is the net removal of carbon dioxide from the atmosphere and could make an important contribution to climate change mitigation. The key for carbon sequestration in soils is to reach a positive balance between carbon inputs and outputs. This can be achieved through improved land management towards increased soil carbon accrual through enhanced inputs of organic matter or through reducing decomposition rates of C in the soil (i.e. by adding C in more stable forms). Such measures are affected by bio-physical (e.g. soil type, climate) and technical constraints (e.g. irrigation). Thus, a differentiated analysis at national and European scale is necessary to assess the true potential of optimized land management to achieve carbon sequestration in soils when implemented on large scale.

In addition to these factors also policies like the Farm to Fork strategy of the EU could potentially have effects on soil carbon sequestration. To reduce nutrient losses from agricultural soils, a reduction in fertilization is foreseen. Likewise socio-economic effects like increasing fertilizer prices or changes in diets could affect soil carbon stocks and/or accrual. To assess potential co-benefits or trade-offs, system boundaries need to be expanded. This allows to include indirect effects on soil carbon stocks and/or accrual through e.g. changes in yields or crop types.

In this session, we welcome contributions that give insights into the topic of carbon sequestration in soils on European and national scales as well as studies that discuss carbon sequestration in soils in a broader context.

A first glance at carbon sequestration potentials of agricultral measures at European scale from the CarboSeq Project

Felix Seidel[1], Florian Schneider[1], Daria Seitz[1], Axel Don[1]

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

In order to estimate a feasible carbon (C) sequestration potential in European agricultural soils, we need to know the area where additional measures that increase soil organic carbon (SOC) can be implemented and the corresponding SOC accrual rates. This will allow us to understand how effective which measure is on European scale.

The practices considered include a higher share of agroforestry, cover crops replacing bare winter fallows, crop residue management, reduced and no-tillage instead of ploughing, the integration of perennial legumes and leys into crop rotations, biochar application and irrigation. Open-access data of European Farm Structure Surveys as provided by EUROSTAT at NUTS2 level serve as a reference for the intensities at which the measures are already implemented in Europe. Only areas where these measures could be additionally implemented were considered.

For the first time, we will bring these measures, their area of implementation and the linked C accrual rates together and show for some measures a feasible C sequestration potential across Europe which is one of the key outputs of the CarboSeq project.

Increasing the share of forage leguminous crops in the crop rotation positively affects the soil organic carbon stocks – Analysis of European LTEs

Panagea Ioanna[1*], De Boever Maarten [1], Quataert Paul[1], Bruno Antonio[2], Di Bene Claudia[2], Vanino Silvia[2], Diacono Mariangela[3], Makoschitz Lisa[4], Alonso-Ayuso María[5], Bárcena Teresa G.[6], Plaza César[7], Carranca Corina[8], Santín-Montanyá Inés[9], Jensen Johannes Lund[10], Jacobs Anna[12], Seitz Daria[11], Seidel Felix[11], Don Axel[11], Ruysschaert Greet[1]

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

2 Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment, Rome, Italy

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

4 Austrian Agency for Health and Food Safety, Department for Soil Health and Plant Nutrition (AGES), Vienna, Austria

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

6 Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway

7Spanish National Research Council (CSIC), Institute of Agricultural Sciences, Madrid, ES

8 National Institute for Agrarian and Veterinarian Research I.P,Portugal

9 National Institute for Agricultural and Food Research and Technology (INIA), Madrid Spain

10 Aarhus University, Department of Agroecology, Blichers Allé 20, DK-8830 Tjele, Denmark

11 Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany

12 Coordination Unit Climate, Soil, Biodiversity of Thünen Institute, Braunschweig, Germany; present address: Institute for Sugar Beet Research, Göttingen, Germany

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

The storage of soil organic carbon (SOC) is subject to human influence through various management options. By adopting appropriate land management practices, agricultural systems can contribute to mitigate climate change by reducing carbon (C) loss from soils or even sequester C in soils. This can be achieved by promoting practices that enhance C inputs to the soil and improve the quality of these inputs, thereby facilitating the removal of atmospheric carbon dioxide, or by reducing C turnover. In this study, we investigate crop rotation options utilizing legumes, identifying their potential for SOC accrual. We propose regression equations, serving as emission factors, to quantify this potential, based on data from mid- and long-term field experiments conducted across Europe. Furthermore, we analyse soil inherent properties, environmental factors, and management practices to evaluate their impact on these emission factors. Our findings indicate that incorporating and/or increasing forage

leguminous crops in the rotations leads to SOC accrual, in contrast to the inclusion of grain legumes. Additionally, our observations suggest that the crop growth duration (annual or multi-annual) does not exert a significant impact on SOC accrual. From the evaluated management and pedoclimatic factors, the climatic zone in which the system is located significantly influences the SOC stocks. Overall, integrating forage legumes in a cropping system can enhance its sustainability and presents a viable option for climate change mitigation.

Keywords: EJPSoil CarboSeq, emission factor, leys, alfalfa, soil organic carbon

Effect of anthropogenic soil management for increasing soil organic carbon status in Lithuanian acid soil

Mockeviciene Ieva[1]*, Vilkiene Monika, Amaleviciute – Volunge Kristina and Karcauskiene Danute

[1] *Lithuanian Research Centre for Agriculture and Forestry, Akademija, Kedainiai district, Lithuania*

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

Soil organic carbon (SOC) represents the largest carbon supply in terrestrial environments making carbon sequestration in them crucial to global climate regulation, food production, nutrient supply, and the control of erosion. For this reason, it is the primary objective of current research and a key subject in soil science. As soils are the largest carbon sink in the world, even little changes there can have a significant impact on the global carbon cycle. Over the last few decades, particularly the last ten, there has been an increase in scientific interest in soil conservation techniques like minimal/no-till agricultural activities, fertilization with both organic and inorganic amendments, and residue retention that aim to improve soil organic carbon and natural soil fertility. Reasonable management practices, especially sustainable fertilization, are urgently needed to enhance the carbon sequestration capacity of acid soils, which could improve soil quality and mitigate climate change. This study aimed to achieve following objectives: (1) analyse the alterations in SOC caused by the various management techniques in Lithuania's acid soil; (2) estimate and compare the effect size of different agro-techniques on SOC sequestration and other chemical parameters in acid soil; (3) determine an appropriate management practice benefiting for SOC sequestration and improving soil quality.

Comparison of data from three long-term studies, carried out in the western region of Lithuania, on physicochemical indicators served as the basis for the study. Over the past 24 years (1999-2023), changes in the properties of the soil have been identified. The most widely used practices in Lithuania, including tillage, residue maintenance, manuring, and soil liming, have been chosen for analysis. The analysis of soil organic carbon sequestration indices of studied agricultural practices ranked as: manuring > residue management > reduced tillage > liming (in the direction of carbon transformation and sequestration). The results of this study showed that long-term fertilization approaches could raise the SOC content in acid soils in Lithuania, and that organic fertilization in combination with liming accumulate more SOC compared to other techniques. Assessment of the relative annual change of SOC content indicated that long-term soil fertilization had considerable SOC sequestration potential. The mean effect size of SOC and other investigated soil parameters was largest under manure fertilized limed soil treatment. This finding indicated that the combination of liming and organic fertilizers was a relatively effective measure to improve soil quality. In general, conducted analysis provide an in-depth quantitative assessment of the effects of management practices on SOC

content and other parameters, which could assist in further understanding the feedback of SOC to agricultural management practices and offer evidence in support of the preservation of the acid soil.

Keywords: soil organic carbon transformation 1; agricultural management practices 2; soil quality 3; response ratio 4; acid soil 5

Some indicators of organic carbon status in Norwegian agricultural soils

Riley Hugh[1], Rittl Tatiana F.[2*], Eischeid Isabell[1], Løes Anne-Kristin[2] and Henriksen Trond M.[1]

[1]*Norwegian Institute of Bioeconomy Research (NIBIO), Kapp, Norway*

[2]*Norwegian Centre for Organic Agriculture (NORSØK), Tingvoll, Norway*

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

Diverse pedoclimatic zones lead to large variations in soil organic carbon (SOC). Key questions involve how much carbon the soil contains, what is its potential for more storage and whether levels are sufficient to maintain soil structure stability (SSS). We evaluate current SOC levels using ratios of clay/silt fractions to SOC, to identify potential SOC storage areas and to gauge likely SSS status.

SOC retention is affected by clay and silt, which protect it from microbial activity. Hassink (1997) used the ratio of clay plus silt <20 µm (fines20) to SOC to indicate this relationship, whilst Dexter et al. (2008) used the ratio of clay to SOC. Jensen et al. (2019) found critical ratios for SSS to be ~10 for clay/SOC and ~20 for fines20/SOC, above which SSS is impaired and below which SOC is less likely to be retained. These ratios appear valid under Norwegian conditions, where greatest declines in SOC have been found in soils with high initial SOC levels and lowest declines in clay soils (Riley & Bakkegard 2008).

After 28 years of a cropping system trial in eastern Norway (Riley et al. 2022), equilibrium between SOC gains and losses was at a fines20/SOC ratio of ~18, whilst in the same trial SSS declined sharply in an arable cropping system with a clay/SOC ratio >10, compared to systems with ratios of 6-8. In western Norway, on grassland soils with generally low fines20/SOC ratios, SOC appears to be declining despite manure inputs, especially in cases with high initial SOC levels (Rittl et al. 2023). To obtain insight into the potential for SOC across Norway, data was used from a study in which SOC and soil texture was analysed on 600 fields in agricultural districts throughout the country. Results are grouped into 13 regions with relatively uniform climate and cropping within each.

Greatest proportions of fields with high ratio levels were found in regions around Oslo and east of Oslofjord, with predominantly clay and silty clay loams, where 65% of fields had clay/SOC >10 and 80% had fines20/SOC >20. Proportions of fields with fines20/SOC >20 were somewhat lower west of Oslofjord (65%) and in central Norway (44%), where many soil textures are found, and in an inland region with predominantly silty soils (55%). Proportions of fields with high ratio levels were low in inland regions with loam soil, where 15-20% had clay/SOC >10 and 24% had fines20/SOC >20. All these regions are mainly arable, with some livestock, and mean SOC levels are <3,0%.

In the predominantly grassland/livestock regions of southern, western and northern Norway, and in upland areas, the soils are mostly sandy and silty loams, and mean SOC levels are mostly >3,5%. In these regions, the proportion of fields with clay/SOC >10 was below 5% whilst that of fines20/SOC >20 was below 10%. Mean clay/SOC ratios were 1-3 and mean fines20/SOC ratios were 4-10. Arable land has thus greater potential for carbon storage than grassland, whilst at the same time increasing SSS and reducing erosion risk.

Keywords: texture; arable; grassland; storage; stability

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Assessing soil carbon sequestration in the Netherlands by enhancing a dynamic soil organic carbon turnover model using Earth Observation data

Hendriks Chantal[1], Lesschen Jan Peter[1], Meijninger Wouter[1], De Wit Allard[1], Roerink Gerbert[1]

[1] *Wageningen University & Research, Wageningen, The Netherlands*

As part of the climate mitigation plan, the Netherlands aims for an additional CO_2 sequestration of 0.5 Mt in mineral agricultural soils by 2030. Besides climate mitigation, soil organic carbon (SOC) can also enhance the resilience and fertility of the soil. However, monitoring SOC stock changes is difficult on the short term, because the changes are relatively small compared to the stock. Dynamic organic carbon turnover models can solve this problem by assessing SOC stock changes over longer time periods. The RothC model is a scientific, widely adopted SOC turnover model that requires relatively little input data that is often available at field level. Assumptions in the input data were made running the model at national level in the Netherlands, but these assumptions seems to be quite rough when running the model at field level. Making use of Earth Observations (EO), which can provide additional information on vegetation cover, the growth period of cover crops, grassland renewing, and crop production, can help improving the input data. This study shows the effect of replacing some input data of the RothC model by EO. The model runs for time period 2018-2023 (i.e. 6 years) for the whole of the Netherlands at varying spatial resolution (i.e. at postal code level for ~3400 units and parcel level for ~500.000 parcels). When weather data were fixed, the effect of land management became more clear. Being able to assess the carbon balance at field level for the entire country brings opportunities, but also challenges for national and regional policy makers as well as for farmers. In a later stage, the adapted RothC simulations will be validated against soil C-measurements taken in approximately 100 fields as part of the national soil sampling campaign of 2018 and 2024.

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The effect of a business-as-usual scenario on the evolution of the soil organic carbon stocks in Flanders' arable fields

Mertens Kaat[1*], Panagea Ioanna[1] and Ruysschaert Greet [1]

[1]*Flanders' Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium * kaat.mertens@ilvo.vlaanderen.be*

Soils play an important role in the carbon cycle and carbon farming practices could significantly contribute to mitigating climate change by ensuring soils become C sinks. In Flanders, there is uncertainty regarding the impact of current soil management practices on the evolution of soil organic carbon (SOC) stocks in arable fields. The objective of this study was to simulate the evolution of the SOC stocks under current management practices across all arable fields in Flanders using a Roth-C based model. This model was tailored for Flanders by adjusting the method for calculating the C-inputs coming from crops and organic amendments and by implementing a simple initialization method to increase its efficiency. The simulation required data on the climate, crop rotation, fertilization and soil characteristics. In Flanders, detailed information on crop rotation, including cover crops, from the Land Parcel Identification System (LPIS) is made publicly available by the government of Flanders. This data layer also contains historical agricultural field information. Additionally, a map for the SOC stock and soil texture is publicly available in the Flemish soil database (DOV). Data on organic fertilization was obtained from the fertilization allocation model (BAM) used by the Flemish Land Agency to allocate the amount and type of fertilization to a field based on certain calculation rules in function of the crop type, type of farm and soil type. All necessary data layers were collected and processed to allow parcel level implementation of the Roth-C based model across Flanders. The output of this simulation will be used as a baseline for scenarios involving the implementation of management practices beneficial for carbon sequestration, as well as scenarios simulating crop rotation changes in arable fields.

Keywords: carbon sequestration; Roth-C model, carbon farming

APPLYING A TRADE-OFF ANALYSIS AT THE EUROPEAN SCALE TO QUANTIFY EFFECTS OF REDUCED FERTILIZATION ON ECOSYSTEM SERVICES OF SOILS

[1]MUHAMMAD MEHRAN ANJUM, [2]ROBERTA CALONE, [1]JENS LEIFELD AND [1]SONJA G. KEEL

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

[2]*CREA - Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment; I-40128, Bologna, Italy.*

Agricultural soils provide a wide array of ecosystem services that need to be maintained and enhanced to improve the sustainability of agricultural production. Building on soil carbon sequestration rates provided by the EJP SOIL project CarboSeq project, we expand the potential for climate-smart soil management through reductions in nitrogen fertilization rates to comply with the EU's Farm to Fork Strategy. To assess potential trade-offs on soil carbon storage we are setting up a modelling framework that allows to quantify effects of 20 % lower mineral nitrogen fertilization rates on crop yields, soil organic carbon (SOC) stocks, nitrous oxide (N2O) emissions and nitrate (NO3) losses. We will apply the SOMMIT Index that was developed within the EJP SOIL project SOMMIT for trade-off analysis with four trade-off components: yield, SOC, N2O and NO3 (Calone et al. 2024). Our results will offer a quantitative assessment of the trade-offs among these components, presenting a comprehensive evaluation of reduced fertilization. We will obtain SOMMIT Index values for main crops grown in Europe and for different pedoclimatic conditions that will indicate the overall desirability/effectiveness of reduced fertilization. Additionally, three narratives will be used to evaluate the results considering varying perspectives. For this purpose, different weighting schemes for young farmers, an agro-chemical corporation and an environmental agency will be applied. Based on the results policy recommendations will be formulated.

Keywords: trade-off components, Nitrogen fertilization, soil organic carbon, greenhouse gas emissions, modelling

Roadmap for improvement of carbon sequestration in the Netherlands

Van der Kolk, Jennie[1]; Slier, Thalisa[1]

[1] *Wageningen Environmental Research, Wageningen, The Netherlands*

In the Netherlands, the government has set goals for climate mitigation and soil health regarding agricultural mineral oils. Measures for carbon sequestration in these soils are important for reaching these goals and were studied in the past five years in the research program Smart Land Use. The results show that it is possible to reach the climate goals for Dutch agricultural mineral soils, but proper implementation of the measures is important. To determine which actions are necessary to reach sufficient implementation, a roadmap has been composed to set the focus of the research in the follow up of Smart Land Use in the period 2024 – 2026. The roadmap takes into account the policy goals, the role of research, the role of farmers and other stakeholders. The roadmap covers the period until 2030, where the policy goals should be reached.

Several outcomes have been identified that contribute to the goals. The main focus of these outcomes is towards placing measures in a complete farm set up, which provides farmers with perspectives on how to implement carbon sequestration at farm level on the long term.

In this poster, we will present the roadmap.

Keywords: roadmap**,** carbon sequestration, mineral soils, climate mitigation, soil health

Sensitivity analysis of a Roth-C based model

Mertens Kaat[1], Quataert Paul[1] and Ruysschaert Greet[1]*

*[1]Flanders' Research Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium * kaat.mertens@ilvo.vlaanderen.be*

The Belgian Soil Organic Carbon Calculator (BeSOCC) is a Roth-C based model specifically developed for Flandersto simulate the evolution of soil organic carbon (SOC) for arable fields. The BeSOCC model differs from the models in many other European countries in the methodology for calculating the C inputs and in the initialisation method. The BeSOCC model will be used to simulate the effect of current management practices and several alternative management scenarios on the C-stock across Flanders. This will require simplification and assumptions regarding the inputs.

The objective of this study is to perform a sensitivity analysis to evaluate which input parameters impact the model output the most, and thus require the highest accuracy. The sensitivity analysis is performed on the following inputs: C-supply and the ratio decomposable plant material to resistant plant material (DPM/RPM) of crops; C-content, DPM/RPM ratios and dose of organic fertilizers; the percentage of incoming C supplied by the fertilizer going to Roth-C's HUM pool; initial SOC percentage and the initial distribution of the SOC stock over the DPM, RPM, BIO and HUM pool. A global sensitivity analysis is performed by using the Monte Carlo approach to account for all interactions between the parameters.

The preliminary results indicate that the initial SOC percentage has the highest impact, while the DPM/RPM ratios exhibit the lowest impact.

Keywords: Roth-C model; sensitivity analysis

Exploring Soil Organic Carbon Persistence for Sustainable Land Management Practices: A Thermal Analysis Approach

Johanna Maria Zenner[1]*, Jeroen H.T. Zethof[1], Tatiana F. Rittl[2], Klaus Schützenmeister[1], Hermann F. Jungkunst[1]

[1] *iES - Institute of Environmental Sciences, RPTU Kaiserslautern-Landau, Landau, Germany*

[2] *Norwegian Center for Organic Agriculture (NORSØK), Tingvoll, Norway*

** Presenting author: johanna.zenner@rptu.de*

Understanding the persistence of soil organic carbon (SOC) is pivotal for developing effective strategies in climate change mitigation and sustainable land management. Relatively cheap and easy to use methods are needed to study the underlying processes on a larger scale. However, the intricate nature of soil organic matter (SOM) and environmental factors poses significant challenges to accurately assess SOC persistence. This study proposes an integrated approach combining standardized thermal analysis methods with density fractionation to quantify SOC persistence. By comparing techniques such as Thermogravimetric Analysis coupled with Differential Scanning Calorimetry and a multiphase carbon and moisture determinator with a ramped heating analysis, we aim to elucidate distinct patterns in SOC stability across diverse soil compositions and environmental conditions. To do so, we will establish a standardized thermal method for determining SOC persistence in the different density fractions (fPOM, oPOM & MAOM). We will expect that the integration of standardized thermal analysis methods with density fractionation for assessing SOC persistence will reveal distinct patterns in SOC stability across different soil compositions and environmental conditions.

Our research seeks to contribute to the advancement of understanding SOM dynamics in the large scale, essential for devising sustainable land management practices and addressing pressing global challenges related to soil carbon storage and climate change mitigation.

Keywords: soil organic carbon, soil carbon stability, climate change mitigation

Relevance of the organic carbon to clay ratio as a national soil health indicator

Eva Rabot[1]*, Nicolas P. A. Saby[1], Manuel P. Martin[1], Pierre Barré[2], Claire Chenu[3], Isabelle Cousin[1], Dominique Arrouays[1], Denis Angers[4], Antonio Bispo[1]

[1] *INRAE, Info&Sols, Orléans, France*

[2] *Laboratoire de Géologie, Ecole Normale Supérieure, PSL Research University, CNRS, Paris, France*

[3] *UMR ECOSYS, INRAE, AgroParisTech, Université Paris Saclay, Palaiseau, France*

[4] *Agriculture and Agri-Food Canada, Québec City, Canada*

The soil organic carbon (SOC) to clay-sized particles ratio (SOC/clay) has recently been selected as an indicator of the soil organic matter status in managed mineral soils within the framework of the European Soil Monitoring Law proposal. This indicator was initially developed to predict soil structural quality, in a local study in Switzerland and subsequently tested at national scales in England and Wales, and in Germany. In this study, we evaluated if the SOC/clay ratio was relevant to assess the structural quality of soils at the national scale in mainland France. We additionally evaluated its variant, SOC/(silt < 20 µm + clay). We confronted SOC/clay and SOC/(silt < 20 µm + clay) to two indicators of soil structure, the soil bulk density and aggregate stability, and we tested the effect of land use and soil type using information from the French Soil Quality Monitoring Network (RMQS). We showed that the SOC/clay and SOC/(silt < 20 µm + clay) were poor indicators of the soil bulk density and aggregate stability. In our analysis, the SOC content was the best indicator of soil structure. Both land use and soil type had an effect on the SOC/clay value. SOC/clay was found to be strongly affected by soil pH with acidic soils consistently being classified as healthy according to the threshold of 1/13 and alkaline soils often being classified as unhealthy. The domain of applicability of SOC/clay excludes soils involving other SOC stabilization mechanisms than associations with the clay fraction and climate is not taken into account. We hence question the relevance of the SOC/clay ratio and its proposed threshold of 1/13 as a soil structure indicator, and more broadly as an indicator of the SOC status of healthy soils for all European pedoclimatic contexts. Based on the RMQS dataset, 63% of cropland, 81% of permanent crop and 23% of grassland soils were below the SOC/clay threshold of 1/13, which would classify them as unhealthy according to the European Soil Monitoring Law. An adaptation of the threshold to soil types and climates seems to be required for France, and probably for other countries, because some pedoclimatic contexts will never allow a satisfactory value to be reached.

Keywords: Soil organic carbon; Clay content; Soil structure

Effects of different crop management options on SOC stocks and deriving emission factors – the CarboSeq approach based on European LTEs

Panagea Ioanna[1*], Blanchy Guillaume[1], Rosinger Christoph[2,4], Keiblinger Katharina[2], Diacono Mariangela[3], Di Bene Claudia[5], Makoschitz Lisa[6], Götzinger Sophia[6], Sandén Taru[6], Spiegel Heide[6], Alonso-Ayuso María[7], Martinez-Garcia Laura[7], Álvaro-Fuentes Jorge[7], Suhadolc Marjetka[8], Ocvirk Kristina[8], Kay Sonja[9], Viaud Valerie[10], Drexler Sophie[11], 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*

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

Crop management options, such as, choice of crops in the rotation, residue management, fertilisation, tillage and irrigation, are known to affect 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). The following crop management options were evaluated: 1) cultivation of cover crops in comparison with not growing cover crops; 2) increased share 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 non-irrigated systems and 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 or regression equations for each crop management option based on the specific variables that significantly affect these in each case. All the management options have the potential for SOC accrual, with agroforestry to present the highest EF. Considering the identified data gaps and limitations, the derived EFs can be used as a basis for the estimation of the SOC accrual in the European croplands.

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

Dynamics of Soil Organic Carbon Stocks on Arable Land under Varied Soil Management and Climate Scenarios: Insights from Long-term Experiments in Eastern Slovak Lowland

Barančíková Gabriela[1*], Koco Štefan[1], Halas Ján[1], Takáč Jozef[1], Makovníková Jarmila[1] and Šoltysová Božena[2]

[1] *National Agriculture and Food Center - Soil Science and Conservation Research Institute, Bratislava, Slovakia*

[2] *Plant Production Research Institute – Institute of Agroecology, Michalovce, Slovakia*

** Presenting author:* gabriela.barancikova@nppc.sk

The soil organic carbon (SOC) is one of the most important indicators of soil quality, and it impacts all soil ecosystem services, especially climate regulation. On arable land, the amount of SOC is low; however, its stock can be positively influenced by good soil management (the optimal doses of mature farmyard manure (FM), ploughing of post-harvested residues, diversification of the cropping procedure, application of intercropping etc.).

Long-term soil experiments provide important data on changes in SOC stocks and can be used to test the accuracy of the SOC inventory changes model. The National Agriculture and Food Center has long-term soil experiments on the experimental station Milhostov, located on the Eastern Slovak Lowland. Milhostov belongs to a warm and very arid lowland continental climate region. The soil type is gleyic Fluvisol, with high gley particles. In this locality, since 2006, the impact of three tillage methods on track changes of soil properties and achieved harvests has been followed. Crop rotation contains corn for gain, spring barley, soybeans, and wheat; all post-harvested residues remain in the soil. The RothC model was used to track changes in SOC stock under conventional tillage. In 2006-2021, validation of the model and the subsequent prediction of SOC stock using the MPI climate model's latest climate scenarios (CS) and several management scenarios (MS) at soil depth 30 cm was carried out. Climate parameters for 2006-2021 were used from the meteorological station Milhostov, and soil data was collected from an experimental field where the SOC concentration is measured annually. The inputs of organic carbon from the plant residues of individual cultivated crops were calculated from the harvests in individual years, and the coefficient Kc represents the amount of carbon in the residues of the evaluated crop according to the mentioned sowing procedure.

From 2006-2021, modelling and measured SOC values fluctuated around 60 t/ha. According to the Kruskal-Wallis test, t-test, sign test, signed rank test and chi-square test, no statistically significant

differences were found between modelled and measured SOC stock values. For the estimation of SOC stock in the future (2022-2100), two CS of the MPI model and four MS were used. CS rcp 2.6 assumed a lower growth, and rcp 8.5 had a higher growth temperature. The MS I (BAU) presents actual climate and management conditions; the MS II has actual crop rotation with FM application; the MS III clover grass was incorporated into crop rotation, and the MS IV has the same crop rotation without ploughing plant residues. Modelling results show that BAU SOC stock is maintained at the present level, and MS IV SOC stock has decreased. An increase of SOC stock can be achieved at the MS II and mainly the MS III at both CS, but a higher increase at CS rcp2.6 was observed. It can be concluded that at the expected temperature increase in the future, an increase of SOC can be achieved only by increasing the input of carbon into soil (FM or including clover grass into crop rotation).

Keywords: soil organic carbon; arable land; RothC model; soil management; climate scenarios

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Synthesis of knowledge availability and knowledge needs in carbon research across European agricultural soils.

Martina Kittinger[1*], Sophie Zechmeister-Boltenstern[1], Rajasekaran Murugan[1,2].

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

[2] *BIOS Science Austria, Vienna, Austria*

** Presenting author: martina.kasper@boku.ac.at*

The interest in agricultural soils as a tool for climate mitigation strategies is increasing all over the world and triggered a rapid growth in European research on soil carbon issues in recent years. For researchers working in this discipline, it is important to keep track of knowledge developed. Gray literature can offer valuable information often prior to peer reviewed publications. Taking advantage of the wealth of knowledge contained in gray literature, this study built an inventory of different types (annual reports, technical reports etc.,) available gray literature relevant to soil carbon and aims to analyze the evolution of knowledge availability, especially the one pertaining to European agroecosystems. This study focuses on reviewing different types of gray literature published (~1000) by 38 European initiatives. This work employs the machine learning technique of topic modeling, an approach to extract the main topics that emerge from gray literature and *analyze their trends over time to conduct a quantitative synthesis*. Performing this activity is important to identify if and how the main soil carbon research trends are adopted in gray literature, *how they have shifted over time (2000 – 2021), to highlight co-occurrences and identify knowledge gaps*. The generated literature pool was analyzed using a set of research concepts and keywords and machine learning tools. Prior to applying the topic modelling technique, a manual screening of titles and abstracts reveals a first ranking of the designated research concepts and keywords in the documents identified. As such, this study can help to clarify the key aspect regarding soil carbon issues in the gray literature of European initiatives and can identify especially the shortcomings which exist in this “big data” pool.

Overall, this study will contribute to the EJP SOIL expected impact areas such as climate change adoption and mitigation, effects of sustainable management practices and harmonization of soil indicators. Furthermore, the study assists to improve the awareness on climate smart soil management practices (EI1), and soil carbon relevant indicators (EI4). In addition, this study results on soil carbon research evolution and knowledge development hold the potential to contribute to the individual roadmaps of European initiatives focusing on soil carbon such as Carbon removal certification, Soil health monitoring directive, nature restoration law etc.

Keywords: soil carbon, European initiatives, gray literature, automated content analysis, topic modelling

Carbon footprints result from livestock production in Poland based on NPC tools from CCCFarming project - limitations and perspectives

Adam Cieslak[1*], Malgorzata Szumacher-Strabel[1], Pola Sidoruk[1], Marion de Vries[2], Diana Ruska[3], Kaspars Naglis-Liepa[3], Paul. R. Hargreaves[4], Robert. M. Rees[4], Xavier Vergé[5], Paul Robin[5], Violeta Juškienė[6], Paul Galama[2], and Abele Kuipers[2]

[1] *Poznan University of Life Sciences, Department of Animal Nutrition, Wołynska 33, 60-637 Poznań, Poland*

[2]*Wageningen Livestock Research, De Elst 1, 6708 WD, Wageningen*

[3]*Latvia University of Life Sciences and Technologies, Liela Street 2, LV-3001 Jelgava, Latvia*

[4]*SRUC, Scotland's Rural College, Scotland, United Kingdom*

[5]*INRAE, UMR SAS, 65 rue de St-Brieuc, CS 84215, 35042 Rennes Cedex, France*

[6]*Lithuanian University of Health Sciences, Animal Science Institute, Žebenkos 12, LT-82317 Baisogala, Radviliškis d., Lithuania*

* *adam.cieslak@up.poznan.pl*

The use of accounting tools for estimating greenhouse gas (GHG) and ammonia (NH3) emissions from dairy farms is of increasing importance for monitoring environmental performance and identifying effective mitigation strategies. In the EU project, Climate Care Cattle Farming Systems ('CCCfarming') three GHG accounting tools were used: ANCA, Agrecalc, CAP'2ER. In Poland – one of the project participants - eight selected farms representing a country-wide variety of housing systems, management practices, breeds, feeding, and land were used. One large farm with 1437 cows and the smaller one's with 10 to 100 cows were monitored. Average milk production per cow was 9241 kg (from 5600 in small 10 cows-farm and in ecological to 15 000 in intensive production farms) in all analyzed farms. Compared with the other farms from the other CCCfarming project countries, based on NPC tools, GHG emission intensity in Poland was one of the highest (1620 g CO_2eq/kg FPCM). The average GHG emission intensity in Polish farms was 1.44 kg CO_2eq/kg FPCM whereas in the other project countries from 0.94 to 1.08 kg CO_2eq/kg FPCM. However, it should be emphasized that the implemented NPC tools were adapted to Polish conditions and were not always easy to use, therefore, the results obtained for other countries such as Latvia, or Lithuania may systematically differ. We can however conclude that the emission reduction strategies proposed in the project, e.g. covering slurry tanks or nutritional strategies, can significantly reduce emissions from Polish dairy farms.

Project CCCfarming National Centre for Research and Development (SUSAN/II/CCCFARMING/03/2021)

Keywords: Climate effects on livestock, Greenhouse gas emissions and environmental impact, Livestock effects on environment

A meta-analysis and modelling exercise on the GHG trade-offs of soil carbon sequestration measures

Hendriks Chantal[1*], Lesschen Jan Peter[1], Porre, R.J.[1], Díaz-Pinés Eugenio[2], Esparza-Robles Ulises[2], Nikolaus Karin[1], Martínez García Laura[3]

[1] *Wageningen University & Research, Wageningen, The Netherlands*

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

[3] *Estación Experimental de Aula Dei (CSIC) , Zaragoza, Spain*

** Presenting author: Chantal.hendriks@wur.nl*

Promoting soil organic carbon (SOC) storage via agricultural management could theoretically store up to 62 t ha^{-1} over the next 50 to 75 years (0.8 to 1.2 t $ha^{-1}y^{-1}$). However, some management practices that increase SOC stocks may also have an impact on other GHG emissions, such as CH_4 and N_2O emissions, and on nitrate leaching. This risk is especially relevant on the longer term, if N_2O emissions remain, while the effect of the carbon sequestration is becoming less due to reaching a new steady state in the soil. Previous studies have shown that this might reduce or even completely off-set the mitigation potential of SOC-sequestration. Therefore, the potential trade-offs of soil carbon sequestration need to be assessed to evaluate the implementation of SOC storage management.

A meta-analysis was carried out as part of the EJP SOIL CarboSeq project. In this meta-analysis the effect of twelve carbon sequestration mitigation practices on N_2O emissions were evaluated. Besides, the causes of these N_2O emissions were explored including the effect of environmental, soil and management practices. The results showed quite some variation in the effect of carbon sequestration measures on N_2O emissions, yet overall, we can conclude that biochar, agroforestry and land use change from cropland to grassland or energy crop reduced N_2O emissions, whereas residues of green plant biomass (mainly vegetables) and the use of digestate increased N_2O emissions significantly, while for irrigation, tillage, and other organic amendments, no significant increase or decrease in N_2O emissions were found.

In addition, trade-offs related to indirect emissions when applying soil carbon sequestration measures were assessed in a modelling exercise. The indirect emissions caused by machinery use, production of fertilisers or pesticides, and fertiliser application were considered. First, literature was searched to find which farm operations change when a carbon measure is applied. The results showed that miscanthus had the highest reduction in emissions compared to the baseline, followed by willow and the inclusion of a legume crop to the rotation. None of the other measures (agroforestry, cover crop, and no -and reduced tillage) had off-set the carbon sequestration by indirect emissions, except when silage maize is replaced by perennial ryegrass, and when straw is incorporated in the soil. These

indirect emissions are respectively caused by an increased use of fertilizer for ryegrass compared to silage maize, and by the loss of straw as bioenergy source.

Keywords: climate change mitigation, N_2O emission, sustainable agriculture, greenhouse gases,

Analyzing efficient incentive mechanisms of carbon farming: A mixed-method approach

Raina, Nidhi[1]; Van Ruymbeke, Kato[2]; Zavalloni, Matteo[3]; Mathijs, Erik[2]; Viaggi, Davide[1]

[1]*University of Bologna, Italy;*

[2]*Katholieke Universiteit (KU) Leuven, Belgium;*

[3]*University of Urbino Carlo Bo, Italy*

The study aims to evaluate incentive mechanisms of carbon farming contracts, with a focus on result-based, action-based, and hybrid models through expert interviews to assess the preference of these mechanisms. Important contract design attributes are measured against key performance indicators specific to carbon farming, identified through literature review. Findings from interviews with ten experts have been analyzed using the multi-criteria decision analysis tool known as Technique for Order Preference by Similarity to Ideal Solution. The alternatives, the contract design attributes, were ranked in order of preference of the experts using TOPSIS using a conceptual framework designed to illustrate an efficient carbon farming contract. The final ranking indicates that "hybrid payments," funded through market-based mechanisms, was scored highest by the experts. In contrast, "low transaction costs" scored the lowest, suggesting that experts believe a mixed mode of incentives from private funds will most significantly contribute to the maximum performance of a carbon farming project, and transaction costs borne by farmers will contribute the least. The underlying reasons for these results are qualitatively analyzed.

Roadmap for improvement of carbon sequestration in the Netherlands

Van der Kolk, Jennie[1]; Slier, Thalisa[1]

[1] *Wageningen Environmental Research, Wageningen, The Netherlands*

In the Netherlands, the government has set goals for climate mitigation and soil health regarding agricultural mineral oils. Measures for carbon sequestration in these soils are important for reaching these goals and were studied in the past five years in the research program Smart Land Use. The results show that it is possible to reach the climate goals for Dutch agricultural mineral soils, but proper implementation of the measures is important. To determine which actions are necessary to reach sufficient implementation, a roadmap has been composed to set the focus of the research in the follow up of Smart Land Use in the period 2024 – 2026. The roadmap takes into account the policy goals, the role of research, the role of farmers and other stakeholders. The roadmap covers the period until 2030, where the policy goals should be reached.

Several outcomes have been identified that contribute to the goals. The main focus of these outcomes is towards placing measures in a complete farm set up, which provides farmers with perspectives on how to implement carbon sequestration at farm level on the long term.

In this poster, we will present the roadmap.

Keywords: roadmap**,** carbon sequestration, mineral soils, climate mitigation, soil health