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BOOK OF ABSTRACTS

Block A

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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[*], 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

A2 Leveraging different approaches in the development of farmer friendsly tools for sustainable soil practices and schemes

Session Description

Involved projects: ROAD4SCHEMES, IntoDIALOGUE, PRAC2LIV

Conveners: Morten Graversgaard, Meriem Jouini, Francesco Galioto and Monika Vilkiene

EJP SOIL is committed to advocate for the utilization of regionally tailored methodologies for furnishing multispectral insights into agricultural soil-based ecosystem services, particularly in the context of climate change. The prevailing trajectory underscores the need to investigate how to further encourage sustainable soil practices and schemes. The degree of practice implementation and adherence to guidelines for sustainable soil management in Europe exhibits considerable heterogeneity among farmers and across regions. Numerous studies have identified a wide range of barriers to the adoption of these sustainable practices, with special reference to soil management, encompassing disparities in advisory frameworks, country-specific data, knowledge creation and dissemination, type of incentive instruments and governance mechanisms.

We invite abstract submissions to elucidate experiences from projects concerning end-users' engagement, development and adoption of new tools and methods or implementation of new agroecological strategies.

More than a Dialogue between actors, seeking the integration of soil-based principles in agroecological systems

Galioto Francesco[1*]

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

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

Into-DIALOGUE focus on investigating contingent soil-related issues and to explore potential solutions. Particular attention is paid to those soil functions that can contribute dealing with environmental issues, including climate change, exploring both adaptation and mitigation actions from the field level to the landscape. Building on the results of previous EU and Turkish projects, Into-DIALOGUE aims to determine:

farmers' knowledge, behaviour and risk perception associated with the progressive loss of functions of their agricultural soils. Assessment of this knowledge according to the different characteristics of the farms (size, crop specialization, soil type, etc.).

drivers and barriers for farmers' acceptability of soil-based agroecological management practices, and whether this depends on their ecological identity.

the complexity of applying integrated policies in soil-based agroecological systems; and options for developing EU strategies, opinions, and actions into national sectoral policies.

the bundles among farms characteristics, farmers ecological identity, barriers to adopt sustainable management practices and policy measures (following the methodology of EJP-Soil SERENA project).

the role of farmers, decision-makers, stakeholders and end users, and the benefits that the postulates of citizen science can bring to the visibility of the soil resource in the management practices recommended by Agroecology.

The study area covers a broad range of agricultural realities of the EU and Turkiye, including various climatic regions and social contexts (that's why the project gives a special emphasis to the ecological identity of farmers). In the different contexts, it is first explored the objective dimension of the problem that makes it possible to identify solutions but not to explore their practicability. The practicability of the required solutions is then investigated through the analysis of farms' structural characteristics, farmers' conditions, the existence of facilitating policies that can contribute legitimating farmers roles and attitudes and finally, farmers perceptions of soil-related challenges and responsibility. All these elements justify the multidisciplinary nature of the research team, made up

of scientists from various disciplines: agronomists, foresters, biologists, geographers, economists, life sciences and political sciences.

Currently, the project is about to end, almost all deliverables are completed. Thus, an overview of main methodologies and key messages from project results are provided with the main purpose to set the general framework from where other contributions from this project are expected to be discussed during the breakout session.

Keywords: Participatory methods; Soil health, Driving forces, Policy solutions, Multi-actor approaches

Living Labs to support sustainable soil management practices and the implementation of decision-support Tools in Europe

Jouini Meriem [1*], Delin Sofia[1], Demir Zeynep [2], Erdal Ulfet [3], Kasparinskis Raimonds [4], Räsänen Timo [5], Stenberg Bo [1], Trinchera Alessandra [6], Warren Raffa Dylan [6] and Hanegraaf Marjoleine[7]

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

[2]- *General Directorate of Agricultural Research and Policies (TAGEM), Turkey*

[3] *UTAEM, Menemen, İzmir, Turkey*

[4] *University of Latvia (UL), Latvia*

[5] *Natural Resources Institute Finland (Luke), Finland*

[6] *Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA), Italy*

[7] *Wageningen University & Research, Wageningen, Netherlands*

** Presenting author: meriem.jouini@slu.se*

Keywords: Living Labs; decision-support tools, implementation, multi-stakeholder, soil management.

Individual decisions taken by farmers determine the change towards more sustainable agriculture and resource management. Sustainable local and regional development may be accelerated by improving farmers' knowledge and capacity to define and decide on sustainable systems. To achieve this, an entity at local level is needed that is legitimate for all stakeholders to support the process of transferring knowledge and innovations, and that ensures the participation of all the legitimate parties concerned by resources management. In this context, the EU has identified Living Labs as a key and legitimate actor in local development, to involve farmers in sustainable resource management, to enable the sharing of knowledge about local resources and decision-support systems, to make it possible to consider the relevant scales of stakeholders: i) the decision-making scale of farmers (plot and farm scale), and ii) the decision-making scale of decision-makers (regional scale) and to ensure the bridge between the different levels. The implementation level of decision-support tools (DSTs) for sustainable soil management in Europe varies among farmers and regions. The aim of this study is to explore, within the EJP SOIL project PRAC2LIV, the main factors that explain why the use of the available tools to improve resource use efficiency and management is still insufficient in Europe, while the necessary tools in many cases are freely available. This study also focused on a case study in Sweden conducted within a Swedish regional project (VGR-project). Within the EJP SOIL project PRAC2LIV, a wide range of DSTs has been identified in Europe: 38 DSTs were reported for soil water availability and retention, 46 DSTs for soil organic carbon and 72 DSTs for soil nutrient use efficiency. Making these tools operational and relevant for farmers is a challenge, let alone for stakeholders in

general. In order to have reliable and accurate input and output data for farmers, the scope and implementation of DSTs must take into account local specificities. Based on farmers' interviews in the Swedish case study conducted as part of the Swedish VGR-project, there is a knowledge gap between farmers and tool developers related to the proposed use and interpretation of tools. Farmers indicated that they receive too little or too much information which effect their capacity to decide whether to use DSTs or not. Instead, many farmers perform on-farm experiments as a method to enhance their decision-making capacity. This underlines the importance of identifying the drivers for sustainability in a real-life context, in order to produce scientific knowledge and make the most of this knowledge at the intervention level. Indeed, experimentation practices might support farmers' transition towards more sustainable practices. The analysis of the interview-results showed that acceleration of sustainable soil management requires efforts by multiple stakeholders, at different organization levels. Living Labs can be key to connect stakeholders in the articulation of tailored interventions for sustainability at the regional level. Furthermore, they can support innovation processes around experimentation to foster sustainable soil management practices and the implementation of DSTs for sustainable development from local to national and European levels.

Advancing carbon farming in Europe: Insights and challenges from research and policy perspectives

Thorsøe Martin[1], Smit Bert[2], Heidecke Claudia[3], Baumgarten Andreas[4], De Cara Stéphane[5], and Graversgaard Morten[1*]

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

[2] *Wageningen Economic Research, the Netherlands*

[3] *Coordination Unit Climate, Johann Heinrich von Thünen-Institute, 38116 Braunschweig, Germany*

[4] *AGES, Dept. for Soil Health and Plant Nutrition, Wien, Austria*

[5] *Université Paris-Saclay, INRAE, AgroParisTech, Paris-Saclay Applied Economics, 91120, Palaiseau, France*

**Presenting author: Morten.Graversgaard@agro.au.dk*

Carbon farming, a key strategy for mitigating climate change and enhancing soil ecosystem services, holds immense promise in Europe. This presentation synthesizes findings from multiple research papers and deliverables within the EJP SOIL - Road4Schemes project to provide comprehensive insights into the landscape of carbon farming schemes in Europe.

Drawing from the inventory and analysis conducted in Work Package 2 (WP2), we evaluate the diversity of carbon farming schemes across Europe, examining their organizational structures, payment models, and adherence to critical principles such as additionality and long-term carbon storage. Additionally, we explore the implications of private versus public schemes and the challenges in standardization and monitoring.

Furthermore, insights from Thorsøe et al. 2024 shed light on the design and implementation of carbon farming schemes, emphasizing the need for credible schemes that ensure quantifiable carbon removal, additionality, and sustainability. While result-based schemes hold promise, the predominant use of activity-based incentives presents a notable observation.

Hönle et al. 2024 delves into the integration of carbon farming into national policies, highlighting the evolving role of carbon farming in achieving national climate targets. Disparities among European countries in policy emphasis, assessment of carbon farming options, and strategies for monitoring and verification underscore the need for harmonization and coherent strategies.

Additionally, insights from farmers' perspectives, as explored in WP3, provide valuable considerations for scheme design and implementation. Farmers' varying levels of interest, adoptability, and opinions on result-based schemes underscore the importance of tailoring schemes to meet their needs while addressing measurement challenges and providing adequate support.

Finally, the roadmap outlined in WP4 offers a decision-making tool for the further introduction of carbon farming, considering local characteristics and environments. This holistic approach integrates natural, economic, technical, and regulatory factors to facilitate informed choices in implementing carbon farming schemes. By synthesizing these insights, our presentation contributes to the ongoing discourse on advancing carbon farming in Europe, addressing challenges, and informing policy and decision-making processes for a sustainable future.

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Keywords: carbon management; scheme design; decision making tools; MRV

Policy gaps and inconsistencies in addressing agricultural soil health challenges in the EU and Türkiye

Francesca Varia[1*], Francesco Galioto[1], Sabina Asins Velis[2], Javier Renovell[2], Martin Pisarcik[3], Pavel Fuksa[3], Jerzy Grabiński[4], Monika Vilkiene[5], Ieva Mockeviciene[5], Raimonds Kasparinskis[6], Baiba Dirnena[6], Akin Ün[7], Stefania Maurino[1], and Giovanni Dara Guccione[1]

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

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

[3]*CZU Czech University of Life Sciences Prague, Prague, Czech Republic;*

[4]*IUNG Institute of Soil Science and Plant Cultivation, Pulawy, Poland;*

[5]*LAMMC Lithuianian Research Centre for Agriculture and Forestry, Vilnius, Lithuania;*

[6]*UL University of Latvia, Riga, Latvia*

[7]*TAGEM General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry, Ankara, Republic of Turkey.*

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

This study focuses on the analysis of policies addressing soil health challenges which have been recently designed and implemented in six EU countries and in Türkiye. To this end, researchers involved in the Into-DIALOGUE project have developed a common research framework consisting of five key policy areas: Incentivising the adoption of sustainable practices, with special reference to voluntary measures supported by agricultural policies (i.e., the CAP for EU countries and IPARD for Türkiye); Enabling participatory processes, with particular reference to regulations empowering collective actions (e.g. Bio-districts, Land associations, Rural districts); Regulating the protection of the environment and the landscape, which includes both nitrate, water, and biodiversity directives, as well as regulations and rules aimed at protecting landscape features; Co-creating and sharing innovation and knowledge, with special reference to EIP-Agri Operational Groups, lighthouses and living labs and advisory services; Triggering new market opportunities, which encompasses rules on geographical indications of origin, short food chain initiatives and voluntary certification schemes.

A comparative analysis based on descriptive statistics and qualitative information was performed in order to: highlight convergences and divergences of the policy interventions adopted in different countries, assess the relevance of the policies compared to current soil health challenges, and identify policy gaps and inconsistencies in the design of policy interventions.

The results show that, in general, policy decisions and the agro-ecological practices promoted by these policies are not supported by robust evidence regarding the extent of soil-related issues at the

territorial level. Moreover, they frequently lack rigorous conditionality requirements, posing a risk to their effectiveness, particularly in certain types of farming systems. In addition, the different national soil health strategies are generally still characterised by a number of weaknesses, partly due to the flexibility with which EU regulations and directives can be implemented, which has often led to weaker commitments, and partly due to deliberate infringements, which have a direct impact on the ability of governments to monitor and control compliance. Conclusions summarise the main findings, discuss the limitations of the policies examined and provide some policy recommendations to address the existing gaps due to the lack or poor design of relevant policy instruments.

Keywords: Policy instruments; soil degradation indicators; agroecology; CAP; conditionality.

Enhancing Soil health through values-based business models

Facq Ennio, Lene Cillen, Hans Vandermaelen, Sylvie Fosselle, Flanders Institute for Agriculture, Fisheries and Food (ILVO), Merelbeke, Belgium, ennio.facq@ilvo.vlaanderen.be

Keywords: soil health, business models, payment for ecosystem services

Soil is a key asset for farmers and land managers and requires continuous investments to prevent land degradation and increase farm resilience[1]. In addition, soils are important for society as a whole, generating key ecosystem services such as clean water, carbon sequestration and biodiversity[2]. However, the importance of well-functioning 'healthy' soils is often not recognised, neither in business decisions nor by the general public, resulting in a lack of incentivesfor private and public land managers to adopt practices supporting soil health[3]. Thus the question rises: *What conditions need to be met in order to develop succesful business models which include soil health and get them adopted by land managers?*

the Horizon Europe project SoilValues comprises six case studies across Europe (Belgium, The Netherlands, Denmark, Germany, Poland and Portugal), in which researchers identify the relationships between farming practices, income, soil health and the ecosystem services provided by land managers.

Land managers then work together with their stakeholders in each case study to formulate implementation plans detailing how they will explore or test options for adaptation of their current business model. The goal is to recognise and capture value from (improvements in) soil health and the delivery of ecosystem services and collaborate with stakeholders on how to distribute this value. This is done in a co-creative setting, involving a wide range of stakeholders through interviews, workshops, focus groups and field visits.

The preliminary results highlight the necessity and added value of including a diverse group of stakeholders to identify new business opportunities and tackle the various accompanying financial, legal and practical obstacles. Besides the possibilities for adapted business models, the various stakeholder interactions are increasing awareness on soil health and related concepts through regional networking. At the same time, the many perspectives represented by these stakeholders demonstrate the subjective nature of attributing (economic) value to concepts such as soil health, of which the benefits in the short- and long-term can be complex and challenging to quantify.

In conclusion, a co-creational approach to developing business models for soil health is promising due to the need for a consensus on the (economic) valuation of soil health and ecosystem services within a specific value chain. This approach recognises the involved nature of business models which have land

management decisions at its core. At the same time, involving many stakeholders is not without challenges and possible pitfalls.

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Identifying farmers' priorities in soil management for climate adaptation to develop attractive support measures

Schreiber Mariella[1*], Braito Michael[1], Bütikofer Nicole[2], Graversgaard Morten[3], Höckert Jenny[4], Lunar-Koch Ernesto[1], Lundström Christina[4], Tiselius Mette[4], Leonhardt Heidi[1]

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

[2] *Agroscope, Zurich, Switzerland*

[3] *Aarhus University, Tjele, Denmark*

[4] *Swedish University of Agricultural Sciences, Skara, Sweden*

* mariella.schreiber@boku.ac.at

Climate change and the associated increase of extreme weather events pose serious challenges for crop farmers across Europe. Climate-smart soil management practices can mitigate these challenges at the farm level. However, adopting such practices requires farmers to change their production system, acquire new equipment, deal with new challenges in pest management, and more, which might result in farmers being reluctant. A widespread uptake of climate-smart soil management practices thus requires supporting the on-farm transformation process. However, farmers, like society, are not a uniform group and their decisions are driven by factors such as social and cultural norms, values, and attitudes. As a result, farmers have different priorities in their soil management. To identify suitable support instruments, it is therefore necessary to identify the soil management priorities of different farmers.

We used a mixed-method approach to answer the following research question: "What priorities do different farmer types have in their soil management?". We conducted a total of 130 Q-methodological interviews with farmers (operators of crop or mixed farms) in five European countries (Austria, Denmark, Spain, Sweden, Switzerland). Q Methodology centres around on a set of statements on a topic (here: soil management priorities), derived from literature, pre-tests and stakeholder interviews. Respondents sort these statements according to their level of agreement with each statement. In the analysis, we then statistically identify typical ways how the statements have been sorted and qualitatively interpret these typical sortings.

We identified five different farmer types or viewpoints, with differing priorities in soil management: Farmers that share viewpoint 1, "sustainability of soil and environment", prioritize soil health and environmental aspects to preserve their farm for future generations. Viewpoint 2, "efficient farm management" is shared by farmers who strive to optimize their farm business for economic sustainability. Accordingly, they focus on soil water retention and an efficient organization of the farm work in their soil management. Farmers aligned with Viewpoint 3, "farming the triple bottom line",

prioritize the long-term economic viability of their farms, while also considering social and environmental impacts. They are open to novel practices and, above all, want to enjoy their work as farmers. Farmers sharing viewpoint 4, “traditional farm work”, strongly believe in providing food for the world through hard and accurate farm work and enabling their successors to continue farming. Moreover, viewpoint 5, “striving for financial stability”, gives top priority to the avoidance of risks that could endanger the farm’s continuation.

Based on these priorities, each viewpoint will also respond differently to different support measures for adapting their soil management. To identify which types of support will be attractive to different viewpoints, we also conducted country-specific workshops with farmers. These show that some farmers will likely respond to financial support, while others might need information campaigns, field days, or societal recognition for their work with the soil. These results can inform policy makers, farm advisors, and other stakeholders to provide tailored information and support measures.

Keywords: Farmer typology, policy recommendations, sustainable soil management, climate adaptation, farmer priorities

Assessing Agri-Environmental Footprints and Pathways to Net-Zero: Insights from Process-Based and Whole-Farm Models

Khalil Mohammad Ibrahim[1*]

[1] *UCD School of Agriculture and Food Science, University College Dublin, Dublin 4, Ireland, and PCD School of Applied Sci-Tech, Prudence College Dublin, Dublin 22, Ireland.*

** Presenting author: Ibrahim.khalil1@ucd.ie*

Agriculture, with its significant environmental footprint, notably in greenhouse gas (GHG) emissions, presents a crucial arena for achieving climate action goals primarily carbon-neutral farms by 2050. Achieving a sustainable future requires strategies aimed at mitigation and offsetting of GHGs through increased carbon sequestration. The labour-intensive measurements of all inputs and outputs at a farm-to-country level trigger to find tools for accounting, and evaluation, and thereby find alternative options for decision making.

Process-based models (PBMs) and whole-farm models (WFMs) emerge as potential solutions to this challenge, offering unique strengths to tackle this complexity. PBMs, like DNDC, excel at dissecting specific agricultural practices like fertilization. By simulating underlying biophysical processes, they shed light on the "why" behind emissions, generating crop-specific and management-specific emission factors (EFs). However, their reliance on site-specific calibration and potential lack of transparency in source code can limit their wider application. WFMs, in contrast, offer a holistic view of the farm ecosystem, encompassing crops, livestock, agroforestry, and management practices. This comprehensive approach allows the assessment of mitigation strategies and explores pathways towards carbon-neutral farms. While WFMs offer a powerful tool for solutions, their data-driven nature and potential complexity can be daunting, particularly for smaller farms with limited resources. Bridging this gap lies in leveraging the synergies and trade-offs of both approaches. PBMs can provide research-grade insights and refined EFs tailored to specific farm contexts. These insights can then be seamlessly integrated into WFMs, enhancing the accuracy and realism of farm-level assessments. This paves the way for targeted intervention strategies and more precise estimations of a farm's environmental impact.

Digital platforms like HOLOS-IE (www.ucd.ie/holos-ie) could play a crucial role in facilitating this synergy. This digital platform, under development, offers a user-friendly interface, transforming the complex modelling process into an accessible tool for farmers and other stakeholders. By streamlining data input and offering intuitive visualisations, HOLOS-IE empowers stakeholders to gain a deeper understanding of their agri-environmental footprint and choices for its reduction. Automation of soil and climate parameters through mapping, along with the integration of default inputs/EFs from PBMs,

could significantly reduce input requirements. This empowers actively track and manage carbon footprint, paving the way for more sustainable agricultural practices.

This paper presents a preliminary version of HOLOS-IE, leading to HOLOS-EU for wider application across Europe, showcasing its potential to be an invaluable tool in the pursuit of net-zero emissions in agriculture. By providing accessible and user-friendly environmental assessment tools, we can empower farmers and other stakeholders to become active participants in the fight against climate change, fostering a more sustainable future for agriculture.

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Keywords: Sustainable Agriculture, Greenhouse Gas Emissions, Modelling, Net-Zero Emissions, Decision Support Systems

Developing a Carbon farming framework supporting Ireland to meet its climate targets.

Gee; Stewart, Lhermite; Ellea, Goldys; Aleksandra, Visser; Saskia

EIT Climate-KIC Foundation; Amsterdam

Presenting author: Saskia.Visser@climate-kic.org

The European Commission defines carbon farming as "a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter, and soils by enhancing carbon capture and/or reducing the release of carbon into the atmosphere, in respect of ecological principles. Carbon farming can enable the facilitation of certified climate action which has the potential to be rewarded through result-based contracts/approach with other actors in the value chain or through public support." In its role of helping Ireland meet its Climate targets, a fit for purpose National Carbon Farming Framework will provide opportunities for Irish farmers/land managers to derive a new and diversified income stream for their farm. It is essential that this Framework provides confidence, trust, fairness, verification and certification to support rewarding Irish farmers/foresters for the actions they take to remove and store carbon in our soils, forests, grasslands, croplands, peatlands and hedgerows.

The Framework will create the structures needed to leverage appropriate financial incentives to scale up adoption of measures by land managers that will result in Ireland achieving its ambitious targets on emissions reductions, biodiversity and water quality improvements. The Core Carbon Principles (CCPs), have been adopted to set out fundamental principles for high-quality credits that create real, verifiable climate impact, based on the latest science and best practice. Following input through public consultation, the CCPs have been adapted to include biodiversity/water quality improvements in the Irish context. Two additional overarching principles have also guided the development of this Framework; Just Transition & Learning By Doing.

This research presents the outcomes of a public consultation, elements of policy lab and describes the process to develop the national framework and outlines the framework that will be submitted for approval by the government. Elements of the new policy identified as key by various stakeholder groups will be described, as well as areas of concern and implementation conditions that should be ensured. Analyzing qualitative data from the entire policy creation process as well as quantitative data from the public consultation stage itself, we use the Transformative Innovation Policy approach, trying to understand what forms of creating climate policies have the greatest potential to activate various resources. **Keywords: Carbon farming, ecosystem, public consultation, climate policy, governance.**

Soil health challenges and farmers adaptation strategies: transition pathways in Türkiye and the European Union

Galioto Francesco[1*], Francesca Varia[1], Giovanni Dara Guccione[1], Sabina Asins[2], Javier Renovell[2], Akin Un[3], Tali Monis[2], Monika Vilkiene[4], Ieva Mockeviciene[4], Raimonds Kasparinskis[5], Baiba Dirnena[5], Alessandra Vaccaro[1], Laura Viganò[1]

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

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

[3] *GAPTAEM GAP Agricultural Research Institute E, Haliliye, Türkiye*

[4] *LAMMC Lithuanian Research Centre for Agriculture and Forestry, Akademija, Lithuania*

[5] *UL University of Latvia, Riga, Latvia*

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

The degradation of agricultural soils in the European Union (EU) and Türkiye poses a significant threat to both human well-being and ecosystems, with around 60-70% of agricultural soils found being unhealthy due to one or diverse soil threats. While agriculture has the potential to mitigate soil degradation through adequate practices, relevant stakeholders are not enough motivated to drive meaningful change, even in the presence of facilitating policies. This underscores the need for a coherent soil strategy that integrates agricultural and environmental policies, tailored to regional realities and equipped with effective instruments to address contingent problems and drive the transition of agricultural systems towards more resilient agroecological states. In this regard, a survey involving 70 farmers from 5 regions around Europe and Türkiye with agricultural soils under threat, is carried out to investigate farmers adaptation strategies. A Data Envelopment Analysis followed by a regression analysis, complemented with qualitative information, is carried out to investigate inefficiencies, barriers, and driving forces. Results reveal the existence of different factors that contribute influencing farmers adaptation strategies. From a preliminary analysis (data analysis is still ongoing), Implementation cost barriers appear particularly strong for small farms, while market barriers for large farms with high income share from agriculture and with leased land. Inefficiencies are also strongly influenced by the territory where farmers operate for both small and large farms. Discussions follow arguing around the driving forces, with special reference to the influence of the territory on a social and biophysical perspective. This is because the different reference territories of the selected farms reflect different forms of social constructions farmers are embedded in and

influenced by, such as markets and governments. The interplay of such forces is thought to influence farmers adaption more than their structural characteristics. The paper is expected to conclude with some policy implications addressing the influence of local governments in recognizing the role of farmers in contributing protecting the environment through appropriate incentive policies followed by facilitating policies to accompanying the transition towards more resilient agroecological systems, such as the provision of advisory services, demonstration fields and better rules to protect the environment and favour the collaboration between farmers, the absence of which can compromise the efficacy of facilitating policies when present.

Keywords: Soil health; Data Envelopment Analysis, Farmers' survey

Knowing and needs on soil quality indicators for agroecological practices: results from a systematic review of long-term experiments in Countries participating in "Into Dialogue" EJP Soil project

A. Maienza[1], A. UN[5], J. Renovell[4]., G. Biancofiore[1]., G. Buttafuoco[1], O., Szabó[2], M. Pisarčik[2]., P. Fuksa[2]., J. Grabinski[8], E. Lumini[1]., S. Di Lonardo[1,3]., M. Kushnir[2]., M. Kovandova[2]

M. Vilkiene[6], I.Mockeviciene [6]., B. Dirnena[7] S. Asins[4].

1 National Research Council, Rome, Italy

2 Czech University of Life sciences in Prague, Czechia

3 National Biodiversity Future Center, Palermo, Italy

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

5 GAP Agricultural Research Institute-TAGEM, Sanliurfa, Turkiye

6 Lithuanian Research Centre for Agriculture and Forestry, Akademija, Kedainiai district, Lithuania

7 University of Latvia, Riga, Latvia

8 Institute of Soil Science and Plan Cultivation, Pulawy, Poland

The study insight into the assessments of the relationships between agroecological practices and soil quality through a literature review of studies carried out within the countries involved in the Into-DIALOGUE project (Italy, Poland, Spain, Czech Republic, Latvia, Lithuania, Turkey). The focus was on the soil quality properties and related soil ecosystem services in relation to agroecological practices in each country.

The results showed how conservation practices are useful for improving soil quality in general and supporting soil ecosystem services, particularly in terms of regulatory and support functions influenced by organic amendment.

Moreover, the results showed the need for a comprehensive dataset including physical, chemical, and biological properties to assess soil quality and to address current needs regarding soil functions and ecosystem services. Biological data should be used more in soil quality assessment due to their completeness of information and faster response compared to physical and chemical aspects of the soil. For this reason, it would be necessary to invest in the harmonization and clarification of methodological aspects required for proper soil quality monitoring. In conclusion, the review sustained that agroecological practices have a strongly positive effect on soil quality and emphasized

the importance of increasing long-term experiments focusing on conservation practices, especially in environmentally sensitive European and Turkish agricultural landscapes.

A novel method to support the discussion of soil management PRACtices and development of decision support TOols through LIVing labs in EU (PRAC2LIV)

Ooms, Daniëlle[1], Matson, Amanda[1], Räsänen, Timo[2], Kasparinskis, Raimonds[3], Warren Raffa, Dylan[4], Delin, Sofia[5], Zeynep Demir[6], Meriem Jouini[5], Valentina Baratella[4], Alessandra, Trinchera[4], Ulfet Erdal[6], Baiba Dirnēna[3] and Hanegraaf, Marjoleine[1]

[1]*Wageningen Research, Wageningen, Netherlands;* [2]*Natural 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 explores how Decision Support Tools (DSTs) for soil management could support soil health in living labs. The DSTs in this case were constrained to those addressing soil organic matter, water retention, and nutrient use efficiency. Assessing the potential of DSTs to support soil health in living labs is a complex issue, given that all the various aspects of context will play a key role. Therefore, there is a need to not only collect information on DSTs but to inspire conversations to understand the needs and expectations of different stakeholders within the different contexts of living labs across Europe. To address that need, we used the novel participatory pictorial approach which include the visualization and short justification text. This method consists of (1) extracting a visualisation out of a team discussion, (2) presenting these visualised key points in expert groups and (3) using the visualisation as a source for discussion. Throughout the process, the visualisation goes through several iterations, all with the end goal of igniting fruitful discussions. Shown here is a pictorial highlighting a set of key topics around DSTs for soil health in living labs within the EJP Soil PRAC2LIV project. We presented the visualization to several expert groups at various scale levels both national and international. In the discussions, the visualization bridged communication gaps between living lab stakeholders with different values and needs. For instance the suggestion to include a digital twin for living labs and to consider financial aspects of soil health. The visualisation approach was found to be useful to generate new directions for programmes such as EJP Soil including important topics that could be (re)evaluated.

Keywords: Decision Support Tool, sustainable soil management, Living Lab, visualisation, pictorial, novel participatory method

Identification of drivers and barriers to the acceptability of agroecological land management practices for farmers in the EU and Turkey

Martin Pisarčik[1], Pavel Fuksa[1], Michelle Kushnir[1], Gozel Challyjeva[1], Zuzana Fuksová[2], Sabina Asins[3], Javier Renovell[3], Giovanni Dara Guccione[4], Francesca Varia[4], Francesco Galioto[4], Maria Valentina Lasorella[4], Monika Vilkiene[5], Ieva Mockeviciene[5], Baiba Dirnēna[6], Kristīne Afanasjeva[6], Raimonds Kasparinskis[6], Jerzy Grabiński[7], Akın Ün[8], Sara Di Lonardo[9,10], Gabriele Buttafuoco[11], Mario Cariello[4]

[1]*Czech University of Life Sciences Prague, Czech Republic*

[2]*Institute of Agricultural Economics and Information, Czech Republic*

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

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

[5]*LAMMC Lithuanian Research Centre for Agriculture and Forestry, Vilnius, Lithuania*

[6]*UL University of Latvia, Riga, Latvia*

[7]*IUNG Institute of Soil Science and Plant Cultivation, Pulawy, Poland*

[8]*TAGEM General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry, Ankara, Republic of Turkey*

[9]*National Research Council of Italy, Sesto Fiorentino, Italy*

[10]*National Biodiversity Future Center, Palermo, Italy*

[11]*National Research Council of Italy, Rende, Italy*

With the new 2023-2027 Common Agricultural Policy (CAP), Member States were called to prepare their own Strategic Plans providing support to the agricultural sector and rural areas with specific common objectives and especially greater environmental ambition. The aims involve conditions for sustainable farming in the European Union (EU), targeted support to farms, and increased flexibility for EU countries to adapt measures to local contexts. Into-DIALOGUE project, funded by the European Joint Programme on SOIL, is focused on exploring eco-schemes' potential impact on climate- and environment-friendly farming practices and biodiversity improvements. Targeted agri-environmental measures strongly support conserving managed areas of significant natural value, natural resources, biodiversity, and landscape maintenance. Similar supporting measures focused on sustainable agriculture and farming practices are realised in Turkey.

In the Into-DIALOGUE project, a questionnaire survey was carried out in the seven participating countries (Czech Republic, Spain, Italy, Lithuania, Latvia, Poland, and Turkey) to identify the drivers and barriers farmers face in adopting sustainable farming practices. The results of the questionnaire survey on a sample of farms provide valuable information on farmers' attitudes towards different agri-

environmental measures. The status of farms (individual farmers or legal entities), type of management (conventional; organic), area of cultivated land, the age structure of management, the labour force (family labour; non-family labour), and other indicators were assessed as classification criteria.

Farmers' attitudes regarding the current status and estimation of the short and medium-term outlook of their farming in relation to the introduction of agroecological practices and possible barriers were surveyed. Details on risk assessment of biodiversity loss, soil erosion, soil compaction, or loss of organic matter were investigated. The evaluation of the data concerning each agri-environmental measure provides results in terms of assessing the financial benefits to the farm, the improvement of soil conditions, the improvement of agroecological parameters, including biodiversity, the assessment of the time and workload on the field, and the administrative burden associated with the implementation of the measures.

Keywords: CAP eco-schemes; agroecology; farmers’ survey; financial benefits; participatory approach