

Keynote Abstract

Soils and sustainable food production

Dr Ismahane Elouafi

Chief Scientist

Food and Agriculture Organization (FAO) of the United Nations

Socio-political conflicts¹, climate change and extremes, and economic slowdowns and recessions, now exacerbated by the COVID-19 pandemic, are behind recent increases in food insecurity, hunger and malnutrition². The new projections confirm that Zero Hunger will not be achieved by 2030 unless bold steps are taken to accelerate progress towards more sustainable agrifood systems.

Healthy soils represent a key ally in alleviating the root causes of food insecurity (particularly availability, access and stability) and malnutrition and ensure access to affordable healthy diets for all, in a sustainable and inclusive manner². Sustainable local food production is a feasible solution³, but financial barriers and lack of legal frameworks need to be addressed. There is a pressing demand for solutions on how to maintain/improve soil productivity while respecting environmental sustainability. The soil science community has an important responsibility to provide viable solutions based on successful experiences and data.

¹ FAO. 2022. Information note: The importance of Ukraine and the Russian Federation for global agricultural markets. Risks associated with the current conflict. <https://www.fao.org/3/cb9236en/cb9236en.pdf>

¹ FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO. <https://doi.org/10.4060/cb4474en>

¹ IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

¹ FAO. 2022. Information note: The importance of Ukraine and the Russian Federation for global agricultural markets. Risks associated with the current conflict. <https://www.fao.org/3/cb9236en/cb9236en.pdf>

² FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. Rome, FAO. <https://doi.org/10.4060/cb4474en>

³ IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Geospatial decision support systems embedding digital soil mapping engines

Dr Giuliano Langella¹

¹Università di Napoli Federico II, Portici, Italy, ²CRISP, Portici, Italy

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Prof. Fabio Terribile & Dr Jack Hannam, Lomond Auditorium, August 1, 2022, 11:00 - 13:00

GeoSpatial Decision Support Systems (SDSS) using soil data are becoming crucial tools to address sustainable land planning and management in agriculture and environment. Most frequently, these systems rely on soil data information produced after old soil survey mapping. To face current environmental challenges, it is fundamental to link these DSS systems with DSM procedures enabling to update soil databases as soon as new certified soil data become available.

The knowledge shared here comes from the implementation of SDSS available over the web and rooted on the deployment of a composite Geospatial Cyber-Infrastructure (GCI)[1,2,3]. It is remarkable to distinguish amongst the three main GCI tiers, that is the presentation, the logic, and the data tiers. The key component crossing the whole infrastructure and tiers is a tool, which can be a complex pipeline often composed by different models opportunely chained together to solve specific end user requirements. In such a framework, there is a huge interest in understanding (i) the role that soil data and related inference systems must have, (ii) how digital soil mapping engines can be wrapped in pipelines feeding, together with other information, the chain of models [4].

The contribution will therefore highlight some of the requirements of the soil information as needed by pipelines and a focus on some characteristics of the DSM engines such as computing time, automation opportunities, continuous code and soil data integration in the core infrastructure, and continuous validation of soil inference engines and processing units.

[1] LANDSUPPORT. The LANDSUPPORT project (<https://www.landsupport.eu>), funded by the European Union's Horizon 2020 Framework Program for Research and Innovation (H2020-RUR-2017-2).

[2] Langella G., Basile A., Giannecchini S., Moccia F. D., Mileti F.A., Munafó M., Pinto F., Terribile F. (2020). Soil Monitor: an internet platform to challenge soil sealing in Italy. *Land Degradation & Development*, <https://doi.org/10.1002/ldr.3628>.

[3] Terribile, F., Agrillo, A., Bonfante, A., Buscemi, G., Colandrea, M., D'Antonio, A., De Mascellis, R., De Michele, C., Langella, G., Manna, P., Marotta, L., Mileti, F. A., Minieri, L., Orefice, N., Valentini, S., Vingiani, S., and Basile, A. (2015). A web based spatial decision supporting system for land management and soil conservation. *Solid Earth*, 6, 903-928, 2015.

[4] Langella G., Basile A., Bonfante A., Manna P., Terribile F. (2012). The SOILCONSWEB Project: how to integrate the spatial component of a Web Based Spatial Decision Support System. In: ECSSS 4° International Congress EUROSIL 2012 "Soil Science for the Benefit of Mankind and Environment", Fiera del Levante, Bari (Italy), 2–6 July 2012.

Digital Soil Mapping predicts spatial patterns in economic yield response to foliar fungicide in maize

Mr Caleb Niemeyer^{1,2}

¹University of Guelph, Guelph, Canada, ²Woodrill Ltd, Guelph, Canada

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

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The higher spatial accuracy and lower cost of Digital Soil Mapping (DSM) as compared to traditional soil survey presents opportunities for farmers to adopt soil-based management of crop inputs. Fungicide yield response in maize is variable; determined by weather and soil variability (1). Soil series associated with high plant biomass and yield were hypothesized to have larger responses to fungicide than soil series with low plant biomass. To test this hypothesis, 15 farms in Southwestern Ontario, Canada were digitally soil mapped in collaboration with a DSM service provider. This DSM product is created using the fuzzy inference approach, with yield, imagery, topography and electromagnetic conductivity as covariates. Each of these farms contained a simple strip trial where foliar fungicide was applied adjacent to a strip which did not receive the fungicide. Yield data were obtained from combine yield monitors and analyzed using paired t-tests aggregated by soil series. Poorly and imperfectly drained soils had high yields and mean responses to fungicide of 627-942kg/ha while rapidly drained, well drained and degraded soils had low crop yields and low mean responses of 0-249kg/ha in 2020. These results suggest that DSM can be used to predict optimal spatial application of foliar fungicide in maize. Fungicide application prescriptions can be generated where fungicide is turned off on soils with non-economic responses to fungicide application and turned on where responsive. Soil-based management will result in increased grower profitability and reduced pesticide applications in agroecosystems, leveraging the significant research and public investment in DSM.

(1) Wise, K. A., Smith, D., Freije, A., Mueller, D. S., Kandel, Y., Allen, T., ... Tenuta, A. (2019). Meta-analysis of yield response of foliar fungicide-treated hybrid corn in the United States and Ontario, Canada. PLoS ONE, 14(6), 1–15. <https://doi.org/10.1371/journal.pone.021751>

National evaluation of an agricultural soil quality index based on the organic matter to clay ratio

Dr Nicolas P.A. Saby¹, Dr Dominique Arrouays¹, Dr Antonio Bispo¹, Dr Blandine Lemerrier², Pr Christian Walter², Pr Denis Angers³

¹Infosol, Orléans, France, ²UMR SAS, Rennes, France, ³Université Laval, Laval, Canada

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

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Simple measures of appropriate levels of soil organic matter are needed for soil evaluation, management and monitoring, based on readily measurable soil properties. Recent studies have proposed to use an index of soil organic matter based on the soil organic carbon (SOC) to clay ratio, defined by thresholds of SOC/clay ratio for specified levels of soil structural quality. A set of thresholds is available, delineated for a small number of Swiss and French soils and then updated for National Soil Inventory of England and Wales soils. In this study we assess and compare the spatial distribution of the index according to the existing sets of thresholds using an extensive dataset collected within two French soil monitoring programs. The first dataset gathers more than 1,8 million soil tests results from agricultural plots over the territory. The second one corresponds to the data collected within the framework of the French soil monitoring program. In this presentation, we present and discuss the statistical and mapping results and explore where French soils are likely to be physically degraded. We compare the distribution within the different classes with existing measurements of slaking index. We propose finally to apply a domain of validity to better consider the large diversity of French soils.

Prout, J. M., Shepherd, K. D., McGrath, S. P., Kirk, G. J. D., & Haefele, S. M. (2020). What is a good level of soil organic matter? An index based on organic carbon to clay ratio. *European Journal of Soil Science*. <https://doi.org/10.1111/ejss.13012>

Saby, N. P. A., Swiderski, C., Lemerrier, B., Walter, C., Louis, B. P., Eveillard, P., & Arrouays, D. (2017). Is pH increasing in the noncalcareous topsoils of France under agricultural management? A statistical framework to overcome the limitations of a soil test database. *Soil Use and Management*. <https://doi.org/10.1111/sum.12369>

Soils and Catastrophic Wildfire: Predictive Mapping of Soil Burn Severity

Dr. Stewart Wilson¹, Mr. Sam Prentice

¹*California Polytechnic University, San Luis Obispo, United States*

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

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Catastrophic fire has accelerated with climate change. Soil burn severity (SBS) is mapped following wildfire to categorize fires effects to soils and estimate the risk of erosion and debris flows. In the United States, current SBS mapping protocol involves field observation of SBS, and validation and manual adjustment of the remotely sensed vegetation burn severity raster to deliver the final SBS map. Improved mapping of fire effects to soils could improve predictions of catastrophic debris flows, potentially saving life and property.

We implemented a digital soil mapping framework to predict SBS following the Creek Fire in California, which burned more then 153,00 hectares. We utilized 149 field observations of SBS in 4 classes (unburned, low, medium and high severity), along with rasters of terrain attributes, vegetation burn severity proxies, vegetation indices and forest fuels data to make predictions to 30 m pixels via Random Forest (RF).

Random forest prediction of SBS had an accuracy of 52%, with a Kappa of 0.32. Digital soil mapping outperformed the traditional method (44% accuracy). RF accuracy was best for observations with high SBS (65% accuracy), whereas existing mapping protocol were worst in pixels with high SBS (29% accuracy). Areas with high SBS are most susceptible to erosion and debris flow and should be prioritized for accurate classification. Therefore, digital soil mapping outperforms traditional mapping in high risk areas. This research updates SBS mapping procedures, potentially improving predictions of catastrophic debris flow, and informs methods in the spatial distribution of fire effects to soils.

Parson, A., Robichaud, P. R., Lewis, S. A., Napper, C., & Clark, J. T. (2010). Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p., 243.

Levi, M. R., & Bestelmeyer, B. T. (2018). Digital soil mapping for fire prediction and management in rangelands. *Fire Ecology*, 14(2), 1-12.

Reaching the 4 per 1000 target in Europe: feasibility and additional carbon input required

Elisa Bruni¹, Bertrand Guenet², Claire Chenu³, Emanuele Lugato⁴

¹CEA, Gif-sur-Yvette, France, ²ENS, Paris, France, ³INRAe, Grignon, France, ⁴JRC, Ispra, Italy

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Prof. Fabio Terribile & Dr Jack Hannam, Lomond Auditorium, August 1, 2022, 11:00 - 13:00

The Mission “A soil deal for Europe” aims to increase soil organic carbon (SOC) stocks in croplands by 1‰-4‰ per year by 2030, to limit future global warming and improve food security. The feasibility of such objective is under debate, since even a relatively low increase of SOC stocks could potentially require substantial amounts of carbon (C) inputs to the soil. The required changes of C inputs can be estimated with process-based models, which simulate the dynamics of OC in the soil. In particular, the use of multi-model ensembles provides the level of uncertainty of such estimates, based on different representations of SOC processes.

In this study, we used an ensemble of SOC models to predict the evolution of SOC stocks during the next Century in Europe, under different scenarios of climate change. For our simulations, we used the European database of topsoil OC (LUCAS) and climate forcing from the ISIMP project. With an inverse modeling approach, we estimated the amount of C input required to increase SOC stocks by 4‰ per year in European croplands.

This approach allowed us to identify areas where a 4‰ SOC increase would be more feasible and where additional efforts should be made to increase SOC stocks. We suggest to take into account this spatial variability when implementing management policies to increase SOC stocks.

Bruni, Elisa, Bertrand Guenet, Yuanyuan Huang, Hugues Clivot, Iñigo Virto, Roberta Farina, Thomas Kätterer, Philippe Ciais, Manuel Martin, and Claire Chenu. “Additional Carbon Inputs to Reach a 4 per 1000 Objective in Europe: Feasibility and Projected Impacts of Climate Change Based on Century Simulations of Long-Term Arable Experiments.” *Biogeosciences* 18, no. 13 (July 2, 2021): 3981–4004. <https://doi.org/10.5194/bg-18-3981-2021>.

Riggers, Catharina, Christopher Poeplau, Axel Don, Cathleen Frühauf, and René Dechow. “How Much Carbon Input Is Required to Preserve or Increase Projected Soil Organic Carbon Stocks in German Croplands under Climate Change?” *Plant and Soil* 460, no. 1–2 (March 2021): 417–33. <https://doi.org/10.1007/s11104-020-04806-8>.

Lugato, Emanuele, Francesca Bampa, Panos Panagos, Luca Montanarella, and Arwyn Jones. “Potential Carbon Sequestration of European Arable Soils Estimated by Modelling a Comprehensive Set of Management Practices.” *Global Change Biology* 20, no. 11 (November 2014): 3557–67. <https://doi.org/10.1111/gcb.12551>.

The ipaast-czo Project: Exploring the Interoperability of Precision Agricultural and Archaeological Remote and Near-Surface Sensing Methods and Data

Dr Rachel Opitz¹, Dr. Philippe De Smedt², Dr. Victorino Mayoral-Herrera³, Prof. Stefano Campana⁴, Prof. Marco Vieri⁵

¹Archaeology, University of Glasgow, Glasgow, Scotland, ²Department of Environment, Ghent University, Ghent, Belgium, ³CSIC (Consejo Superior de Investigaciones Científicas-Spanish National Research Council), Mérida, Spain,

⁴Landscape Archaeology & Remote Sensing LAB, Department of History and Cultural Heritage, Siena, Italy, ⁵GESAAF, Università degli Studi di Firenze, Florence, Italy

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Prof. Fabio Terribile & Dr Jack Hannam, Lomond Auditorium, August 1, 2022, 11:00 - 13:00

Precision agriculture (PA) is beginning to transform rural land management. While today PA data is primarily used in individual farm management, it can play a critical role in addressing environmental sustainability and rural heritage as interrelated challenges. Remote and near-surface sensing technologies including spectral imaging and geophysical survey techniques are applied in PA (Weiss, Jacob & Duveiller 2020). Archaeologists use these same technologies to investigate buried evidence of past human activities (Verhoeven, Cowley & Traviglia 2021). Fundamentally, practitioners and researchers in both domains aim to better understand near surface variations, emphasising soils, their impacts on plant development, and implications for land management (Webber et al. 2019).

Building on these overlapping methods, data and interests, the Interoperable Precision Agricultural and Archaeological Sensing Technologies – Critical Zone Observation (ipaast-czo) Project is developing an interdisciplinary network around PA as a key emerging source of data relevant across archaeology, heritage management, agriculture, and rural land management. The project is investigating barriers to interoperability of advanced sensing data collection practices and developing workflows and data documentation to support coordinated work.

This paper outlines the ipaast-czo project's approach to developing:

- methods to collect interoperable data across archaeological and PA applications;
- workflows to incorporate data and insights from PA into archaeological analysis and heritage management routines, and the converse;
- proposals for dataset documentation including metadata and 'scope of application' notes, designed to increase confidence in data sharing and improve interpretability.

It will present the project's framework and give examples of data and workflow documentation. Verhoeven, G., Cowley, D., & Traviglia, A. (Eds.). (2021). Archaeological remote sensing in the 21st century : (re)defining practice and theory. Basel: MDPI.

Webber, H., Heyd, V., Horton, M., Bell, M., Matthews, W., & Chadburn, A. (2019). Precision farming and archaeology. *Archaeological and Anthropological Sciences*, 11(2), 727–734. <https://doi.org/10.1007/s12520-017-0564-8>

Weiss, M., Jacob, F., & Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. *Remote Sensing of Environment*, 236, 111402. <https://doi.org/10.1016/j.rse.2019.111402>

Digital Soil Mapping to Predict and Enable Cover Crop Adoption and Performance with Multi-Scale Decision Support Systems

Dr. Brian Needelman¹, Dr. Steven Mirsky², Dr. Jyoti Jennewein², Dr. Reshem Thapa³

¹University of Maryland, College Park, United States, ²United States Department of Agriculture, Agricultural Research Service, Beltsville, United States, ³North Carolina State University, Raleigh, United States

Interdivisional 1: Spatial decision making and mapping for implementing polices for sustainable soil management:

Chairperson: Prof. Fabio Terribile & Dr Jack Hannam, Lomond Auditorium, August 1, 2022, 11:00 - 13:00

A significant amount of resources has been spent to increase cover crop adoption in the United States; however, cover crop use still occurs on only a minority of US agricultural croplands. In this presentation we will discuss a project that integrates soil landscape analysis (digital soil mapping and applications of US soil survey data), remote sensing, social science methodologies, and process-based modeling to better understand patterns of cover crop adoption and management. The primary digital soil mapping method used in this study is spatial disaggregation, in which soil survey polygons are disaggregated using machine learning algorithms to identify the most likely soil component in a given pixel. Inputs to the machine learning algorithms are metrics derived from topographic and other remotely sensed data. Through this project we are designing and developing a decision support tool that will enable: near real-time cover crop management decision-making and future planning; mapping of factors associated with cover crop adoption and adoption “hot spots”; and, policymakers to be informed on management that increase cover crop performance to best structure incentive programs.

Goldman, M.A., B.A. Needelman, M.C. Rabenhorst, M.W. Lang, G.W. McCarty, P. King. (2020).

Digital soil mapping in a

low-relief landscape to support wetland restoration decisions. *Geoderma* 373: 114420.

Nauman, T.W., Thompson, J.A. (2014). Semi-automated disaggregation of conventional soil maps using

knowledge driven data mining and classification trees. *Geoderma*

213:385–399.

Strengthen global and national capacities on soil information, soil mapping to support Sustainable Soil Management (SSM) decision planning

Prof. Rosa M Poch¹

¹*Intergovernmental Technical Panel on Soils - Global Soil Partnership (FAO)*

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Prof. Fabio Terribile & Dr Jack Hannam, Lomond Auditorium, August 1, 2022, 11:00 - 13:00

Since 2013 The Global Soil Partnership (GSP) and the Intergovernmental Technical Panel on Soils (ITPS) are promoting Sustainable Soil Management (SSM) and soil governance to guarantee healthy and productive soils, in relation to UN (e.g. SDGs) and OECD initiatives. The GSP is assisting countries to implement the Voluntary Guidelines for Sustainable Soil Management (VGSSM), published in 2016, through technical aspects, publication of SSM assessment protocols and building capacity development for soil monitoring and natural resource management. In order to do so, there is an urgent need of georeferenced soil information linked to Decision Support Systems.

The Global Soil Information System (GLOSIS) provides the tool for monitoring global soil resources. In particular, the GSP and its partners designed SoilSTAT to monitor, forecast and periodically report on the status of global soil resources. The Digital Soil Profile Databases SPDB, with a tiered approach, is a result of a collaboration of FAO with IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), and the Joint Research Centre of the European Commission (JRC). New regional soil data and information will be available for updating the last Harmonized World Soil Database (HWSD, 2017).

Improving the availability and suitability of datasets for countries to report on SDG 15.3.1 and LDN is a major focus to enhance, or to complement national data sources, which are the input data for land management Decision Support Systems.

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Soil Science in the Age of Carbon Sequestration

Professor Ronald Amundson

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

The large mass of organic C stored in global soils has inadvertently propelled segments of the soil science community into the complex issues of global climate change and its stabilization. This is a societal problem of such enormous scope that soil science, like most natural sciences, has little prior experience to draw on. There are few ground rules in place for guidance, and the resulting paths and community practices are sometimes novel.

Due to the interest in natural climate mitigation strategies, it is an opportune time for science to push a “pause” button and examine the robustness of the science, and the social structures needed to ensure scientific integrity and plausibility of outcomes. Some urgent points of discussion include:

- How robust are the best estimates of C sequestration rates, and can the community make more transparent, and testable, the assumptions and parameters embedded in the key model scenarios?
- How will climate change, and the positive soil C feedbacks, affect sequestration estimates?
- How can the community, and the scientific establishment, create adequate firewalls between science and advocacy/business/COI, a boundary that is blurring in this emerging problem?
- What constitutes Conflict of Interest in the modern world of funding and social media?
- How can natural science partner with the relevant social sciences to prevent what has been termed “legitimizing the unbelievable”, or creating policy based on technical proposals lacking in practicality of application?

Carbon storage in soils of hedge agroforestry systems: new insights on the drivers controlling storage potential

Mr. Lucas Lesaint¹, Dr. Valérie Viaud¹, Dr. Safya Menasseri-Aubry²

¹UMR SAS, INRAE, Institut Agro, 35000 Rennes, France, ²Institut Agro, UMR SAS, INRAE, 35000 Rennes, France

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

In the current context of climate change, agroforestry systems are acknowledged to have a good potential to increase carbon sequestration in agricultural areas. However, the carbon storage potential of agroforestry systems still needs to be quantified accurately, especially for hedges, a traditional form of agroforestry in numerous regions of the world.

The objectives of this study were: (1) to provide additional references to the existing literature on soil organic carbon (SOC) storage potential near hedges, (2) to identify the main factors controlling the variability of this potential. For these purposes, we focused on 46 study sites, located in three geographical regions in France. Each site comprises a hedge and its adjacent agricultural field. The study sites present a range of pedoclimatic conditions and contrasting cropping systems (annual crops, crop rotations including temporary grasslands, and permanent grasslands). We measured SOC stocks in the field adjacent to hedges, up to 90 cm depth, and at distances of 1, 2, 3, and 10m from the hedge. Additional SOC stocks by the hedge were assessed by comparison to the reference stock at 10m.

The results confirmed a local impact of hedges on SOC stocks. They showed a strong variability of the storage potential between the study sites and allowed us to evaluate the effect of soil type, rainfall, and adjacent cropping systems on SOC storage potential of of hedge. The contribution to climate change mitigation of this type of land management depends thus on the local context in which it is implemented.

Drexler, S., Gensior, A., Don, A., (2021). Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. *Regional Environmental Change* 21.

Mayer, S., Wiesmeier, M., Sakamoto, E., Hubner, R., Cardinael, R., Kuhnel, A., Kogel-Knabner, I., (2022). Soil organic carbon sequestration in temperate agroforestry systems - A meta-analysis. *Agriculture Ecosystems & Environment* 323, 11.

Mapping and monitoring changes in soil organic carbon stocks of the world

Prof Budiman Minasny¹, **Dr José Padarian**, Dr Mercedes Roman Dobarco, Prof Alex McBratney

¹*University of Sydney, Sydney, Australia*

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

Soil is one of the earth's greatest non-renewable natural resources, existential to humanity for the provision of food. As we need to double agricultural production by 2050 while simultaneously maintaining functioning ecosystems it is time to get serious about securing soils and their life-supporting functions.

Recent advances in big data science have now made forecasting soil conditions in the near- and long-term much more possible. This has been enabled by the confluence of large data, sophisticated modelling and computing infrastructure. We have large soil databases coupled with earth- and soil- observing remote and proximal sensors that provide exciting new opportunities to extract soil knowledge. This paper will present how soil carbon has changed over time at the global scale using machine learning models. At the continental scale in Australia, we quantify the change of soil carbon using the concept of genosoils and phenosoils.

Minasny, B., Malone, B. P., McBratney, A. B., Angers, D. A., Arrouays, D., Chambers, A., ... & Winowiecki, L. (2017). Soil carbon 4 per mille. *Geoderma*, 292, 59-86.

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Humus as a problem of civilisation: hopes of climate politicians, business expectations of certificate traders, conflicts between conservationists and farmers

Dr Nikola Patzel¹

¹*luss&dbg, Überlingen, Germany*

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

This paper reports on discussions in Germany and Switzerland that highlight the humus build-up and emission certificate debate as a problem of current civilisation (at EU and national levels).

In question are identity concepts and financing structures of farmers, the climate issue as a megatrend of the societal debates, and the generic cultural conflict between conservationists and farmers. In addition, differences between the attempt to ecologically redirect the cultural narrative of progress at one side and at the other side the intention to develop a targeted rehabilitation policy against the damage caused by it become clear.

The presentation here is based on the author's experience in position-finding processes between various associations and institutions, in agro-conservationist background discussion groups, and public debates on humus build-up and emission certificate issues.

Policy paper references will be provided.

Microbial Carbon Transfer between Microhabitats

Prof. Ellen Kandeler¹, Dr. Anna Abrahao¹, Luise Brandt¹, De_Shorn Bramble², Dr. Marion Schrupf², Dr. Ingo Schöning², Dr. Christian Poll¹, Dr. Sven Marhan¹

¹University of Hohenheim, Stuttgart, Germany, ²Max-Planck-Institute of Biogeochemistry, Jena, Germany

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

The largest carbon dynamics occur in microhabitats in soil that are intensively colonized by microorganisms. While a great deal of data is already available on microbial colonization and carbon turnover in the rhizosphere, much less attention has been paid to the detritu-, hypho- and mineralosphere. This talk will provide an overview of methodological approaches that can be used to study microbial colonization and soil microbial functions in these hotspots under field conditions. The basis for these studies are some experiments in grassland soils, which are currently running within the project of Biodiversity Exploratories (<https://www.biodiversity-exploratories.de/en/>). For example, we have developed hyphoboxes that can detect microbial colonization and carbon transfer between the detritosphere, hyphosphere and rhizosphere compartments. In addition, exposure of mineral containers in 150 grassland could clarify the microbial colonization and carbon use of either pristine goethite or illite creating over a period of five years a newly formed mineralosphere. Special emphasis will be placed on demonstrating the improvement of a mechanistic understanding of carbon cycling in microhabitats.

Boeddinghaus R.S., Marhan S., Gebala A., Haslwimmer H., Vieira S., Sikroski J., Overmann J., Soares M., Rousk T., Kandeler E. (2021) The Mineralosphere – Interactive zone of microbial colonization and carbon use in grassland soils. *Biology and Fertility of Soils* 57, 587-601.

Kandeler E., Gebala A., Boeddinghaus R.S., Müller K., Rennert T., Soares M., Rousk J., Marhan S. (2019) The mineralosphere - Abundance and carbon partitioning of bacteria and fungi colonising mineral surfaces in grassland soils under different land use intensity. *Soil Biology and Biochemistry*, DOI: 10.1016/j.soilbio.2019.107534

Vieira S., Sikorski J., Gebala A., Boeddinghaus R.S., Marhan S., Rennert T., Kandeler E., Overmann J. (2020) Bacterial colonization of reactive minerals in grassland soils is selective and highly dynamic. *Environmental Microbiology* 22, 917–933 DOI: 10.1111/1462-2920.14751.

CARBON IN SOILS: AGGREGATION AND STABILITY

Doctor Alba Otero-Fariña, Professor Pippa Chapman¹, Professor Steven Banwart¹, Professor Joseph Holden¹, Professor Caroline Peacock¹

¹*University of Leeds*

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

Increasing our understanding of soil processes underpins efforts to improve soil management for better soil resilience and food security and is central to increasing soil organic carbon storage for climate change mitigation. Two processes and their interplay that might be important for organic carbon storage involve the formation of primary organo-mineral complexes via the sorption of dissolved organic carbon to fine-grained soil minerals, and their subsequent formation into micro and macroaggregates. In complexes and aggregates carbon is protected from degradation and can persist over long timescales. Despite the importance of sorption and aggregation, the controls on these processes are unclear. In particular it is largely unknown how the reactivity of different types of organic carbon affects complex and aggregate formation and stability, and thus the longevity of mineral-associated carbon in the soil environment. Here we assess for the first time how the chemical composition of soil organic carbon sources affects the formation, aggregation and stability of organo-mineral associations under soil conditions. We perform controlled laboratory experiments with a range of different carbon molecules representative of those found in soils, and the ubiquitous iron (oxyhydr)oxide mineral ferrihydrite, which is shown to strongly associated with organic carbon and potentially promote its preservation over hundreds to thousands of years in soils and sediments. We investigate organo-mineral complex formation, and the aggregation of these complexes into micro and macroaggregates using a novel dynamics image analysis technique which allows us to quantify aggregate size and growth rate as a function of carbon composition.

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Soil organic carbon storage potential in global croplands

Dr José Padarian¹, Budiman Minasny¹, Alex McBratney¹, Pete Smith²

¹*Sydney Institute of Agriculture & School of Life and Environmental Sciences, The University of Sydney, Australia,*

²*Institute of Biological & Environmental Sciences, University of Aberdeen, Aberdeen, UK*

Interdivisional 2 – Soil Carbon: from particle to planet

Chairperson: Curtis Monger, Clyde Auditorium, August 1, 2022, 11:00 - 13:00

Soil organic carbon sequestration (SOCseq) is considered an attractive carbon capture technology to partially mitigate climate change. However, there is conflicting evidence regarding the potential of SOCseq. The additional storage potential on existing global cropland is missing. SOCseq is region-specific and conditioned by management but most global estimates use fixed accumulation rates or time frames (Fuss et al, 2018). Here, we show how the SOC storage potential and its steady state varies globally depending on climate, land use and soil. Using 83,416 soil observations, we developed a quantile regression (Cade and Noon, 2003) neural network that quantifies the SOC variation within soils with similar characteristics. This allows us to identify similar areas that present higher SOC with the difference representing an additional storage potential. The estimated additional SOC storage potential of 29 to 67 Pg C in the topsoil of global croplands equates to only 2 to 5 years of emissions offsetting and 32% of agriculture's 92 Pg historical carbon debt estimate due to conversion from natural ecosystems. Since SOC is temperature-dependent, this potential is likely to reduce by 18% by 2040 due to climate change.

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Agri-environmental measures reduce N₂O emissions without compromising yields

Prof. Sophie Zechmeister-Boltenstern¹, MSc Cecilie Foldal¹, MSc Martina Kasper¹, Dr. Edwin Haas¹

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

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

The “greening” policy of the EU aims to reduce the climate impact of agriculture by supporting farmers, who adopt practices that help meet environmental and climate targets, but whether these measures can be considered “climate-smart” must be evaluated. Therefore, we applied the LandscapeDNDC model to calculate emissions and nitrogen budgets over ten years for three different regions in Austria, considering their crops, soil types and weather conditions. We compared four management approaches: organic farming, conventional nitrogen fertilization at a standard rate, and conventional nitrogen fertilisation at 85% and 75% of the standard rate respectively. The results showed that all these measures mitigated N₂O emissions. This was especially pronounced in a wet, high-yielding region with cumulative mean annual emissions of up to 15.6 kg N₂O-N ha⁻¹. Remarkably, a 15% reduction in nitrogen fertilization led to a 22% reduction in N₂O emissions and only a 5% decrease in yield. A 25% reduction in nitrogen fertilization led to a 39% reduction of N₂O emissions and only a 9% decrease in yield. Organic farming systems produced the lowest annual N₂O emissions, approx. half of those of the conventional systems. Reduced or low nitrogen fertilization also decreased the losses of nitrogen into water and atmosphere. All management systems achieved positive mean nitrogen budgets. This is the first systematic modelling evaluation of the effects of European policy measures on N₂O emissions. Knowledge of emission patterns from cropping systems under different environmental conditions allows more targeted nitrogen management and promotes climate-smart farming. Molina-Herrera S, Haas E, Klatt S, et al (2016) A modeling study on mitigation of N₂O emissions and NO₃ leaching at different agricultural sites across Europe using LandscapeDNDC. *Sci Total Environ* 553:128–140. <https://doi.org/10.1016/j.scitotenv.2015.12.099>

The interaction between key soil nutrients; carbon, nitrogen and phosphorus on N-cycling, productivity and N₂O emissions.

Ms Rosie, M. O'Neill^{1,2}, Dr Nick, T., Girkin^{1,3}, Dr Dominika., J. Krol¹, Dr David., P. Wall¹, Dr Fiona., P. Brennan¹, Dr Gary., J. Lanigan¹, Dr Florence Renou-Wilson², Dr Christoph Müller^{2,4}, Dr Amanuel Gebremichael¹, Dr. Karl., G. Richards¹

¹Teagasc, Johnstown Castle, Ireland, ²University College Dublin, , Ireland, ³University of Nottingham, , UK, ⁴Justus-Liebig University Giessen, Giessen, Germany

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Agriculture accounts for 60% of the world's N₂O and 90% of Irish N₂O emissions. Nitrogen (N), phosphorus (P) and carbon (C) are frequently the main limiting nutrients in agricultural systems, but not much is known about how their cycles interact and their relative impact on emissions, soil productivity and microbial requirements. Two incubation experiments were conducted using soils collected from a long-term P trial in Ireland, which consisted of ongoing P application of 0, and 45 Kg-1 P ha-1 (P0 and P45). This incubation investigated N₂O and CO₂ emissions from P(0) and P(45) amended soils in response to a 40 kg N ha-1 with a +/- carbon fertiliser application. We found negligible N₂O emissions and low CO₂ emissions from the carbon-excluded soils. Cumulative N₂O evolved from N+C amended soils was significantly (over 70 times) greater in P0 soils than in P45 soils (P > 0.001). There was no significant effect of soil P on CO₂ emissions. A field trial, which ran for three months, reinforced the incubation findings and found that under three different forms of N fertilisation (KNO₃, NH₄SO₄, (both applied at 40 Kg N ha-1) and Synthetic urine (applied at 750 kg N ha-1), N₂O emissions remained consistently higher, with no increase in herbage yield from P0 soils. These results highlight the existence of an optimum C:N:P ratio with the aim to tailor nutrient application tailored to individual soil requirements, to promote maximum productivity and reduce waste through N-loss pathways.

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Aggregate size, moisture regime, substrate quality and phosphorus control on biogeochemical N cycling in floodplain soil

Dr. Muhammad Riaz^{1,2}, Dr. Pascal A. Niklaus³, Dr. Beat Frey⁴, Dr. Beat Stierli⁴, Dr. Joerg Luster²
¹Department of Environmental Sciences & Engineering, Government College University Faisalabad, Faisalabad, Pakistan, ²Forest Soils and Biogeochemistry, Swiss Federal Research Institute WSL, Birmensdorf, Switzerland, ³Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland, ⁴Rhizosphere Processes, Swiss Federal Research Institute WSL, Birmensdorf, Switzerland

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Processes of nitrogen (N) cycling are strongly influenced by the availability of water, oxygen and substrate, and these processes may differ between small and large aggregate. We performed a microcosm incubation experiment using soil from restored floodplain section of the Thur River in NE Switzerland to investigate the effects of aggregate size, moisture, carbon (C) sources and phosphorus (P) fertilization on N cycling. Experiment included aggregate size (<250 µm; 250 µm - 4.00 mm), moisture level (60% WHC; submerged conditions), C source (glucose; litter; litter-derived DOC) and P as experimental factors. Head space gas samples were collected for N₂O gaseous analysis and flux calculation. After 28 days incubation, the soil samples were analysed for N species (KCl-extractable NH₄-N, NO₃-N, dissolved organic N total N, water-extractable total N), water-extractable organic C, microbial biomass N, leucine aminopeptidase activity (LEU), denitrification enzymatic activity (DEA), bacterial abundance (16S-qPCR), fungal abundance (ITS-qPCR) and some N cycling pathway functional genes (nirS, nosZ & nxrB). N₂O flux was generally higher in larger aggregates and soil treated with litter-derived DOC and after P addition. Mineral N concentrations were many-fold higher for litter-derived DOC and litter treated soil amended with P under submerged conditions. Dissolved organic N varied dramatically between the treatments. LEU activity was significantly higher in soil treated with litter and P in smaller aggregates. Bacterial and fungal diversity and functional gene abundance varied significantly among the treatments. Results suggested that strong heterogeneity in environmental factors could control hotspots and hot moments of N cycling.

Nitrogen cycling differences associated with grassland sward composition reveal promising N loss mitigation strategies at key times of the year

Dr Conor Bracken¹, Dr Gary Lanigan¹, Dr Karl Richards¹, Prof Christoph Müller³, Dr Saoirse Tracy², Dr Helen Sheridan², Dr David Wall¹, Dr Paul Murphy²

¹Teagasc, Environmental Research Center, Johnstown Castle, Ireland, ²UCD School of Agriculture and Food Science, University College Dublin, Belfield, Ireland, ³Institute of Plant Ecology, Justus Liebig University, , Germany

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Inefficient N fertiliser use can lead to reactive nitrogen loss as nitrous oxide (N₂O) emission and nitrate (NO₃⁻) leaching from agricultural soils, both exasperating anthropogenic climate change and poor water quality, respectively. Generally, in grass-based production systems, yields are most limited by nitrogen supply. Multispecies swards containing grasses, N-fixing legumes and forage herbs are considered an alternative solution for dry matter (DM) production, independent of intensive synthetic fertiliser use. A year-long lysimeter experiment was conducted to investigate N₂O and NO₃⁻ losses plus DM yields and N uptake from four systems. These were: Perennial Ryegrass only (PRG, 250 kg N ha⁻¹ yr⁻¹), Perennial Ryegrass and Low White Clover (PRG+LWC, 90 kg N ha⁻¹ yr⁻¹), Perennial Ryegrass and High White Clover (PRG+HWC, 0 kg N ha⁻¹ yr⁻¹) and Perennial Ryegrass, White Clover and Ribwort Plantain (PRG+WC+P, 45 kg N ha⁻¹ yr⁻¹). The fractions of nitrification (FN) and denitrification (FD) were calculated from an N₂O isotopomer-mapping approach. Cumulative N₂O and NO₃⁻ along with cumulative DM yield and N uptake were not significantly different among the four systems. However, seasonal and even monthly variation indicated key times of the year when N loss could be mitigated by adopting multispecies swards, e.g. Spring fertiliser applications resulted in higher N₂O emissions from PRG and PRG+LWC. Ribwort plantain was linked to a numerically lower FN supporting the biological nitrification inhibition property associated with this species. Further research underway will help determine if seasonal N loss savings will accrue making multispecies production systems overall more efficient and sustainable.

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Assessing the long-term impact of urease and nitrification inhibitor use on microbial community composition, diversity and function in grassland soil

Dr. Aoife M. Duff¹, Dr. Patrick Forrestral¹, Dr Israel Ikoyi¹, Dr. Fiona Brennan¹

¹*Teagasc, Johnstown castle, Ireland*

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Urease and nitrification inhibitors (UI and NI) applied in association with fertiliser have been demonstrated to slow microbial N transformation rates, with resulting decreases in environmental N losses. To date there has been minimal assessment of the long-term and potentially non-target impacts of UI and NI on soil microbial communities and biological function in grasslands. The specific objectives of this study were to assess whether there was an impact of 1) individual or combined inhibitor use on non-target microbial community composition and abundance; 2) the use of N inhibitors on the N functional community; and 3) applied N fertiliser type (i.e. CAN or Urea) on microbial community composition and function. A 5 year inhibitor trial on grassland was sampled in the southeast of Ireland. Treatments included a control (no N); CAN (Calcium ammonium nitrate); Urea; Urea & UI; Urea & NI; and Urea & NI & UI. A combination of phenotypic assays; gene abundances of total, nitrifiers and denitrifiers and 16S rRNA and ITS amplicon sequencing data were used to assess the objectives. The results indicated while there was no impact of either UI or NI use on non-target microbial community composition or abundance; there was a significant impact of the use of NI on the nitrogen cycling functional community compared to standard urea. Finally, there was a significant impact of fertiliser type (i.e. CAN or Urea) on the fungal community structure but no impact on the bacterial community structure.

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Elucidating the effects of land management and role of soil microbes in nitrogen transfer in a clover-ryegrass pasture

Dr Michaela Reay¹, Dr Katrina Pears¹, Mrs Alison Kuhl¹, Professor Richard Evershed¹, Professor Phillip Murray², Dr Laura Cardenas², Professor Jennifer Dungait^{2,3}, Dr Ian Bull¹

¹*Organic Geochemistry, School of Bristol, University of Bristol, Bristol, UK*, ²*Department of Sustainable Agriculture Sciences, Rothamsted Research North Wyke, Okehampton, UK*, ³*Carbon Management Center, SRUC - Scotland's Rural College, Edinburgh, UK*

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Nitrogen (N) transfer from white clover (*Trifolium repens* cv.) to ryegrass (*Lolium perenne* cv.) has the potential to meet ryegrass N requirements, reducing agricultural fertiliser needs, and associated negative environmental impacts, while maintaining crop yields. This study quantified N transfer in mixed pasture, focusing on the role of the microbial community and land management. Split root ¹⁵N-labelling was used to quantify N transfer in a model system via intrinsic pathways (e.g., root exudation, microbial assimilation, decomposition) and management (e.g., defoliation, soil biota). For the first time, incorporation into the microbial protein pool from clover N-transfer was determined using compound-specific ¹⁵N-stable isotope probing, via GC-C-IRMS (Charteris et al., 2016). Total N transfer was quantified using EA-IRMS. N transfer to ryegrass and soil microbial protein in the model system was relatively small, attributed to previous N fertilisation and young pasture, with one-third from root exudation. N transfer to ryegrass increased with no microbial competition but soil microbes were central to increased N transfer observed during shoot decomposition. Addition of mycorrhizal fungi did not alter N transfer, whilst weevil grazing on roots decreased microbial N transfer. N transfer was bidirectional, and comparable on a short-term scale. The application of compound-specific ¹⁵N-SIP offered previously unattainable detail regarding the role of soil microbes in plant N nutrition via N transfer. Short-term mechanisms for N transfer, and the role of the soil microbial community, must be considered alongside the long-term management of mixed pastures to support N transfer as a method of meeting plant N demands. Charteris, A. F., Knowles, T. D. J., Michaelides, K., & Evershed, R. P. (2016). Compound specific amino acid ¹⁵N stable isotope probing of nitrogen assimilation by the soil microbial biomass using gas chromatography/combustion/isotope ratio mass spectrometry. *Rapid Communications in Mass Spectrometry*, 30(16), 1846–1856. <https://doi.org/10.1002/RCM.7612>

Unveiling microbial drivers of nitrogen transformation in agricultural soils: towards novel and practical soil management for soil health

Prof. Keishi Senoo¹

¹*The University of Tokyo, Japan*

16 Division 2: Nitrogen cycling and soil health:

Chairperson: Prof. Liz Baggs, Forth, August 1, 2022, 11:00 - 13:00

Microbial nitrogen transformations in agricultural soils are closely related to soil nitrogen health. Recent advances in soil microbial analysis enable us to figure out detail picture of microbial processes in soils, leading to novel soil management strategies for soil health.

Waterlogged paddy soils possess anoxic zones where microorganisms actively drive reductive nitrogen transformation (RNT), nitrogen fixation, dissimilatory nitrate reduction to ammonium, and denitrification, which contribute to sustainable soil nitrogen fertility and less release of nitrogen loads (NO₃⁻ and N₂O) to environment. Our metatranscriptomic analysis and bacterial isolation studies revealed that iron-reducing bacteria (*Anaeromyxobacter* and *Geobacter*) predominant in paddy soils are potent drivers of RNT in paddy soils. We hypothesized that adding ferric iron to paddy soil as an electron acceptor for respiration of the iron-reducing bacteria could enhance their nitrogen-fixing activity and boost paddy rice productivity. We verified this hypothesis by laboratory and field experiments.

Upland soil is a major source of N₂O emission, generated through microbial processes after nitrogen fertilizer application. We revealed that the overlooked denitrifying microorganisms were involved in N₂O generation, e.g., denitrifying fungi after organic fertilizer application onto soil surface. To mitigate such N₂O emission, we established simple and economic soil management boosting the fungivorous activity of soil mesofauna. We found that the application of coconut husks to soil can supply a favorable habitat for fungivorous mites due to its porous structure and thereby increase the mite abundance. Because mites rapidly consume denitrifying fungi in soil, the increase in mite abundance substantially decreases the N₂O emissions.

Masuda, Y., Itoh H., Shiratori, Y., Isobe, K., Otsuka, S., & Senoo, K. (2017). Predominant but previously-overlooked prokaryotic drivers of reductive nitrogen transformation in paddy soils, revealed by metatranscriptomics. *Microbes and Environments*, 32, 180-183

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Soil Mapping for hydro pedological assessments

Dr George van Zijl¹, Prof Johan van Tol², Prof Pieter Le Roux³

¹Unit for Environmental Sciences and Management, North West University, Potchefstroom, South Africa, ²University of the Free State, Bloemfontein, South Africa, ³Digital Soils Africa, Port Elizabeth, South Africa

36 WG2.1: The Legacy of Henry Lin and the future of Hydro pedology

Chairperson: Prof. Hans- jörg Vogel & Dr Johan van Tol, Alsh 1, August 1, 2022, 11:00 - 13:00

Hydro pedology assessments are regularly requested for new developments in South Africa. The soil surveys required for these assessments have different needs than conventional soil surveys, in that not only is the spatial coverage of the area important, but observations must be placed along transects for the hydro pedologists to create conceptual hydrological response models. This talk will explore various differences between conventional and hydro pedological soil surveys using case studies. A methodology whereby representative hillslopes were selected as opposed to representative locations is proposed, using the City of Johannesburg hydro pedological assessment as case study. Within this case study the representative hillslopes were selected using the conditioned Latin hypercube sampling method. The hydro pedologist conducting the survey then placed the observations on the hillslope as desired. QQ-plots and the chi-square test between the covariate layers for the entire site, the selected hillslopes and the observation locations showed that the hillslopes were representative of the entire site, but that the observation locations were statistically different from the entire site, despite covering 98.7% of the pixels of the covariates in question. However, a digital soil mapping approach using the multinomial logistic regression algorithm was able to use the observations and create an acceptable hydro pedological soil map with a Kappa value of 0.59. It is concluded that the hillslope based method is worthwhile as it allows for acceptable maps to be created, while also serving the transect needs of the hydro pedologist, despite the “cost” incurred of the dissimilar covariate distribution between the site and the observation locations.

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<https://doi.org/10.1016/j.geoderma.2019.11388>

Soil types and modelling as carriers of dynamic soil degradation information.

Phd Antonello Bonfante¹, Dr Angelo Basile¹, Em. Prof Soil Science Johan Bouma²

¹*Institute for Mediterranean Agricultural and Forestry Systems, National Research Council, Portici (NA), Italy,* ²*Em. Prof Soil Science, Wageningen University, The Netherlands*

36 WG2.1: The Legacy of Henry Lin and the future of Hydropedology

Chairperson: Prof. Hans- jörg Vogel & Dr Johan van Tol, Alsh 1, August 1, 2022, 11:00 - 13:00

Soil Taxonomy – a benchmark of pedology - is not only a system of soil classification for making and interpreting soil surveys but can act as a “carrier” of modern soil information, refreshing – in such a way – its image. This can be done in a hydropedological framework by linking soil types information to the soil-water-atmosphere-plant modelling.

Specifically, traditional soil surveys were accompanied by interpretations with a qualitative, empirical, and static character valuable for broad land-use questions on a regional or national scale. But in a light of the well-recognized multifunctional role of the soils, a series of soil functions and related soil ecosystem services – varying in space and time – has to be estimated and evaluated. Obviously, the traditional interpretations of soil survey reports can’t provide this type of information, but Soil Taxonomy can still be relevant in a modern context where a comprehensive systems analysis is provided by applying soil-water-atmosphere-plant simulation models in order to improve assessment of soil moisture regime and for developing alternative land-use options that satisfy the often-contrasting demands of the various ecosystem services (e.g., for provisioning and regulating).

Examples will be shown where models express the effects of several forms of soil degradation: compaction, organic matter depletion and erosion, showing that different soil types show significantly different forms of behaviour illustrating the potential of using soil types as “carriers” of essential information to define suitable management procedures resulting in sustainable development under several climate change scenarios.

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Hydropedological interpretation of soil information to serve the hydrological community

Prof Johan van Tol¹, Prof Pieter Le Roux², Prof Simon Lorentz³, Dr Darren Bouwer²

¹University of the Free State, Bloemfontein, South Africa, ²Digital Soils Africa, Port Elizabeth, South Africa, ³University of KwaZulu-Natal, Pietermaritzburg, South Africa

36 WG2.1: The Legacy of Henry Lin and the future of Hydropedology

Chairperson: Prof. Hans- jörg Vogel & Dr Johan van Tol, Alsh 1, August 1, 2022, 11:00 - 13:00

Capturing internal catchment hydrological processes in hydrological models is important for accurate predictions of the impact of climate and land-use change on water resources. Characterising and quantifying these processes are however difficult and expensive due to their dynamic nature and spatio-temporal variability. Hydropedological interpretations of soils and soil distribution patterns can be used to characterise key hydrological processes, especially in areas with no or limited hydrometric measurements. Here we applied a hydropedological approach to reflect flowpaths through detailed routing in SWAT+ for a 157 ha catchment (Weatherley) in South Africa. The hydropedological approach and a standard (no routing) approach were compared against measured streamflow (two weirs) and soil water contents (13 locations). The models were not calibrated against hydrometric measurements to establish the direct contribution of hydropedological interpretations on modelling efficiency. Streamflow was predicted well ($NSE > 0.8$; $R2 > 0.82$) for both approaches at both weirs. The standard approach yielded slightly better streamflow predictions. The hydropedological approach resulted in considerable improvements in the simulation of soil water contents ($R2$ increased from 0.40 to 0.49 and PBIAS decreased from 40 to 20%). The routing capacity of SWAT+ as employed in the hydropedological approach reduced the underestimation of wetland water regimes drastically and resulted in a more accurate representation of the dominant hydrological processes in this catchment. We concluded that hydropedology can be a valuable source of 'soft data' to reflect internal catchment processes and, potentially, for realistic calibrations in other studies, especially those conducted in areas with limited hydrometric measurements.

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Current challenges in Hydropedology

Dr Hans-jörg Vogel¹

¹*Helmholtz Centre for Environmental Research - Ufz, Halle (SAALE),*

36 WG2.1: The Legacy of Henry Lin and the future of Hydropedology

Chairperson: Prof. Hans- jörg Vogel & Dr Johan van Tol, Alsh 1, August 1, 2022, 11:00 - 13:00

In this presentation we build upon the original idea of hydropedology as an interdisciplinary approach in soil science. It is based on the fact that at a wide range of spatial scales, pedological processes are shaping subsurface structures that are of critical importance for water dynamics within soil and terrestrial systems, while, at the same time, water dynamics is shaping pedogenetic processes significantly through transport of solutes and solid materials. The concept of hydropedology was considerably inspired by the work and spirit of Henry Lin who made substantial contributions to improve the understanding and modelling of hydrological processes at different spatial scales from the local soil profile to the landscape. This was accompanied by his passionate appeal for systems thinking and his firm conviction that the classical concepts were not sufficient to adequately represent water dynamics in soils.

This is a formidable research challenge until today. With climate change, the research field of hydropedology will gain additional momentum since water shortage will become a highly critical issue for agriculture and the functioning of terrestrial ecosystems. This is true also in many regions that have rarely suffered from water shortages since. We will discuss possible avenues how to improve classical concepts for modelling water movement in soil by including soil structural characteristics at the scale of soil profiles and how to leverage our pedological knowledge to better parameterize the subsurface at the scale of landscapes for the sake of hydrologic modeling.

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Matter of scale: merging process understanding and decision-making in soil-carbon-climate predictions

Prof Dr Hermann Jungkunst¹, **Prof. Dr. Hermann F. Jungkunst¹**

¹*University of Koblenz-landau, Germany*

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

Soil organic carbon (SOC) is essential to sustain certain ecosystem services (ESS). Both, decreasing losses of SOC and sequestration of atmospheric carbon in soils can counterbalance climate change. Earth system model scenarios capture our present knowledge of soil-carbon-climate interactions. However, uncertainties remain high because mechanistic insights are available at scales that lack sufficient resolution for global modeling. Consequently, the key challenge gaining a global overview of soil carbon-climate interactions is to identify the scale that best reflects the underlying processes without getting lost in details less relevant at the transnational, global or system Earth scales. We suggest that overarching proxies at a critical mesoscale combine climatic and soil factors and could enable regionally tailored approaches. Here, the Holdridge Life Zone (HLZ) classification proved to be more than a descriptive tool to guide our understanding of soil carbon-climate interaction allowing for linking top-down (from global to local) and bottom-up (from local to global) approaches. Regionally tailored solutions for both, experiments and modeling appear appealing and can lead to better management of soil and the ESS it provides. Improving 'translations' from the scales relevant for process understanding to the scales of decision-making is key to sustainable soil management and to improve predictions of the fate of our largest terrestrial carbon reservoir during climate change.

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- Rasmussen C, Heckman K, Wieder WR, Keiluweit M, Lawrence CR, Berhe AA, Blankinship JC, Crow SE, Druhan JL, Pries CEH, et al. 2018. Beyond clay: towards an improved set of variables for predicting soil organic matter content. *Biogeochemistry* 137(3): 297-306.

Semi-quantitative evaluation and mapping of bundles of soil ecosystem services in agricultural and forested lands at the regional scale

Dr Clementine Chirol¹, Dr Delphine Derrien², Prof Laurent Saint-André², Dr Paul-Olivier Redon³, Dr Geoffroy Séré¹

¹LSE, University of Lorraine, Nancy, France, ²BEF, INRA, Centre de Nancy, Champenoux, France, ³ANDRA, Research and Development Division, Châtenay-Malabry, France

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

Soils provide multiple ecosystem services (ES) including food production, biomass-energy and contribution to climate change regulation through carbon storage. However, implementing changes in land use and management can create trade-offs between services¹. Therefore, new land planning approaches that consider ES relationships are needed to optimise overall ES delivery. Such an approach should be based on an understanding of the variability of soil bio-physico-chemical properties, both spatially within a given region and vertically across a soil profile, since these properties affect ES delivery².

Our study estimates the spatial repartition of ES delivery for various combinations of soil types and land occupation choices within a 900 km² region dominated by agricultural and forested lands (Meuse / Haute Marne, France). Based on information from a 1/50 000 soil map and the description of 84 soil profiles, we separate the study area into homogeneous zones characterised by specific soil, land occupation and topographical properties. In each zone, soil functions and ES are rated on a scale of 0-3 using the DESTISOL decision support tool³. Maps of soil ecosystem services are then compared for different land cover scenarios. Firstly, we compare the evolution in soil ES delivery between 1850 and 2018. Secondly, we define realistic scenarios of land planning over the next 50 years, based on climatic, socioeconomic and public decision factors; finally, we propose scenarios that optimise each components of bundle of ES delivery at the regional scale.

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2. Martín, M. Á. et al. Soil structure and function in a changing world: Characterization and scaling. *Geoderma* 287, 1–3 (2017).

3. Blanchart, A. et al. Towards an operational methodology to optimize ecosystem services provided by urban soils. *Landscape and Urban Planning* 176, 1–9 (2018).

ConstraintID: web-based tool for spatial diagnosis of soil constraints

Dr Yash Dang¹, Dr Thomas Orton¹, Dr McClymont David², Professor Neal Menzies¹

¹*The University of Queensland, St Lucia, Australia*, ²*DHM Environmental Software Engineering Pty Ltd., Toowoomba, Australia*

Interdivisional 1: Spatial decision making and mapping for implementing polices for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

Within-field spatial variation of crop yields can occur for various reasons, but perhaps the most important driver is the soil. There are different management strategies available to growers to address soil constraints, but a necessary first step is the identification of constrained areas. Persistent spatial patterns of yield variation within fields might imply the presence of a soil constraint. Thus, better knowledge and understanding of the variation of past crop yields (both spatially across a field, and temporally from season to season) can help farmers identify constrained soils and make better management decisions. We have used historical remote-sensing data from 1999-present, to look for consistent spatial patterns using a crop yield index (CYI), derived from enhanced vegetation index (EVI) Landsat data around peak EVI. A reasonable agreement between CYI and crop yield monitor data was observed, with a median concordance correlation coefficient of pixel yield rankings of 0.64 for 53 harvested crops. We subsequently constructed a web-based tool, ConstraintID (<https://constraintid.net.au/>), that uses remote-sensing data and the CYI to enable farmers in the grains growing regions of north-eastern Australia to identify consistent spatial patterns in the field. The tool also enables the user to input their own local soil data and assess this against crop-specific tolerance limits for 17 crops commonly grown across the region to identify whether soil salinity, acidity, sodicity or compaction are potentially responsible for the yield loss. Farmers and advisors alike are showing substantive interest in this tool, which is providing valuable information for closing yield gaps.
<https://constraintid.net.au/>

A geospatial dss for soil health: a regional scale case study

Phd Antonello Bonfante¹, Dr Angelo Basile^{1,3}, Dr Giuliano Langella^{2,3}, Dr Alessia Perego⁴, Dr Fabio Terribile^{2,3}, Em. Prof Soil Science Johan Bouma⁵

¹*Institute for Mediterranean Agricultural and Forestry Systems, National Research Council, Portici (NA), Italy,*

²*Department of Agriculture, University of Naples Federico II, Portici (NA), Italy,* ³*CRISP - Interdepartmental Research Center on the Earth Critical Zone, Portici (NA), Italy,* ⁴*Department of Agricultural and Environmental Sciences –*

Production, Landscape, Agroenergy, University of Milan, Milano, Italy, ⁵*Em. Prof Soil Science, Wageningen University, the Netherlands*

Interdivisional 1: Spatial decision making and mapping for implementing polices for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

The concept of soil health has been proposed to communicate the importance of soils to stakeholders and policymakers. Scientific literature specifically addressing “Soil Health” (SH) has increased exponentially in the last four years, producing a large variety of definitions, approaches and methodologies without a proper standardization. In such complex scenario, the EU Soil Mission initiative has put some order defining Soil Health as “the continued capacity of soils to support ecosystem services, in line with the Sustainable Development Goals (SDGs) and the Green Deal (NGD)”. In agreement with this definition, we produce an operational set of Geospatial Decision Support Systems tools devoted to evaluate such Soil Health. These tools are mainly based on modelling soil physical aspects of soil health by applying physically-based soil-plant-atmosphere models with the objective to define a procedure with worldwide rather than only regional applicability, addressing important questions regarding possible effects of soil degradation and climate change. The developed tools were implemented in a web Geospatial Cyberinfrastructure platform (www.landsupport.eu) and evaluate the followings: (i) soil resilience by the lowering of SH when land degradation processes occur (e.g., soil compaction) (ii) increase of SH after sustainable land management practices (e.g., increase of soil organic carbon) and (iii) actual soil health of a specific soil in a specific pedoclimate using farmer input data. Currently they are applied in three European regions in Italy, Austria and Hungary.

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Bonfante, Antonello, Basile, A., & Bouma, J. (2020). Exploring the effect of varying soil organic matter contents on current and future moisture supply capacities of six Italian soils. *Geoderma*, 361, 114079. <https://doi.org/10.1016/j.geoderma.2019.114079>

Using Spatially Explicit Soil Mapping and Modelling to Understand and Mitigate Nitrate Leaching in an Agricultural Catchment

Miss Naila Hina¹, Dr Julia Cooper¹, Mr John Gowing¹, Dr Jeremy Dearlove³, Miss Melissa Swartz²
¹Newcastle University, Newcastle Upon Tyne, United Kingdom, ²Environment Agency, , United Kingdom, ³Northumbrian Water, , United Kingdom

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

Diffuse water pollution is one of the concerns associated with nitrate leaching from agricultural catchments to groundwater sources. Several factors including agricultural management practices, soil texture and soil depth to the bedrock are considered responsible for this pollution. In this study, high resolution soil sensing was used to produce digital soil maps to understand soil texture and depth to the bedrock variability within the study area. Based on the predicted soil texture components, soil texture (clay and sand %) varied within a field and soil depth to the bedrock varied from very shallow (30 cm) to deep (> 120 cm). Due to the relationship of soil texture and depth to bedrock with nitrate movement, locations with sandy shallow soil profiles might be hotspots for nitrate leaching. The effect of these spatially variable factors along with land use on nitrate leaching losses estimated using soil water analysis and weather data. A mechanistic nitrogen dynamics model was also used to simulate nitrate leaching and the impact of soil texture and thickness on nitrate leaching. The results showed high nitrate leaching from shallow sandy soils compared to deep clayey soils and maximum leaching after winter wheat followed by potatoes during the 2017/2018 drainage season with minimal leaching from grass. This approach of modelling can be used by farmers in the catchment area to track N dynamics in crop rotations and can be used for decision-making to manage the field in a way to minimize N losses via leaching. Hina, N. (2021). Using Spatially Explicit Soil Mapping and Modelling to Understand and Mitigate Nitrate Leaching in an Agricultural Catchment. (PhD), Newcastle University, Newcastle University.

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Future of UK soil carbon and nutrient cycles - modelling climate and land use and management scenarios

Prof Jess Davies¹, Dr Dmitry Yumashev, Dr Victoria Janes-Bassett, Dr John Redhead, Dr Ed Rowe

¹*Lancaster University, Lancaster, United Kingdom*

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

The United Kingdom (UK) is currently developing environmental land management policies that will have a large influence on soils across the country and the role they play in delivering national priorities and sustainable development. To help support policy making, national-scale tools are needed that help assess how soils and their functions will change in response to the land management actions and land use change that result from policy options. This analysis, however, also, needs to take into account other drivers of soil change, such as climate change. Here, we present results from a national-scale modelling analysis examining changes in terrestrial carbon storage under combined scenarios of land use, management and climate change. Building on previous work exploring UK-scale soil carbon and nutrient cycle change over the Anthropocene (Janes-Bassett et al 2021), we use the process-based integrated plant-soil C-N-P model, N14CP, to simulate future scenarios from present day to 2100. The model is driven with a suite of UKCP18 climate scenarios, and land use and management scenarios developed as part of the ASSIST project (Redhead et al 2020). We present results from this modelling analysis and consider the opportunities and challenges in integrating models of this kind with soil data, and Decision Support Systems in support of policy formation, implementation and evaluation.

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A web-based open-access Spatial Decision Support tool to monitor soil sealing and support decision making in urban planning

PhD Giuliano Langella¹, **Phd Piero Manna²**, PhD Angelo Basile², Dr Federica Cavaliere⁴, Dr Giuliano Ferraro¹, PhD Florindo Antonio Mileti¹, Dr Michele Munafò⁵, Dr Marco Di Leginio⁵, Prof Fabio Terribile¹

¹Department of Agriculture, University of Naples Federico II, Portici (Napoli), Italy, ²Institute for Mediterranean Agriculture and Forestry Systems (ISAFOM) – Italian National Research Council (CNR), Portici (Napoli), Italy, ³Ariespace S.r.l., Napoli, Italy, ⁴EMM Informatica S.r.l., Napoli, Italy, ⁵Italian National Institute for Environmental Protection and Research (ISPRA), Roma, Italy

Interdivisional 1: Spatial decision making and mapping for implementing policies for sustainable soil management:

Chairperson: Dr Jack Hannam & Prof Erika Micheli, Lomond Auditorium, August 1, 2022, 15:00 - 17:00

Soil is a limited natural resource which provides essential ecosystem services to humans. However, in Europe demand for developed land continues to raise resulting in a loss of agricultural, forest and other natural land to urban areas. This leads to enormous loss of soil functions and services so much so that the European Commission has proposed in the Environment Action Programme to have policies in place to achieve 'no net land take' by 2050. To address these issues we developed a web based Spatial Decision Support tool dealing with soil sealing phenomena by monitoring its evolution over time/landscape and simulating its potential effects on soil ecosystem services. The tool named "Zero net land take by 2050" is part of an ensemble of several tools developed within an HORIZON2020 project named "Landsupport: development of Integrated Web-Based Land Decision Support System Aiming Towards the Implementation of Policies for Agriculture and Environment" (www.landsupport.eu). The tool is applied to all EU territory and it works processing on-the-fly imperviousness data from Copernicus and national Agencies services. The users (spatial planners, researchers, policy makers) enable to select (i.e. municipality) or draw an area of interest (AOI) and run a query. The system can quantify and report or map surfaces lost due to urbanization during a user-defined time period and match this information with other data such as affected soils quality or ecosystem services lost. New urban development and soil impacts can be simulated and several urban development indexes can be mapped or plotted by graphs.

Piero Manna, Angelo Basile, Antonello Bonfante, Amedeo D'Antonio, Carlo De Michele, Michela Iamarino,

Giuliano Langella, Florindo Antonio Mileti, Paolo Pileri, Simona Vingiani, Fabio Terribile (2017). Soil sealing: quantifying impacts on soil functions by a geospatial decision support system. *Land Degrad. Develop.* DOI: 10.1002/ldr.2802.

Giuliano Langella, Angelo Basile, Simone Giannecchini, Francesco D. Moccia, Florindo A. Mileti, Michele Munafó, Francesco Pinto, Fabio Terribile (2020). Soil Monitor: an internet platform to challenge soil sealing in Italy. *Land Degrad. Develop.* DOI: 10.1002/ldr.3628

Low OC stabilization capacity of mineral-associated organic matter in tropical-alkaline soils of southern India

Dr. Soh Sugihara¹, Mr. Eito Nonomura¹, Dr. Mayuko Seki¹, Mr. Hidetoshi Miyazaki², Dr. Muniandi Jgadeesan³, Dr. Pandian Kannan³, Dr. Haruo Tanaka¹

¹Tokyo University of Agriculture and Technology, , Japan, ²Global Environmental Forum, , Japan, ³Tamil Nadu Agricultural University, , India

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Understanding the soil organic carbon (SOC) stabilization mechanisms is essential to develop the appropriate management for C sequestration, especially in degraded tropical ecosystems. The OC stabilization capacity was controlled by clay minerals, such as Al/Fe oxide stabilizing the OC in acidic soil, while Ca/clay stabilizing the OC in alkaline soil. We hypothesized that the alkaline condition has a relatively low OC stabilization capacity than the acidic condition. As a case study to assess this hypothesis, we evaluated the OC stabilization capacity of fine (<53 μ m) fraction, such as mineral-associated organic matter (mOM) in tropical alkaline soils of southern India. We collected the surface soils (0-10 cm) at 48 sites (paddy; n=13, cropland; n=29, bush; n=6) (pH; 7.5~8.3, Clay; 18~25%, OC; 0.5~0.7%), and evaluated the mass and OC contents of mOM fraction (>1.7 g cm⁻³, <53 μ m), using physical fractionation method. We found that the mass of the mOM fraction was 28~38%, and 64-72% of total OC were in the mOM fraction. We calculated the OC stabilization capacity as the slope of the regression equation of the mass and OC contents of mOM fraction, and it was 0.10 (in all sites), 0.13 (in paddy), and 0.10 (in cropland), respectively ($p < 0.01$). These values were apparently low compared with the previously reported values in tropical acidic-neutral soils (0.33) (Fujisaki et al. 2018). Thus, our results suggested that OC stabilization capacity in tropical-alkaline soils of southern India was ca. 1/3 of tropical acidic-neutral soils, though further case study in tropical alkaline soils is necessary.

Diochon et al., 2016. Recovery and dynamics of decomposing plant residue in soil: An evaluation of three fractionation methods. *European Journal of Soil Science*, 67(2), 196–205.

Fujisaki et al., 2018. Data synthesis of carbon distribution in particle size fractions of tropical soils: Implications for soil carbon storage potential in croplands. *Geoderma*, 313, 41–51

Soil organic carbon and fine particle stocks change along a volcanic chrono- and elevation-sequence on the Galápagos archipelago

Prof. Martin Gerzabek¹, Dr. Maria Valentina Rechberger¹, MSc Greta Schmidt¹, Dr. Karin Wriessnig¹, Prof. Franz Zehetner^{1,2}

¹University of Natural Resources and Life Sciences Vienna, Vienna, Austria, ²Galápagos National Park Directorate, Puerto Ayora, Ecuador

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

We investigated the influence of soil age (between 1.5 and 1,070 ka) and climate (arid to very humid) on the stocks of soil organic carbon (SOC) and silt- and clay-sized particles across four volcanic islands of the Galápagos archipelago.

The youngest soil profile of the chronosequence had the lowest SOC stock (7.7 kg m⁻²), and a first maximum of 21.6 kg m⁻² was observed in an allophanic Andosol (at 4.3 ka age), followed by somewhat lower SOC stocks in older soils and a second maximum in the oldest and particularly deep soil (25.6 kg m⁻²). In the deep, highly weathered soils, the share of subsoil SOC stocks (>20 cm) was 50% or higher. Climatic differences induced similar variability in SOC stocks (0.8 to 20.3 kg m⁻²) as did soil age. The SOC stocks were likely influenced by several factors, i.e. increasing solum thickness and proportions of fine fractions with soil age, but decreasing specific surface area related with changes in the mineralogical composition from allophanes to increasingly crystalline pedogenic oxides.

Stocks of silt+clay-sized particles varied from 9.6 to 1724 kg m⁻² across all soil profiles studied. Along the chronosequence, the clay particle formation rate decreased logarithmically from >90 to <0.2 g m⁻² a⁻¹ with increasing age. Soil age and changes in moisture regime showed similarly strong effects on the stocks of fine fractions. With increasing stocks of silt- and clay-sized particles in older soils, additional SOC binding became less, likely due to mineralogical composition and microstructure.

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Catastrophic Carbon Movement: Tracing Changes to Icelandic Carbon Cycling due to Increasing Erosion over the past Millennium

Miss Lucy Weidner¹, Dr. Anthony Newton, Professor Andrew Dugmore, Dr. Joanna Cloy

¹*University Of Edinburgh, Edinburgh, Scotland*, ²*Scotland Rural College, Edinburgh, Scotland*

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

According to the Intergovernmental Panel on Climate Change (IPCC), soil carbon sequestration is an effective option for mitigating critically rising CO₂ concentrations. Icelandic soils and their organic carbon contents are extremely vulnerable to wind and water erosion due to bulk density, high porosity, and large water retention capabilities. From the late-9th century, Norse settlers cleared the woodland cover and rapidly introduced grazing animals and other agricultural practices, which homogenized the vegetation and deteriorated the landscape's stability. By stripping the land of woody vegetation, the surface cover was weakened, leading to extensive soil erosion. While the drivers of this erosion have been studied, indicating the degradation is and has been driven by combined environmental and cultural factors, the impact of increased erosion on carbon movement is less understood. This project characterizes and tracks the movement of carbon over the last few thousand years before and after the precisely-dated settlement of a well-studied archaeological site in southern Iceland. Bulk soil and sediment samples were collected from across a river catchment where there are well-dated tephra layers. Using tephrochronology to establish sedimentation and accumulation rates, an age depth model was established and bulk sediment samples were taken. These samples were analysed (bulk density, organic carbon contents) and used to calculate carbon stocks and create a temporal chronosequence of maps tracking the movement and loss of carbon through a river catchment. This project demonstrates the utility of using tephra layers to explore the relationship between archaeology, soil erosion, and carbon storage, movement, and loss.

Arnalds O et al. (2001) Soil Erosion in Iceland. (trans.) SCSARI, Reykjavik, Iceland. 121.

Dialynas YG et al. (2016) Topographic variability and the influence of soil erosion on the carbon cycle. *Global Biogeochemical Cycles*. 30:644-660, DOI: 10.1002/2015gb005302.

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Óskarsson H et al. (2004) Organic carbon in Icelandic andosols: Geographical variation and impact of erosion. *Catena*. 56:225-238, DOI: 10.1016/j.catena.2003.10.013.

Pedogenesis in the Phyllosphere: Do arboreal histosols increase soil carbon capture in the tropics?

Dr. A. Peyton Smith¹, Jessica Murray², Hannah Connuck³, Dr. Myrna Simpson⁴, Dr. Malak Tfaily⁵, Dr. Bonnie Waring⁶

¹Texas A&M University, College Station, United States, ²Utah State University, Logan, United States, ³Franklin and Marshall College, Lancaster, United States, ⁴Environmental NMR Centre and Department of Physical and Environmental Sciences, University of Toronto, Toronto, Canada, ⁵University of Arizona, Tuscon, United States, ⁶Grantham Institute on Climate Change and the Environment, Imperial College, London, United Kingdom

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Arboreal histosols, or canopy soils, i.e., organic soils formed in the canopy of epiphyte-colonized forests, play a vital role in forest ecosystems & may sequester significant amounts of carbon (C). Despite their importance, factors determining their distribution, properties, & C content are largely unknown. Coupling high-resolution mass spectrometry (FT-ICR, ¹³C NMR) with soil physical properties & C fluxes, we surveyed canopy soils across a climate gradient in Costa Rica to determine patterns of abundance, C content, & composition. Compared to mineral soils, canopy soils held nearly 3 & 10x more labile C & total C, respectively. Canopy soil C stocks ranged 0.44 - 6.46 kg C m⁻² branch area. In a laboratory incubation, canopy soils emitted 3x more CO₂-C than mineral soils - reflecting the difference in labile C pools. Canopy soils in warmer climates contained more aromatic & phenolic compounds than soil at cooler sites. Yet, the degree of microbial processing, i.e., alkyl-to-O-alkyl ratio, didn't vary, largely due to within-site variability, which indicates that across sites, canopy soils are at relatively similar stages of soil organic matter decomposition. Fog correlated with canopy soil distribution across forests, while tree size determined where canopy soil is found within a forest. Temperature & fog influenced canopy soil C:N ratio, DOC, and organic matter composition. Our results suggest that canopy soils may double the amount of estimated carbon sequestered in tropical forests and highlight the importance of tree size & fog in determining the quantity & quality of canopy soil organic matter.

Wildlife conservation accumulates carbon and lignin in soils

Dr. Alexandra Sandhage-Hofmann¹, Dr. Ramona Mörchen¹, Prof. Anja Linstädter², Liana Kindermann², Dr. Simon Angombe³, Prof. Wulf Amelung¹

¹University of Bonn, Soil Science and Soil Ecology, Bonn, Germany, ²University of Potsdam, Institute of Biochemistry and Biology, Biodiversity and Systematic Botany, Potsdam, Germany, ³University of Namibia, Faculty of Agriculture & Natural Resources, Neudamm Campus, Windhoek, Namibia

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Conservation in Sub Saharan Africa is inextricably linked to wildlife numbers with elephants as key species. The impact elephants have on vegetation structure is often considered to cause a decline in carbon storage in woody vegetation. However, little is known about how this affects soil organic carbon (SOC) stocks down to 1m soil depth and its lignin contents. Our aims were to study 1) the effects of increasing elephant numbers on SOC and 2) whether these were also reflected in contents and composition of lignin. We selected plots with low, medium, and high elephant densities in the Kavango Zambezi Transfrontier Area (Namibia), and quantified carbon storage in both woody vegetation and soils (1 m), supplemented by the assessment of soil $\delta^{13}\text{C}$ and lignin analyses in topsoils (0-10cm). We found that with increasing elephant densities SOC stocks increased by 4.7 t ha⁻¹ despite losses of tree carbon storage by 6.4 t ha⁻¹. These higher SOC stocks were mainly found in the upper 0-30cm, but also visible in subsoils and were largely related to the formation of SOC from woody biomass and elephant dung. Contents of lignin-derived phenols were highest in plots with high elephant density. Here, the lignin composition indicated woody components as the main input sources. Consequently, increasing elephant numbers does not necessarily result in a negative carbon footprint, as soil carbon sequestration and carbon storage in dung nearly offset tree biomass losses. Furthermore, lignin analyses revealed that soil C sequestration was largely driven by the accumulation of woody plant residues.

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Scientific Reports,

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Soil carbon research from past, present, and future using synchrotron-based techniques

Dr Han Weng¹, Dr Lukas Van Zwieten², Professor Stephen Joseph³, Professor Caixian Tang⁴, Professor Roger Armstrong⁵, Professor Steve McGrath⁶, Professor Peter Kopittke¹

¹*School of Agriculture and Food Sciences, The University of Queensland*, ²*NSW Department of Primary Industries, Wollongbar Primary Industries Institute*, ³*University of New South Wales*, ⁴*Department of Animal, Plant & Soil Sciences, Centre for AgriBioscience, La Trobe University*, ⁵*Agriculture Victoria Research, Department of Jobs, Precincts & Resources*, ⁶*Rothamsted Research*

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Building and protecting soil carbon is critical to agricultural productivity, soil health and climate change mitigation. This study aims to answer new questions of the molecular scale mechanisms at the organo-mineral interfaces for building soil carbon in the past: Terra Preta Australis (ancient indigenous dark earth in Australia, dated back to 1600 years BP) and the Classical experiments at the Rothamsted Research, United Kingdom (the oldest, continuous agronomic experiments in the world); present: the longest, continuous biochar field experiment in the world, located at Wollongbar, New South Wales, Australia (building new carbon over 14 years); future: the Soil Free Air CO₂ Enrichment (SoilFACE) field facility at Horsham, Victoria, Australia (mimicking elevated CO₂ conditions in the field over 8.5 years in the Southern Hemisphere). For the first time, we integrate scanning transmission X-ray microscopy (STXM at the PoLLux beamline, Swiss Light Source, Switzerland) with near-edge X-ray absorption fine structure (NEXAFS) spectroscopy and infrared microspectroscopy (IRM) at the Australian Synchrotron. Enrichment of amide N (401.2 eV) and aliphatic C (287.3 eV) may indicate the increased microbial metabolites, which are presumably richer in N (lower C:N ratio), act as a binding agent for increased progressive formation of microaggregates over the long-term. Based upon synchrotron-based in situ spectromicroscopy, we reveal the functional complexity and spatial resolution of soil organic carbon under contrasting management practices, cropping histories and soil types over millennium. It will provide critical information to advance knowledge of building soil carbon for productive, sustainable and resilient cropping systems.

Soil carbon credits for climate mitigation: opportunities and challenges

Dr. Martin Wiesmeier^{1,2}, Dr. Stefanie Mayer¹, Dr. Carsten Paul³, Prof. Dr. Katharina Helming³, Dr. Axel Don⁴, Dr. Uwe Franko⁵, Dr. Markus Steffens⁶, Prof. Dr. Ingrid Kögel-Knabner¹

¹Technical University of Munich (TUM), Freising, Germany, ²Bavarian State Research Centre for Agriculture (LfL), Freising, Germany, ³Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, ⁴Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany, ⁵Helmholtz Centre for Environmental Research (UFZ), Halle, Germany, ⁶Research Institute for Organic Agriculture (FiBL), Frick, Switzerland

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Increasing soil organic carbon (SOC) stocks in agricultural soils by improved management could significantly contribute to climate mitigation and adaptation. For farmers, CO₂ certificates for carbon sequestered in soils represent an additional incentive to implement management practices that increase SOC stocks. These certificates are issued by initiatives and companies within the voluntary CO₂ market and can be purchased to offset greenhouse gas emissions. Soil carbon credits may stimulate the willingness of farmers to implement more sustainable management practices for healthy and resilient soils. Furthermore, carbon credits can promote the social perception of agricultural soils as a globally important carbon sink. To ensure climate benefits, carbon credits must meet scientific standards with regard to measurement, reporting and verification of SOC and other aspects. However, scientific standards have so far been given little consideration. An analysis of selected business models in Germany showed that there are significant deficits in the current allocation of carbon credits, particularly with regard to SOC measurement and the suitability of agricultural practices for carbon sequestration. In addition, it has not yet been clarified to what extent soil carbon credits are generally suitable for offsetting greenhouse gas emissions in view of the permanence of sequestered SOC, additionality and the risk of leakage effects.

Wiesmeier, M., Mayer, S., Paul, C., Helming, K., Don, A., Franko, U., Steffens, M., Kögel-Knabner, I. (2020). CO₂ certificates for carbon sequestration in soils: methods, management practices and limitations. BonaRes Series. DOI: 10.20387/bonares-ne0g-ce98

Changes in SOC stocks and aggregates in alpine and pre-alpine grassland soils in a changing climate

Dr. Noelia Garcia Franco¹, Dr Martin Wiesmeier^{1,2}, Dr Bernd Josef Berauer³, Max Schuchardt³, Dr. Anne Schucknecht⁴, Dr Katrin Schneider⁴, Marcus Zistl-Schlingmann⁴, Diana Andrade Linares⁵, Michael Schloter⁵, Stefanie Schulz⁵, Mirella Schreiber⁴, Benjamin Wolf⁴, Anke Jentsch³, Ralf Kiese⁴, Michael Dannenmann⁴, Prof. Dr. Ingrid Kögel-Knabner^{1,6}

¹Chair of Soil Science, TUM School of Life Sciences Weihenstephan, Technical University of Munich, Freising, , Germany,

²Institute for Organic Farming, Soil and Resource Management, Bavarian State Research Center for Agriculture,

Freising, , Germany, ³Bayreuth Center of Ecology and Environmental Research, Department of Disturbance Ecology and Vegetation Dynamics, University of Bayreuth, , Germany, ⁴Institute of Meteorology and Climate Research, Karlsruhe

Institute of Technology (KIT), Campus Alpin Garmisch-Partenkirchen, , Germany, ⁵Research Unit Comparative Microbiome Analysis, Helmholtz Zentrum München, Neuherberg, , Germany, ⁶Institute for Advanced Study, Technical University Munich, Garching, , Germany

Interdivisional 2 – Soil Carbon: from particle to planet, Clyde Auditorium, August 1, 2022, 15:00 - 17:00

Alpine and prealpine grasslands not only provide various ecosystem services, they are also hotspots for the storage of soil organic carbon (SOC) in Central Europe. Yet, information about changes in SOC stocks and aggregate-related SOC in these soils is limited. The study sites were located along an elevation gradient in the Northern Limestone Alps of Bavaria (Germany): Fendt (600 m a.s.l.), Graswang at (860 m a. s. l.); and Esterberg (1,260 m a. s. l.). In 2016, the study sites were initially sampled before plant-soil mesocosms were translocated downslope along the elevation gradient to simulate climate change (temperature increase of +1 K from high- to mid-elevation, +2 K from mid- to low elevation, and +3 K from high- to low-elevation). In addition, two management practices (extensive vs. intensive) were implemented. In 2020 we took undisturbed samples from each translocated soil-plant mesocosm to study the changes of SOC stocks and the SOC distribution according to different aggregate size classes. We observed a significant decrease of SOC and N contents after four years, but no significant effect on stocks due to inconsistent changes of bulk density. The analysis of soil aggregation showed a OC decrease of macroaggregates in both extensive and intensive management, while OC in microaggregates and the silt/clay-sized fraction increased. Our study provided evidence that climate change will lead to significant losses of C in these SOC-rich soils, which not only contributes to climate change but also probably deteriorates the functionality of these grassland soils

Garcia-Franco et al., 2020

Soil science skills for the future: a European perspective

Dr Jennifer Lydia Veenstra¹, Prof. Yves Coquet², Dr Romain Melot¹, Prof. Christian Walter³

¹INRAE, Paris, France, ²Agroparistech, Paris, France, ³Institut Agro - AgroCampus Ouest, Rennes, France

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

As part of the European Joint Project (EJP) SOIL on agricultural soil management, we designed and conducted a survey dedicated to the apprehension of the soil science skills required in the future (i.e. 20 years from now). The study adopted an interdisciplinary approach between Soil Science and Social Sciences. Various categories of stakeholders were contacted, including representatives of farmer organizations, farmer advisors, public policy makers, industry and retailers, NGOs, education and research organizations, and certifying and funding agencies. People were asked to provide personal opinions.

The survey was handled and distributed on line using LimeSurveyTM. The survey was available in English and in the national language of each of the 24 countries taking part in the EJP SOIL.

Stakeholders were contacted through the National Hubs set up within the framework of the EJP SOIL. More than a thousand stakeholders were invited to collaborate. Efforts were made to balance participation between countries and stakeholder categories. The response rate and the distribution of the responses between stakeholder categories were satisfactory.

The analysis of the survey results allowed to identify (i) the skills considered most important according to the categories of stakeholders; (ii) new competences traditionally not included in training curricula but considered necessary by stakeholders; (iii) differences in appreciation according to countries; (iv) possible evolutions of job profiles related to soil science. The results of this survey will contribute to EJP's roadmap on agricultural soil management by providing an objective basis for recommendations on training program evolution within EU.

Villa Solis, A., Fahlbeck, E., Barron, J. (2021). Synthesis report of soil science capacity in Higher Education in Europe. Swedish University of Agricultural Sciences, Uppsala. 40 p.

Using social science approaches to integrate local knowledge when modelling the impact of natural flood management measures

Dr Charlotte Chivers¹, Professor Chris Short¹, Dr John Hammond², Professor Anne Verhoef², Ms Barbara Percy, Professor Anne Verhoef², Dr Maleki Badjana², Professor Hannah Cloke², Mr David MacDonald³, Ms Sarah Collins³, Ms Amanda Ingham⁶, Ms Bel Whitham⁷, Ms Louise Webb⁹, Mr Tom Ormesher⁸, Dr Majdi Mansour³, Mr Ryan Jennings⁵, Mr Steve Rose⁵, Mr Barry Hankin⁵, Ms Samantha Broadmeadow⁴, Dr Tom Nisbet⁴, Professor Joanna Clark²

¹*Countryside and Community Research Institute, University of Gloucestershire, Cheltenham, United Kingdom,*

²*University of Reading, Reading, United Kingdom,* ³*British Geological Survey, Wallingford, United Kingdom,* ⁴*Forest Research, , England,* ⁵*JBA Consulting, Wallingford, United Kingdom,* ⁶*The Wildlife Trusts, , England,* ⁷*FWAG SW, , England,* ⁸*Southern Water, , England,* ⁹*Natural England, , England*

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

This presentation will explain how a truly transdisciplinary approach has led to the identification of the most effective and acceptable locations for natural flood management (NFM) measures for reducing downstream flood risk. When exploring the efficacy of NFM measures, there has often been a top-down approach and overreliance on hydrological modelling, ignoring the views of local land managers regarding the broader feasibility and acceptability of measures on their land. NFM interventions need to be implemented by farmers and land managers who may be unlikely to uptake the measures recommended by modelled scenarios because they rarely reflect the reality of actual land management scenarios or farming systems. This is because hydrological models have a limited number of parameters, which makes it hard to represent the many differences seen between individual farms. LANDWISE, a NERC-funded project, has brought together hydrologists, soil scientists, agricultural researchers, farmers, farm advisors and regulators to inform and co-design land management scenarios and model applications, using a mix of online survey and telephone interviews. The results revealed high levels of complexity surrounding the interplay between soil types and intervention preferences on different farms, with some underlying patterns linked to type of farming system (conventional, regenerative, organic). This has allowed model scenarios to better reflect local knowledge and preferences, increasing the chances of NFM measures being implemented at an appropriate scale to benefit downstream communities at risk of flooding. We review the lessons learned and argue for the wider adoption of this more sustainable approach to flood risk management.

We expect to have published at least two peer-reviewed journal articles on this work in time for the conference in 2022 - references to follow in due course.

Linking the soil microbiome with human health

Dr. Winfried E.H. Blum¹, Dr. Katharina M. Keiblinger¹, Dr. Martin Grassberger²

¹*University of Natural Resources and Life Sciences (BOKU), Vienna, Vienna, Austria,* ²*University of Vienna Austria, Department of Evolutionary Anthropology, Vienna, Austria*

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

Soils are highly diverse and are considered as one of the most diverse habitats on our planet. Global change and anthropogenic activities cause a dramatic decline in the diversity of organisms on earth. Here we stress the importance of the soil microbial diversity, and the protection of its functioning in terrestrial ecosystems under the increasing intensity of (agricultural) soil management and its linkage with human health.

From hunter-gatherers to an urbanized society a loss in human gut richness was observed, while the beta-diversity increased, meaning that urban people show more contrasting individual microbiomes. In addition, little contact with soil and manure, hygienic measures, medication, and a low fiber-diet resulted in a decline of beneficial microbes in the human intestine. Furthermore, a decrease in soil biodiversity is observed in many rural areas, likely due to the rise in agrochemical use, monoculture cropping and severe soil tillage practices. Owing to these developments, lifestyle diseases have risen dramatically in industrialized countries, and can be related to the human microbiome. Here we show the detachment of the microbial cycle of urban human environments compared to pre-industrial rural surroundings. To restore this detachment and reconnect humans with a vital (soil) environment it is of crucial importance to adopt a different perspective. Symbiotic microorganisms and their hosts have likely co-evolved and play a crucial role in the sustained health and fitness of its host, be it plants or humans, and a close contact may refresh or re-inoculate the human microbiome.

Blum, W., Zechmeister-Boltenstern, S., & Keiblinger, K. M. (2019). Does Soil Contribute to the Human Gut Microbiome?. *Microorganisms*, 7(9), 287.

<https://doi.org/10.3390/microorganisms7090287>

Understanding the Adoption of Zero Budget Natural Farming in Andhra Pradesh, India

Dr Sarah Duddigan¹, Dr Grady Walker¹, Dr Sarah Cardey¹, Dr Zakir Hussain², Dr Henny Osbahr¹, Prof Liz Shaw¹, Dr Tom Sizmur¹, Mr Vijay Kumar², Prof Chris Collins¹

¹University of Reading, ²Rythu Sadhikara Samstha (RySS), India

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

Zero Budget Natural Farming (ZBNF) in Andhra Pradesh emphasises synthetic chemical-free inputs and regenerative techniques as a means to achieve socio-ecological resilience for smallholder farmers. Public messaging about ZBNF describes transformations in the soil through enhanced microbial activity and nutrient availability, and across society, as lower input costs and higher yields are able to protect farmers against debt, food insecurity, and change. This study explored the accuracy and efficacy of ZBNF public messaging through an interdisciplinary soil and social science investigation, which sought to understand motivations behind the adoption of an agricultural practice projected to reach over six million farmers in Andhra Pradesh by 2024.

Working in the same communities across three agroecological zones, spanning over 800km, University of Reading researchers established controlled field experiments alongside participatory photography investigations led by farmers. Field experiments revealed that the performance of ZBNF agriculture, when compared to conventional or organic farming yields, is largely congruent with the public messaging. The participatory photography—focusing on farmer perceptions of ZBNF innovations—demonstrated that farmer-defined reasons behind adoption defy a simple cost-benefit analysis and point toward a combination of subjective gains not limited only to yield and income but inclusive of memory, legacy, independence, and a rejection of industrialized agriculture. Together, the parallel soil and social science approaches reveal the effect of ZBNF on the soil, as well as the perceptions of those transformations among the community members themselves, including the way those transformations became embedded in the overarching narratives farmers used to define their lives.

Walker G, Osbahr H, Cardey S. Thematic Collages in Participatory Photography: A Process for Understanding the Adoption of Zero Budget Natural Farming in India. *International Journal of Qualitative Methods*. 2021. doi:10.1177/1609406920980956

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Integrating land-water-people connectivity concepts across disciplines for co-design of soil erosion solutions: the Jali Ardhi [Care for the Land] project

Prof. William Blake¹, Claire Kelly¹, Francis Mkilema², Alex Taylor¹, Mona Nasser³, Aloyce Patrick², Alice Kalnins¹, Maarten Wynants¹, David Gilvear¹, Nyambilia Amuri⁴, Reuben Kadigi⁴, Kelvin Mtei⁵, Patrick Ndakidemi², Linus Munishi²

¹*School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, United Kingdom,* ²*School of Life Sciences and Bio-Engineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania, United Republic of,* ³*Ecological Design Thinking, Schumacher College, Totnes, United Kingdom,* ⁴*Department of Soil Science, Sokoine University of Agriculture, Morogoro, United Kingdom,* ⁵*School of Materials, Energy, Water and Environmental Science, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania, United Republic of*

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

Soil resources in East Africa are being rapidly depleted by erosion, threatening food, water and livelihood security in the region. The Jali Ardhi [Care for the Land] project promotes an integrated, interdisciplinary approach to support co-design of sustainable and regenerative land management decisions tailored to the needs of specific communities and places within agro-pastoral landscapes. Activities are grounded in an implicit farmer understanding of the need for effective governance mechanisms at both community and District levels, to enable community-led actions to be implemented effectively.

Phase 1 focussed on problem definition through iterative integration of interdisciplinary evidence bases. Natural science, social science and design thinking methodologies were combined to underpin community-led co-design of bottom-up pathways to land management change (e.g. byelaws co-design). In Phase 2, connectivity concepts were used to evaluate process interaction between cultivated and grazing land and relative success of current soil conservation measures. Geospatial analysis revealed that plot connectivity was a key factors in the development of rill networks driven by weak boundaries between newly formed plots. Demonstration of the critical time window of erosion risk during early phases of slow-forming terrace development catalysed a community-led tree planting and grass seed sowing programme to mitigate soil erosion.

Building on these advances in approach, collective understanding and action, Phase 3 focusses on development of a guiding framework within which communities can make informed choices from myriad options within sustainable land management paradigms. In this context, we evaluate opportunities for research impact through interdisciplinary collaboration outside soil science.

Taylor A, Wynants M, Munishi L, Kelly C, Mtei K, Mkilema F, Ndakidemi P, Nasser M, Kalnins A & Patrick A (2021) 'Building Climate Change Adaptation and Resilience through Soil Organic Carbon Restoration in Sub-Saharan Rural Communities: Challenges and Opportunities' *Sustainability* 13, (19) 10966-10966

Blake WH, Kelly C, Wynants M, Patrick A, Lewin S, Lawson J, Nasolwa E, Page A, Nasser M & Marks C (2020) 'Integrating land-water-people connectivity concepts across disciplines for co-design of soil erosion solutions' *Land Degradation & Development* 32, (12) 3415-3430

Kelly C, Wynants M, Munishi LK, Nasser M, Patrick A, Mtei KM, Mkilema F, Rabinovich A, Gilvear D & Wilson G (2020) 'Mind the Gap': Reconnecting Local Actions and Multi-Level Policies to Bridge the Governance Gap. An Example of Soil Erosion Action from East Africa' *Land* 9, (10) 352-352

Wynants M, Kelly C, Mtei K, Munishi L, Patrick A, Rabinovich A, Nasser M, Gilvear D, Roberts CN & Boeckx P (2019) 'Drivers of increased soil erosion in East Africa's agro-pastoral systems: changing interactions between the social, economic and natural domains' *Regional Environmental Change*, 19, 1901-1921

Blake WH, Rabinovich A, Wynants M, Kelly C, Nasser M, Ngondya I, Patrick A, Mtei K, Munishi L & Boeckx P (2018) 'Soil erosion in East Africa: an interdisciplinary approach to realising pastoral land management change' *Environmental Research Letters* 13, (12) 0-0 Author Site , DOI Open access

Participation in citizen science is a promising avenue for fostering environmental stewardship

Ms Nerea Ferrando Jorge^{1,2}, Professor Hilary Geoghegan¹, Professor Joanna Clark¹, Dr Macarena L. Cárdenas², Dr Toos Van Noordwijk²

¹University Of Reading, Soil Research Centre, Reading, England, ²Earthwatch Institute, Oxford, England

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

Irreversible losses and deterioration of urban soil is a global challenge that is often overlooked. Recent studies highlight the need to increase and integrate understanding of the valuable ecological services provided by soil across disciplines and professions for collective mobilization. Our work explores the different benefits of engaging non-scientists in citizen science. This research is part of Earthwatch's Sustainability Training Programme, where corporate participants become citizen scientists for two-days and contribute to scientific research by collecting soil measurements whilst learning about the benefits of urban soils and green spaces for climate change mitigation. We use a mixed-methods approach, including surveys and overt participant observations, to understand the impact of the events on participants learning and environmental attitudes. Initial analysis from surveys shows that approximately 93% of participants were positively impacted by the programme in both their professional and personal lives. Likewise, data collected from participant observations demonstrated that taking part in this immersive, hands-on research experience positively influenced participants to take action on climate change and gain a deeper appreciation of soils. Key themes that emerged suggest participants felt motivated to act because they gained a better understanding of the science and its importance, felt empowered with their role in the bank as "sustainability leaders" to influence others, and were inspired to do something meaningful after working closely with scientists. This work reaffirms that benefits of citizen science go beyond the collection of big data sets and how these participatory experiences can help increase scientific literacy and foster environmental stewardship.

Cárdenas, M., Wilde, V., Hagen-Zanker, A., Seifert-Dähnn, I., Hutchins, M., and Loiselle, S. (2021). The circular benefits of participation in nature-based solutions. *Sustainability*, 13(8).

Kosmala, M., Wiggins, A., Swanson, A. and Simmons, B. (2016). Assessing data quality in citizen science. *Frontiers in Ecology and the Environment*, 14.

Lee, K. Lee, J., Bell, P. (2019). A review of Citizen Science within the Earth Sciences: potential benefits and obstacles. *Proceedings of the Geologists' Association*, 854.

Lewandowski, E. and Specht, H. (2014). Influence of volunteer and project characteristics on data quality of biological surveys. *Conservation Biology*, 29.

Rossiter, D., Liu, J., Carlisle, S., Xing Zhu, A. (2015). Can citizen science assist digital soil mapping? *Geoderma*, 259-260.

Lessons learn from the development and use of Scotland's soils website - <https://soils.environment.gov.scot/>

Dr Patricia Bruneau¹, Dr Karen Dobbie², Dr Allan Lilly³, Dr Ken Loades³, Dr Sandra Marks⁴

¹NatureScot, Stirling, UK, ²Scottish Environment Protection Agency, Edinburgh, UK, ³The James Hutton Institute, Aberdeen, UK, ⁴Scottish Government, Edinburgh, UK

Inter-divisional 3 – Interdisciplinary soil science for impact, M1, August 1, 2022, 15:00 - 17:00

Scotland has a rich repository of soil information gathered over many decades through public and privately funded programs. However, this information can often be difficult to access and is of limited use to non-soil experts and users from other disciplines.

The importance of soil is being widely recognised to support a range of policies. Healthy soils are essential for the continued provision of a wide range of services and benefits, including growing food, storing carbon, protecting water and its supply, reducing flood risk, and providing a home for nature. An awareness of the role of soil and the ability to access relevant spatial information is critical to help understand the impacts of land-based activities and to support policy development.

Scotland's Soils Website (SSW) is a Scottish Government initiative which was developed as part of Scotland's environment gateway following user-needs research to create a "one-stop shop" for accessing information on soils. SSW allows users to view a range of maps with links to where the associated data can be downloaded, provides interpretation of the data for specific users groups and signposts to other useful sources of data and information. The website is regularly updated and since its launch in 2017, there have been every year more than 22,000 users averaging over 80,000 page views.

Lessons learnt include:

- Making raw data accessible does not necessarily help non experts
- Data needs to be interpreted to support the needs of specific users
- Agile development is key in a quickly changing world.

Scotland's soils (n.d.). <https://soils.environment.gov.scot/>

Remote sensing of cover crop legacies on soil health and main crop N-uptake dynamics

Dr Nikolaos-Christos Vavlas¹, Dr Ali El Hakeem¹, Dr Lammert Kooistra², Dr Gerlinde De Deyn¹

¹*Soil Biology Group, Wageningen University and Research, Wageningen, The Netherlands*, ²*Laboratory of Geo-information Science and Remote Sensing, Wageningen University and Research, Wageningen, The Netherlands*

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

The dynamic nature of soil health makes it vital to adjust soil management to the ability of the soil to provide nutrients to crops at the right time to avoid nutrient losses through air and leaching. Cover crops promote nutrient retention in the soil and provide N to the main crop during main crop development. However, different cover crops will differentially affect the soil biology and N allocation to different soil pools and N-losses. Remote sensing technology enables monitoring the field heterogeneity and the temporal changes of the cover and main crop development. We explore how different cover crop treatments affect the balance of the N & C cycles and the microbial communities that make N available for plant uptake. In this presentation, the dynamics of the main crop responses to the legacies of different cover crop monocultures and species mixtures via soil processes are examined. We use UAV with RGB and multi-spectral camera's to quantify the temporal dynamics of the main crop responses to seven different cover crop treatments in a long-term field experiment on sandy soil. We first aim to analyse the minimum set of in situ plant and soil data needed to calibrate the remote sensing data and, second, provide remote sensing derived crop N budget information at high spatial and temporal resolution. The application of this technology can cost-effectively increase the model accuracy and allow better simulation of the N movement in the soil, quantifying N pools and the farm system's losses thereby enabling improved N-management.

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Recent developments in rice paddy modeling research on water balances and water quality assessment

Dr. Jaehak Jeong

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

Water quality impact of rice paddy management is significant in many Asian countries and other rice producing countries. Cultivation of rice in lowland paddy fields involves substantial amount of irrigation during growing seasons. Thus, environmental impact assessment of paddy practices must be assessed via addressing the entire water balances at the cropping systems scale or at the watershed scale. Computational modules were developed to evaluate agricultural management practices in rice paddies using the Agricultural Policy and Environmental eXtender (APEX) for field-scale assessment and the Soil and Water Assessment Tool (SWAT) for watershed-scale assessment. The Paddy module was evaluated in three case studies in South Korea and Japan. At the field scale, APEX was used to calibrate discharge and N yield from two experimental paddy fields, Icheon (ICH, 14 ha) and Gimje (GIM, 0.6 ha) in South Korea (ICH, 15 ha). At the watershed scale, SWAT was calibrated for streamflow in an agricultural watershed of the Kashima river basin in Japan (KAS, 11,700 ha). Results show that APEX is capable of replicating edge-of-field discharge rate ($R^2 > 0.8$) and N yields ($R^2 > 0.67$) and daily evapotranspiration rate ($R^2 = 0.8$). In the KAS watershed, the paddy module helped improve field level discharge volume ($R^2 = 0.8$) compared with the SCS-CN method ($R^2 < 0.1$). However, the improved water balance estimation in rice paddies did not exhibit improved flow estimation at the watershed outlet due to limited discharge contribution by paddies in the KAS (9% area). Water input to ICH comprised 60 % irrigation and 40 % rainfall, from which 28 % made runoff discharge, 28 % evapotranspiration, and 44 % infiltration. The largest N yield was attributable to subsurface return flow, followed by runoff discharge.

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On-farm strategies for improving soil health: Building a network in Kansas - USA

MSc Carlos Bonini Pires¹, Ph.D Ignacio Ciampitti¹, Ph.D. Dorivar Ruiz Diaz¹, Ph.D. Charles Rice¹

¹*Kansas State University, Manhattan, United States*

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

Soil health is proven to have wide-ranging benefits and is of increasing interest to farmers and agricultural stakeholders. As soil health practices become more common, data on on-farm soil health metrics changes are needed to target middle and late adopters. The objective of this study was to assess the effect of cover crops on soil health indicators and soybean yield. This study is part of the Kansas Soil Health Partnership, a farmer-led initiative that fosters transformation in agriculture through improved soil health and currently involves four farms across the state of Kansas in the United States: (1) Solomon, (2) Bucyrus, (3) Beloit, and (4) Glen Elder. For this abstract, we will focus on site 1. Site 1 is located at the Knopf Farms and is in year three of five. The experimental design was four randomized and replicated strips (RCBD) of the farmer standard practice (no cover crop) and the improved practice (cover crop). Soil samples were taken on a GPS coordinated grid at 0-5 cm soil depth at the first (2019 - benchmark) and third (2021) year of the study. The soil health indicators measured were: (1) Biological: microbial biomass (MB), saprophytic fungi, total fungi, and gram-positive bacteria; (2) Physical: water-stable aggregates; and (3) Chemical: soil organic carbon and total nitrogen. We observed that cover crops significantly increased all biological indicators at 0-5 cm. The addition of cover crops to the cropping system did not significantly affect soybean yield. Chemical and physical properties are still being analyzed. Sackett, J.L., 2013. An NCR-SARE cover crop project: Farmer-cooperator motivation and agronomic practices. *Journal of the NACAA* 6(2).

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Long-term N fertilization effects on soil N dynamics, plant N use efficiency and ecosystem N balance

Dr Jonathan Holland¹, Dr Dario Fornara¹

¹*AFBI, Belfast, United Kingdom*

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

Chronic nitrogen (N) additions to agricultural soils may have multiple detrimental effects on soil ecosystem functioning. There is urgent need to better understand how soils, plants and the N balance of managed ecosystems might respond to long-term N fertilization either in inorganic or organic forms. Here we focus on N fertilization of agricultural grasslands, which are crucial to support livestock-based production systems across the UK. We use data from a long-term grassland experiment established in 1970 in Northern Ireland where N has been added across eight different fertilization treatments including: (1) control (no N added), (2) inorganic fertiliser (NPK: 200 kg N ha⁻¹ year⁻¹), cattle slurry at three application rates (3) 50, (4) 100 and (5) 200 m³ ha⁻¹ year⁻¹, and pig slurry at the same three application rates (6) 50, (7) 100 and (8) 200 m³ ha⁻¹ year⁻¹. We use data from this long-term experiment to show how the treatments have affected (1) soil N dynamics, (2) plant nutritional status (ratios and indices) and (3) ecosystem N balance (net N changes based on inputs, outputs and N retention in soils). We provide evidence of how slurry type and application rate affect soil N stocks over time. Greater N applications decreased both the N use efficiency (NUE) and the physiological efficiency (PEN) of applied N. These findings confirm that high N applications are clearly associated with higher risks of N loss. This study fills nutrient balance knowledge gaps associated with intensively managed temperate grasslands.

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Simulating nitrogen loss due to ammonia volatilisation after urea fertiliser application in APSIM

Dr. Yunru Chloe Lai^{1,2}, Dr. Jonathan Ojeda³, Asso. Prof. Keith Pembleton^{1,2}

¹*Centre for Sustainable Agricultural Systems, Institute for Life Sciences and the Environment, University of Southern Queensland, Toowoomba, Australia*, ²*Cooperative Research Centre for High Performance Soils, Callaghan, Australia*, ³*Regrow Ag, Brisbane, Australia*

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

Excess nitrogen (N) use in agriculture has greatly disturbed N cycling exceeding its planetary boundary with serious sustainability implications. Systems modelling allows the integration of interactions between daily moisture, energy and processes of N cycling to better understand N dynamics in diverse farming systems to improve N use efficiency. However, the most widely used agricultural systems model in Australia, the Agricultural Production Systems sIMulator (APSIM), only assesses nitrate leaching and denitrification losses. Ammonia (NH₃) volatilisation is a key pathway for N loss in agricultural systems. This study implemented two methods to estimate likely N loss due to NH₃ volatilisation after urea application in APSIM Next Generation and assessed their reliabilities in dryland cereal cropping and pasture systems using published datasets from diverse locations in Australia. The methods allowed the prediction of N volatilised from topsoil N pools using easy-to-obtain parameters based on whether the field is cropped, in fallow or under pasture, and whether detailed climate data (e.g., wind speed) is available. Cross validation showed that the methods have moderate predictive accuracy at a daily time step compatible with the certainty of the model inputs and the scale of model application, allowing flexibility for users to choose the appropriate method based on data availability. The inclusion of NH₃ volatilisation pathway is useful for the realistic representation and analysis of N dynamics to enable effective N fertilisation to achieve sustainable outcomes.

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Characterising the variation in UK background emissions of nitrous oxide

Dr Kairsty Topp¹, Prof Robert Rees¹, Dr Kate Smith², DR Rachel Thorman²

¹SRUC, Edinburgh, United Kingdom, ²ADAS, Boxworth, United Kingdom

16 Division 2: Nitrogen cycling and soil health, Forth, August 1, 2022, 15:00 - 17:00

In agricultural systems, understanding the variation in background emissions (BNE) of nitrous oxide (N₂O) is critical as it is used to derive the emission factors that are used in the national reporting of greenhouse gas emissions. These BNE have been observed in experiments using static chambers where measurements have been made in the absence of nitrogen additions alongside those where nitrogen has been applied. The timing and the intensity of the measurement campaign may influence the absolute BNE. However, the BNE also reflect the previous cropping and fertiliser management strategies. Recent global analyses reported in the literature have indicated a link between land use and emissions that could be associated with differences in site and soil properties. A UK wide database of recent experiments (including the UK's Agricultural and Environmental Data Archive <http://www.environmentdata.org/>) has been used to explore the variation and potential drivers of BNE. The mean BNE from UK soils was below the IPCC default of 1.0 kg N₂O-N ha⁻¹ yr⁻¹, and BNE from arable soils was c.2.5 times higher than that of grasslands. However, the results indicated that the timing the measurements were taken was influential. The BNE for arable soils measured alongside autumn manure applications was higher than from grassland suggesting that autumn incorporation of arable soils contributed to the arable BNE. The regression analysis indicated that annual precipitation was a key driver of BNE from arable soils, whereas for grasslands the interaction of soil clay content and precipitation, and soil bulk density were key drivers.

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High mountain soils in the Andes of Central Chile

Mr Marco Pfeiffer¹, Ms. Valentina Cárdenas¹, Dr. Oscar Seguel¹, Mr. Jimmy Cordero¹

¹*Departamento de Ingeniería y Suelos, Facultad de Ciencias Agronómicas, Universidad de Chile, Santiago, Chile*

27 WG1.01: Progress in understanding cryogenic soils at the ends of the Earth: mountainous, polar and periglacial regions, Alsh 1, August 1, 2022, 15:00 - 17:00

The western flank of the Andes at Central Chile is of particular interest as their high summits embrace a thin strip of land containing one of the worlds few Mediterranean climates. This area is located between the Atacama Desert toward the north and the evergreen temperate forest toward the south, all considered to be one of the worlds 25 hotspot to conserve biodiversity. Accordingly, flora, geology and geomorphology of this area have being largely studied. However, soils of the Andes are largely unknown, in contrast to the well-studied fertile soils of the Central Depression. In this study we analyze eleven soil profiles located between the lower andean belt (2500-3500 masl), the upper Andean belt (3500-3700 masl) and the nival/desert belt (>3700 masl). Results show a high variability in soil properties and soil types in short distances. Soil properties along the altitudinal gradient show different drivers influencing pedogenic processes, at the lower Andean belt organisms and weathering have a primary role in developing Mollic, Cambic and Histic horizons. The upper belt shows intensive leaching processes that stand out in the presence of argillic horizons. Above, in the unvegetated zone, soils are dominated by cryogenic processes generating features like ice wedges, sorted polygons, venticular and granular structure, as well as aeolian processes generating dessert pavement and vesicular horizons. This work indicates the existence of well-developed soils in areas believed to be primarily covered by rocks, providing valuable information about soil properties and processes in a region hitherto unknown to soil science.

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The Global Maps of the Global Soil Partnership: from bottom to top

Prof. Rosa M Poch¹, **Dr Natalia Rodriguez Eugenio**

¹*Intergovernmental Technical Panel on Soils - Global Soil Partnership (FAO)*

30 WG1.04: Global soil map; main advances and ways forward, Alsh 2, August 1, 2022, 15:00 - 17:00

In a world where visualization of scenarios is important, soil maps are essential tools for decision making. The FAO/GSP facilitates a participatory process involving member countries in the generation of global soil maps. In 2017 the GSOCmap was launched based on the SOC cookbook prepared by the ITPS and GSP. Various mapping methods were used by the countries, among them conventional upscaling, machine learning, ensemble models combining different DSM approaches and geostatistical methods. A 66% of the countries used digital soil mapping techniques, which demonstrates the overall success of the capacity building program undertaken by the FAO/GSP, and only 7% of the countries used conventional upscaling. The map produced forms a continuous surface of SOC distribution with acceptable differences around country borders. A similar approach was followed for the Global soil organic carbon sequestration potential (GSOCseq) and soil salinity map (GSASmap). The GSOCseq is being generated by modelling the potential of soils to sequester carbon under four management scenarios 20 years in the future. It is the first attempt to provide data to set attainable targets on soil carbon sequestration. The GSASmap was launched in October 2021. The work on salt-affected soils so far shows that information on soil salinity is scanty in most countries. This map has served to update country level maps while at the same time contributing to provide a basis for monitoring salt affected soils in the frame of future challenges, such as global climate change.

Recent steps in the DSM related development of the Hungarian Soil Spatial Data Infrastructure

Dr. László Pásztor¹, Dr. Gábor Szatmári¹, Dr. Annamária Laborczi¹, Dr. János Mészáros¹, Dr. Katalin Takács¹, Dr. Mátyás Árvai¹, Tünde Takáts¹, Zsófia Kovács¹, Dr. Sándor Koós¹, Dr. Brigitta Szabó¹
¹*Institute for Soil Sciences, Centre for Agricultural Research, Budapest, Hungary*

30 WG1.04: Global soil map; main advances and ways forward, Alsh 2, August 1, 2022, 15:00 - 17:00

Hungarian Soil Spatial Data Infrastructure has been recently renewed in the frame of DOSoReMI.hu initiative. Soil property, soil type and functional soil maps were compiled. The set of the applied digital soil mapping techniques has been gradually broadened incorporating and eventually integrating geostatistical, machine learning and GIS tools and very recently spatially non-exhaustive ancillary observations, which has been also hypothesized to be successfully utilizable within DSM framework. (i) Vast, digitally processed legacy soil data, (ii) a spectrum library compiled by the measurements of 6600 soil samples with countrywide origin, (iii) and the results of a nationwide citizen science campaign targeted to collect proxy data on soil health were involved. Soil property maps have been compiled partly according to international specifications (GlobalSoilMap.net, GSOC, GSASmap), partly to fulfill specific demands on the final products. Secondary (derived) soil features were also predicted. (i) Soil hydraulic properties were mapped applying generalized pedotransfer functions; (ii) spatial assessment of certain provisioning and regulating soil functions was carried out by the involvement of soil property maps in digital process/crop models. The nationwide, thematic digital soil maps compiled in the frame and spin-off of our research is utilized in a number of ways, for the support of national activities (LDN, SDGs, ESS assessment). A new soil portal was also elaborated for publishing of the created DSM products together with the result of their accuracy assesment.

Our paper will present

- (i) the new approaches for the population and extension of DOSoReMI.hu, and
- (ii) various national functional applications of DOSoReMI.hu.

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Multi-scale Soil Property Mapping with Conventional Soil Survey Data for the Continental U.S.

Dr. COLBY BRUNGARD¹, Suzann Kienast-Brown, Travis Nauman, David White, Stephen Roecker, Dylan Beaudette, Jessica philippe, James Thompson, Zamir Libahova, Alex Stum, Claire Simpson, Chad Ferguson, Rob Vaughn

¹*New Mexico State University, Las Cruces, United States*

30 WG1.04: Global soil map; main advances and ways forward, Alsh 2, August 1, 2022, 15:00 - 17:00

Soils are our most critical natural resource. However, urgent environmental issues are forcing us to seek answers to questions using incomplete data and/or inappropriate information. Soil property maps are integral for supporting effective land management decisions. The U.S. National Cooperative Soil Survey – Digital Soil Mapping Focus Team is applying the latest methods to produce continuous soil properties predictions and estimates of uncertainty for the continental USA. A novel weighting scheme was applied to legacy data from the Kellogg Soil Survey Laboratory and Rapid Carbon Assessment laboratory measurement data, as well as field-estimated measurement data from the US National Soil Information System database to develop a training dataset. Predictions at 100m spatial resolution for 12 key soil properties at six depths were produced using machine learning with accuracy estimated from spatial cross-validation and uncertainty estimated using relative prediction intervals. This workflow was expanded to 30m property predictions through the inclusion of additional multi-scale terrain derivatives and observations from the US Forest Service National Resource Management database. Interpretations for soil use and management will be derived from the resulting products. This effort yielded a framework for delivery of seamless raster-based soils data for all areas of the U.S. on yearly cycles. This framework will foster an environment of continuous improvement and support a complete, consistent, correct, comprehensive, and current inventory of the soil resources of the U.S.

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Global mapping of complex soil properties

Dr Laura Poggio¹, Dr Bas Kempen¹, Maria-Eliza Turek¹, Dr Niels H. Batjes¹, Giulio Genova¹, Dr Luis de Sousa¹, Dr David Rossiter¹, Prof Dr Gerard Heuvelink¹

¹ISRIC - World Soil Information, Wageningen, The Netherlands

30 WG1.04: Global soil map; main advances and ways forward, Alsh 2, August 1, 2022, 15:00 - 17:00

Addressing many of the sustainable development goals would be greatly aided by the provision of directly relevant soil information at different scales. Digital Soil Mapping (DSM) is an established methodology to create maps of soil properties at different resolutions and extents. Many DSM projects across the globe have provided information on primary soil properties, such as soil textural fractions, soil carbon content, cation exchange capacity and soil reaction. DSM can also be used to map complex soil properties, i.e., properties that can not be measured directly in the laboratory but are derived from primary soil properties by pedotransfer functions, e.g., available water capacity, soil carbon density and stocks, and erodibility. There are two approaches to map such properties: 1) “model first, interpolate later”, where the complex property is calculated at point observations and then mapped; and 2) “interpolate first, model later”, where the complex property is calculated from maps of the primary properties contributing to it.

We present and discuss these two approaches for global applications using legacy data with a non-uniform and biased spatial distribution of observations and the SoilGrids workflow. We compare the results for available water capacity of the 0 to 100 cm depth interval and soil carbon densities for six depth layers. There are substantial differences in both point-wise evaluation metrics and in landscape patterns.

IndianSoilGrids project- Advances, Challenges and way forward

Dr S Dharumarajan¹, Dr M Lalitha¹, Dr R Vasundhara¹, Dr B Kalaiselvi¹, Dr Rajendra Hegde¹, Dr BS Dwivedi²

¹ICAR-National Bureau of Soil Survey and Land Use Planning, Bangalore, India, ²ICAR-National Bureau of Soil Survey and Land Use Planning, Nagpur, India

30 WG1.04: Global soil map; main advances and ways forward, Alsh 2, August 1, 2022, 15:00 - 17:00

IndianSoilGrids project aimed to map key GlobalSoilMap properties of India which are essential to assess the soil security onto a three-dimensional grid at fine spatial resolution with local uncertainty estimates. The project is organised following a bottom-up approach involving a task force of soil scientists trained in DSM techniques. The soil database developed during soil resource mapping project (1:250 000 scale), reconnaissance survey (1:50 000 scale) and detailed soil survey (1:10 000 scale) was used as soil input data for DSM models. Standard terrain covariates, satellite imageries and global climate model outputs were used for mapping of different soil properties. Different machine learning algorithms were tested to map the soil properties of South Indian states like Karnataka (191,791 Km²), Tamil Nadu (130 058 Km²), Andhra Pradesh (160 205 Km²) and Kerala (38, 863 Km²). Random forest and regression kriging algorithm were yielded better results compared to other models. Most important GlobalSoilMap outputs were soil depth (R²=30-42%), soil organic carbon stock (R²=7-43%), soil hydraulic properties (R²=24-39%), soil pH (R²=15-42%), cation exchange capacity (R²=5-56%), particle size fractions (sand R²=41-48%, silt R²=29-52%, clay R²=18-39%), coarse fragments (R²=21%) and bulk density (R²=1-36%). These predicted soil database could aid the policy makers to take timely decisions for soil resource management, revert the land degradation process and to preserve soil quality by executing suitable land use policies. The main challenges like collection of legacy datasets and inter/intra institute sharing of data are need to be addressed in the future for implementing the project at national level.

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Farmers characteristics, indigenous knowledge and soil management practices influenced carbon stock and emissions in contrasting agroecological zones of Ghana

Dr Christian Adler Phares¹, Dr Emmanuel Amoakwah², Miss Lucy Richlove Beyaw³

¹*Department of Soil Science, University of Cape Coast, Ghana, Cape Coast, Ghana,* ²*Soil Research Institute, CSIR, Kumasi, Ghana,* ³*Department of Molecular Biology and Biotechnology, University of Cape Coast, Cape Coast, Ghana*

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Attempts to improve farmer's practice to mitigate emissions of carbon is less explored in sub Saharan Africa, particularly Ghana. Our study sought information on farmer and farm characteristics, indigenous knowledge and soil management practices and how they relate to soil carbon stock and emissions. Sample of 300 farmers each were selected from Dry Savannah and Forest agroecological zones of Ghana and interrogated for their knowledge regarding contribution of soil and soil management to climate change, using a researcher assisted questionnaire. Further, 100 farms were monitored across the two zones, over two seasons for four years, to document their soil management practices, and determine carbon stock and emissions in the laboratory. Descriptive and inferential statistics such as mean scores, correlation and regression were used to analyse data. Years of farming, fertilization, fertilizer application method, farm size, tillage, biomass/residue management, education, crop grown, cropping system, access to extension services, location of farm, education on climate change significantly associated with farmer's intention to reduce CO₂ emissions from soil. Mean scores regarding knowledge on how soil management practices relate with climate change mitigation ranged between 2.21 ± 0.40 and 2.91 ± 0.56 on a scale of 5.0. Intra and inter agroecological zone; tillage, fertilization, residue management and farming systems showed significant relationship with carbon stock and emissions. Our study demonstrated inadequate knowledge amongst farmers about how soil management practices influence climate change mitigation. This reflected in farmers' pro-poor field practices in improving soil carbon stock and reducing emissions.

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Towards a Science of City-Soil Pedogenesis

Dr. Dan Richter¹, Dr. Anna Wade

¹*Duke University, Durham, USA*

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Soil surveys that map city soils as more than “urban-complexes” deserve strong support as they represent significant frontiers for soil science. A genetic model for city-soil pedology that seamlessly integrates human forcings in soil formation and help us better understand not just urban landscapes but all polygenetic landscapes forced by human action is the classic process model of Simonson. This process model takes soil to be evolutionary, polygenetic products of material and energy inputs, translocations, transformations, and removals. Here, we review soil concentrations of lead, which in rural soils is typically <30 mg/kg, whereas in cities ranges to >10,000 mg/kg due to historic lead-contamination from gasoline, paint, smelters, incinerators, and other sources. While the geo-spatial heterogeneity of urban-soil lead is relatively well characterized, the temporal dynamics of urban-soil lead contamination are not. We hypothesize that during the decades in which gasoline and fresh paint have been lead-free, urban-soil pedogenesis has decreased city-wide lead concentrations in many areas, mainly due to water and wind erosion, anthro- and bioturbations, and burial or removal in cut and fill operations. We assert not only that Simonson’s process model can be applied to urban-soil pedogenesis, but that a science of urban-soil pedogenesis can contribute much to the emerging fields of environmental health and justice, archeology, urban planning, landscape architecture, and urban forestry. Wade, A., Richter, D.D., et al. *Environmental Science and Technology* (2021)

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Finding common ground; developing a shared understanding of tropical peat swamp forest fires and restoration across disciplines and cultures

Dr Samantha Grover¹, Dr Andrea Rawluk²

¹RMIT University, Melbourne, Australia, ²The University of Melbourne, Parkville, Australia

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Tropical peat soils comprise 1/3 of peat soils globally and emissions of carbon dioxide from drained tropical peats are nationally and internationally significant. Indonesia has made a presidential commitment to restore its degraded peatlands, as its primary contribution to reducing greenhouse gas emissions. Restoration in this context is defined as rewetting, revegetation and the restoration of livelihoods. Soil science knowledge of the physical properties of degraded peat is crucial to the design and implementation of successful rewetting infrastructure. Biological, chemical and physical soil properties of degraded and rewet peat all impact upon the success of revegetation. Revitalisation of livelihoods is dependant upon an end to uncontrolled fires and flooding, which the rewetting aims achieve. However, tropical peatland degradation is a complex social ecological problem, to which multiple stakeholders bring differing, often unstated, values and priorities. This paper presents an interdisciplinary collaboration co-led by a soil scientist and an environmental sociologist, in which adaptive doing was applied to co-create a new shared understanding of the problem of tropical peatland fires and restoration, in collaboration with Indigenous and non-Indigenous Indonesian and Australian researchers from the disciplines of soil science, forest science, economics, policy and social science. The impact of this new shared understanding was a change in research practice and project direction. Adaptive doing can help soil scientists to link technical knowledge with sustainable land management, policy and practice change, as well as decolonise research and engage Indigenous and non-Indigenous local communities.

not applicable

Using data mining techniques to model citizen scientist collected data on litter decomposition in Austrian urban school soils

Dr. Taru Sandén¹, Dr Anna Wawra¹, Helene Berthold¹, Julia Miloczki¹, Dr. Agnes Schweinzer², Dr. Brigitte Gschmeidler³, PD Dr. Heide Spiegel¹, Prof Marko Debeljak^{4,5}, Prof Aneta Trajanov^{4,6}

¹Austrian Agency for Health and Food Safety (AGES), Vienna, Austria, ²InfoXgen Inputs Evaluation, EASY-CERT Services GmbH, Enzersfeld, Austria, ³Open Science–Life Sciences in Dialogue, Vienna BioCenter, Vienna, Austria, ⁴Department of Knowledge Technologies, Jozef Stefan Institute, Ljubljana, Slovenia, ⁵Jozef Stefan International Postgraduate School, Ljubljana, Slovenia, ⁶Faculty of Management and Engineering, University of Nova Gorica, Slovenia

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Litter decomposition plays a pivotal role in the global carbon cycle, but is difficult to measure on a global scale, especially by citizen scientists. In our study, citizen scientists, i.e. school students with their teachers, used the globally applied and standardized Tea Bag Index (TBI) method to collect data on litter decomposition in urban areas in Austria. They also sampled soils to investigate the linkages between litter decomposition and soil attributes. For this study, 54 sites were selected from the school experiments and assembled into a TBI dataset comprising litter decomposition rates (k), stabilization factors (S), as well as soil and environmental attributes. An extensive pre-processing procedure was applied to the dataset, including attribute selection and discretization of the decomposition rates and stabilization factors into three categories each. We generated predictive models (classification trees) that identified the soil attributes governing litter decomposition rates (k) and stabilization factors (S). The main governing factor for both k and S was the sand content of the soils. The data mining models achieved an accuracy of 54.0% and 66.7% for k and S, respectively. The data mining results enhance our knowledge about the driving factors of litter decomposition in urban soils, which are underrepresented in soil monitoring schemes. This approach may also encourage further participatory researcher-teacher-student interactions, helping to create an enabling environment for citizen science research in urban school settings.

Keuskamp, J. A., Dingemans, B. J. J., Lehtinen, T., Sarneel, J. M., & Hefting, M. M. (2013). Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. *Methods in Ecology and Evolution*, 4(11), 1070-1075. doi:10.1111/2041-210X.12097

Sandén, T., Wawra, A., Berthold, H., Miloczki, J., Schweinzer, A., Gschmeidler, B., . . . Trajanov, A. (2021). TeaTime4Schools: Using Data Mining Techniques to Model Litter Decomposition in Austrian Urban School Soils. *Frontiers in Ecology and Evolution*, 9(432). doi:10.3389/fevo.2021.703794

Metaphors about soil. An interdisciplinary investigation to reveal biases and foster action for soil preservation.

Dr Abigaïl Fallot¹, **Ms Antonia Taddei²**

¹CIRAD, Montpellier, France, ²Xtnt, Paris, France

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Soil plays a vital role for climate change and is being studied within several disciplines.

Unfortunately, there is little spillover effect of these studies on actual soil conservation (Rumpel et al., 2020).

Many metaphors about soil are found in scientists' speeches and writings. Though metaphors are not neutral (Taylor & Dewsbury, 2018), the diversity of their use has remained undocumented and their consequences on recommendations from science to action and policy is overlooked.

Our investigations helped us identify four groups of metaphors in the scientific literature on soils or in its communication:

- Soil as an heritage to be protected and passed on, a bank account or an historical monument;
- Soil as a living and reactive body or as body organs, whose health must be taken care of;
- Soil as communities engaged in multiple interactions with quite unknown emergent properties; and,
- An heterogeneous group: a battery, a sponge...

We found that despite their potential explanatory power, metaphors are often mentioned with little analysis of their implication.

We have developed two ways to further explore metaphors:

- Through a series of interviews with soil scientists, we have helped them complete their suggested images, revealed certain biases and helped to correct them; and,
- Through two interdisciplinary workshops with soil scientists - one on soil health (Janzen et al., 2021) with human health experts; the other on soil as an historic monument (Chenu, 2016) with law experts – we have helped them generate concrete propositions for soil conservation.

Chenu, C. (2016). Le sol est-il considéré comme une ressource renouvelable ? [L'esprit sorcier].

<https://www.lespritsorcier.org/dossier-semaine/sol-et-climat/> .

Janzen, H. H., Janzen, D. W., & Gregorich, E. G. (2021). The 'soil health' metaphor: Illuminating or illusory? *Soil Biology and Biochemistry*, 159, 108167.

Rumpel, C., Lehmann, J., & Chabbi, A. (2018). '4 per 1,000' initiative will boost soil carbon for climate and food security. *Nature*, 553(7686), 27-28.

Taylor, C., & Dewsbury, B. M. (2018). On the problem and promise of metaphor use in science and science communication. *Journal of microbiology & biology education*, 19(1), 19-1.

Transdisciplinary research: assemblages of disciplines meet assemblages of microorganisms

Mr Matthew Tarnowski¹, Miss. Emily Phelps¹, Dr. Jim Scown³, Dr. Gilda Varliero¹, Dr. Thomas Goroehowski^{1,2}

¹*School of Biological Sciences, University of Bristol, Bristol, United Kingdom*, ²*BrisSynBio, University of Bristol, Bristol, United Kingdom*, ³*School of English, Communication and Philosophy, University of Cardiff, Cardiff, UK*

Inter-divisional 3: Interdisciplinary soil science for impact, M1, August 1, 2022, 17:30 - 19:30

Knowledge is often trapped within academic disciplines. By connecting distant disciplinary approaches, shared holistic knowledges can arise where the whole is greater than the parts. Here we show that transdisciplinary research between environmental history, microbial ecology, synthetic biology and the school curriculum allows co-creation of datasets and interpretations which transcend disciplinary dogmas. DNA sequencing was used to characterise bacterial microbiomes across six sites, revealing the diversity-reducing impact of human-centric land management practices and diversity-boosting ecotones where ecosystems meet. Situated transdisciplinary research elucidated the non-objectivity of datasets and the connectedness of human and non-human microbiomes. Understanding microbiomes as open ecologies and assemblages arising from human and non-human actions beckons approaches of land stewardship rather than land management and biorespecting rather than bioprospecting.

Kreisel, D., Griffiths, D., (2020) Open Ecologies: Introduction, *Victorian Literature and Culture*.
<https://doi.org/10.1017/S1060150319000470>.

Sekurova, O. N., Schneider, O. and Zotchev, S. B., (2019) Novel bioactive natural products from bacteria via bioprospecting, genome mining and metabolic engineering, *Microbial Biotechnology*.
<http://doi.org/10.1111/1751-7915.13398>.

Multi-scale terrain feature construction and machine learning for the spatial interpretation of soil organic carbon stocks in West Greenland

M.Sc. Philipp Gries^{1,2}, **Prof Thomas Scholten**^{1,2}, Dr Peter Kühn^{1,2}, Dr Thorsten Behrens¹, **Dr Karsten Schmidt**^{1,2,3}

¹*Department of Geosciences, Chair of Soil Science and Geomorphology, University of Tübingen, Tübingen, Germany,*
²*SFB 1070 ResourceCultures, University of Tübingen, Tübingen, Germany,* ³*eScience-Center, University of Tübingen, Tübingen, Germany*

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:
 Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

Soils of the northern circumpolar region are a key organic carbon storage strained by global warming. Thawing of permafrost-affected soils increases greenhouse-gas emissions whose quantification is limited by sparse, uncertain and spatially diverse soil organic carbon stocks (SOCS) data across this region. The spatial distribution of SOCS results from interactions and feedbacks of environmental factors and processes varying across scales. Recent developments in machine learning allow to entangle effects of multiple scales in soil data using contextual feature construction techniques.

The objective of this study is to identify dominant spatial scales and process interactions relevant to the spatial interpretation of SOCS in periglacial landscapes of Arctic low mountains using contextual spatial modelling. This study includes SOCS data from 140 sampling locations from two study areas (coast and ice margin) in West Greenland and a set of multi-scale terrain features reflecting soil forming factors and relocation processes. Random forest models were applied to account for scale-dependent effects within the data set.

Variation in model accuracy across different scales shows that the distribution of SOCS in both study areas is scale-dependent. Aspect and curvature are key terrain features to interpret the distribution of SOCS. On a small scale, both represent the heterogeneous periglacial landscape with different site conditions (microclimate) and relocation processes (solifluction), both of which influence SOCS. On a large scale, the aspect reflects the effects of different climatic conditions on SOCS, such as dry katabatic winds at the ice margin and moist onshore winds at the coast.

Gries, P., Schmidt, K., Scholten & T., Kühn, P. (2020). Regional and local scale variations in soil organic carbon stocks in West Greenland. *Journal of Plant Nutrition and Soil Science*, 183(3), 292–305. doi: 10.1002/jpln.201900390

Behrens, T., Schmidt, K., MacMillan, R.A. & Viscarra Rossel, R.A. (2017). Multiscale contextual spatial modelling with the Gaussian scale space. *Geoderma* (310), 128–137. doi: 10.1016/j.geoderma.2017.09.015

Kühn, P. & Henkner, J. (2019). Permafrost-affected Soils, Climate, and Feedbacks in West Greenland. Lal, R. & Stewart, B.A. (Eds.). *Soil and Climate. Advances in Soil Science* (pp. 92–97). CRC Press. ISBN: 978-1498783651

Bridging the gap with SNAp? Combining localized soil sampling with network analysis to tackle elemental migration through the soilscape 14

Dr. Christoph Weihrauch¹, Collin J Weber², Dr. Christian von Sperber³

¹University Of Wuppertal, Wuppertal, Germany, ²Philipps-University Marburg, Marburg, Germany, ³McGill University, Montreal, Canada

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

Elements migrate vertically through soil profiles, but also laterally through the soilscape. This can result in spatial patterns of element distribution across the landscape that influence vegetation patterns and environmental quality. However, studying the migration of elements through the soilscape is methodologically difficult. Often, we have to rely on localized soil samples that do not represent the continuous soilscape and are not temporally resolved. With such a database, spatial dynamics such as migration are difficult to investigate under field conditions. Therefore, we are often unable to identify distribution patterns of elements at the soilscape level and their potentially harmful effects. This is of particular interest for soils at the land-water interface, whose elemental contents can contribute to pollution of aquatic ecosystems. For example, it has recently been shown that “deep phosphorus stocks” in floodplain soils can influence nutrient concentrations of adjacent freshwaters and promote eutrophication and algal blooms. Improved knowledge of the build-up of such deep phosphorus stocks could provide valuable impetus for water quality protection and sustainable land management. In this talk, I propose the Soilscape Network Approach (SNAp) as a novel analytical tool to translate conventional geospatial soil data into relational network data. Using a case study of deep phosphorus stocks in German floodplain soils as an example, I show how SNAp can help us explore the migration of elements through the soilscape, opening new perspectives for the analysis of geospatial soil data.

Weihrauch, C., Weber, C.J. & von Sperber, C. (2021): A Soilscape Network Approach (SNAp) to investigate subsurface phosphorus translocation along slopes. *Science of the Total Environment* 784:147131.

Large scale survey of anthropogenic soil landscapes in New England, USA, using state-of-the-art machine learning techniques (Yolov4)

M.sc. Alexander Bonhage¹, Wouter Verschoof-van der Vaart², Prof. Thomas Raab¹, Prof. William Ouimet³, Dr. Anna Schneider¹, Alexandra Raab¹

¹BTU-Cottbus-Senftenberg Geopedology, Germany, ²Leiden University Archaeological Sciences, Netherlands, ³University of Connecticut Geography, United States of America

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

The use of automated mapping approaches, based on machine learning Convolutional Neural Networks (CNNs), in combination with high resolution airborne LiDAR digital elevation models (DEMs) has led to an interdisciplinary surge in publications in the domains of archaeology, geoarchaeology and geopedology. State-of-the-art object detectors are used to detect geomorphological features on DEMs commonly associated with historic anthropogenic activities e.g., burial mounds and charcoal production sites. In this study we present the results of a large-scale mapping of Relict Charcoal Hearths (RCHs, sometimes referred to as charcoal kilns) spanning different regions in New England (USA) using a modified YOLOv4 object detector. RCH sites are circular or slightly elliptical shaped micro relief structures with average diameters of about 11 meters. As part of the research, we have optimized the output bounding boxes of YOLOv4 to allow for the determination of the area covered by RCHs. Furthermore, we have included a GIS-based post-processing step to detect the site-specific local slope. This geometrical information enables the calculation of specific RCH site volumes and thereby soil element stocks. In a GIS-based geospatial analysis the RCH site distribution and site densities in relation to topographic landscape units and other potential controlling factors is determined. We present a comprehensive assessment of the often discussed legacy effect of historic charcoal production on today's soil properties on a regional and landscape scale.

Bonhage, A., et al. (2020). "Characteristics of small anthropogenic landforms resulting from historical charcoal production in western Connecticut, USA." *Catena* 195.

Bonhage, A. (2021). "A modified Mask region-based convolutional neural network approach for the automated detection of archaeological sites on high-resolution light detection and ranging -derived digital elevation models in the North German Lowland." *Archaeological Prospection*.

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Quantitative uses of soil color for the development and presentation of soil survey data in the United States

Dr Dylan Beaudette¹, Mr Charles Ferguson¹

¹USDA-NRCS, Lincoln, USA

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

The color of soil is one of the few things in nature that is arguably of equal interest to both scientists and children at play. Soil scientists and surveyors appreciate the wealth of information that is typically related to soil color variation in depth and space. Soil color supports a practical, qualitative scaffolding for our understanding of a landscape's recent and long-term history, clues about dominant mineralogy, a striking picture of where organic matter has accumulated, and many other factors that affect our use and understanding of the soil resource. The Munsell system provides soil scientists and other technical users of soils data a convenient system of communication. Given the right context, a depiction of soil color and its interpretation can effectively communicate: "what types of soils are where, and why?"

We describe four ways the National Cooperative Soil Survey is advancing the use of soil color. First, soil color maps (several depths) were created from our best available soil survey data and Official Soil Series Descriptions. Second, new standards are being drafted to include the use of perceptually based color difference metrics [1] as the primary vehicle for color comparisons between samples and among field staff. Third, we will demonstrate several new graphical methods to develop and present a "range in characteristics" for soil color, as grouped by soil series. Fourth, a searchable soil color database was constructed from the 26,000 Official Soil Series Descriptions and pair-wise distances evaluated between profiles using the CIE 2000 color difference metric.

Sharma, Gaurav; Wu, Wencheng; Dalal, Edul N. (2005). "The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations". *Color Research & Application*. Wiley Interscience. 30 (1): 21–30. doi:10.1002/col.20070.

Effect of animal bioturbation on chemical and physical soil properties and sediment redistribution across climate gradients

Ms Paulina Grigusova¹, Diana Kraus¹, Annegret Larsen², Sabrina Köhler¹, Jadzia Witt¹, Roland Brandl¹, Kirstin Übernickel³, Nina Farwig¹, Jörg Bendix¹

¹Philipps University Marburg, Marburg, Germany, ²Wageningen University and Research, Wageningen, The Netherlands, ³Eberhard Karls University Tübingen, Tübingen, Germany

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

Bioturbation has been shown to affect soil properties, hydrology and nutrient cycling. Despite this, previous research was to date limited to case studies concentrating on single species. However, a broad study showing the influence of burrowing animals on soil properties and sediment redistribution along several climate zones on a broader catchment scale is missing.

In our study, we identified the influence of animal bioturbation on vertical and lateral sediment fluxes across climate gradient in Chile. For this, we measured the locations of mounds created by bioturbators along the gradient and upscaled them to the catchment using satellite data. Then, we implemented the mound distribution into a soil erosion model and compared the volume of redistributed sediment in areas with and without mounds. Additionally, we compared C, N, P, soil texture and water content of soil samples from mounds and from not affected control soil and upscaled the nutrient cycles to the catchment.

The soil erosion modelling showed that the volume of laterally redistributed sediment in all catchments, but was most pronounced in the mediterranean climate zone and was related to the occurrence of extreme weather events in the arid climate zone. The soil sample analysis showed that bioturbation leads to an increase in C, N and P when compared to the control sites. Clay and sand content was higher within mounds while silt content was lower compared to unaffected soil.

Grigusova, P.; Larsen, A.; Achilles, S.; Klug, A.; Fischer, R.; Kraus, D.; Übernickel, K.; Paulino, L.; Pliscoff, P.; Brandl, R.; Farwig, N.; Bendix, J. Area-Wide Prediction of Vertebrate and Invertebrate Hole Density and Depth across a Climate Gradient in Chile Based on UAV and Machine Learning. *Drones* 2021, 5, 86. <https://doi.org/10.3390/drones5030086>

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Soils as a key factor for recovery of forest patches after disturbance in the central Mongolian forest-steppe

Prof. Dr. Daniela Sauer¹, Dr. Florian Schneider¹, Dr. Michael Klinge¹, Jannik Brodthuhn¹

¹*University of Göttingen, Göttingen, Germany*

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

In the central Mongolian forest-steppe, forest patches are clearly restricted to north-facing slopes, as water limitation does not allow for tree growth on south-facing slopes and in plains. However, regrowth of trees after disturbance of forest patches (e.g., by fire or logging) does not proceed equally everywhere, even when comparing only north-facing slopes. This observation led us to the question about the reasons for the observed differences. We hypothesized that soil properties might be a key factor for forest regrowth after disturbance in this sensitive ecotone. We described and sampled 57 soil profiles on north-facing slopes, including sites (i) under forest, (ii) under steppe, (iii) with succession after disturbance, (iv) without succession after disturbance. In the field, we carried out measurements of water conductivity, using a compact constant head permeameter. In the laboratory, we analyzed particle size distribution and nutrient stocks, and measured k_f and pF curves.

The soils generally had sandy texture, whereby soils with forest regrowth were slightly loamier than those without regrowth. Apparently, already slightly loamier texture may make the decisive difference for water storage during dry periods and thus for forest regrowth. Differences in nutrient supply could be ruled out, because nutrient stocks were low at all sites and did not significantly differ between sites. Our results underline the crucial role of water availability for forest regrowth after disturbance in central Mongolia, and the importance of soil hydrology for water availability in dry periods, which may be decisive for whether or not forest patches can recover.

Schneider F, Klinge M, Brodthuhn J, Peplau T, Sauer D, 2021. Hydrological soil properties control tree regrowth after forest disturbance in the forest steppe of central Mongolia, *SOIL*, 7, 563-584.

Klinge M, Schneider F, Dulamsuren C, Arndt K, Bayarsaikhan U, Sauer D, 2021. Interrelations between relief, vegetation, disturbances, and permafrost in the forest-steppe of central Mongolia. *Earth Surface Processes and Landforms*, 5116.

Comparison of global versus soil-order models for soil properties estimation from Vis-NIR Laboratory spectral data of Northern Karnataka (India)

Dr S Dharumarajan¹, Dr Cécile Gomez², Dr M Lalitha¹, Dr B Kalaiselvi¹, Dr R Vasundhara¹, Dr Rajendra Hegde¹

¹National Bureau of Soil Survey and Land Use Planning, Bangalore, India, ²LISAH, Univ. Montpellier, IRD, INRAE, Institut Agro, Montpellier, France

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

Rapidity of Visible Near Infrared (Vis-NIR) spectroscopic soil properties prediction takes advantage over the cumbersome laboratory estimation specially in the regions where the soil information is scarce. The objectives of this study are to 1) identify the soil properties which can be predicted from Vis-NIR laboratory spectral data over the northern Karnataka plateau and 2) compare a global model (built over the entire database) with soil-order models (built over each specific soil order). Spectral reflectance of 482 soil samples of 139 soil profiles belonging to four soil orders (Alfisols (217), Vertisols (82), Inceptisols (153) and Entisols (31)) were used to predict the soil properties. This work highlighted that 1) only soil properties characterized by a large range of values (e.g., clay) and either spectral response due to physico-chemical responses (e.g., clay) or having correlations to one property (e.g., sand, silt, pH and CEC correlated to clay) were successfully predicted at global scale by global models, 2) prediction performances obtained with global models at local scale differed from those obtained at global scale, depending on the soil properties range at soil-order scale and 3) no recommendation to choose between a global or soil-order model may be given for estimating soil properties at soil-order scale. So this work highlighted the risk to overestimate prediction accuracy at soil-order scale when figures of merit are based on a validation dataset built at global scale and can assist in the building of holistic and updated spectral libraries of vast and diverse soil resources of India.

Gomez, C., Lagacherie, P., & Coulouma, G. (2012). Regional predictions of eight common soil properties and their spatial structures from hyperspectral Vis–NIR data. *Geoderma*, 189–190, 176–185.

Viscarra Rossel, R. A., McGlynnand, R. N. & McBratney, A. B. (2006). Determining the composition of mineral-organic mixes using UV–Vis–NIR diffuse reflectance spectroscopy. *Geoderma*, 137(1), 70–82.

Vasques, G.M., Grunwald, S. & Harris, W.G. (2010). Spectroscopic models of soil organic carbon in Florida, USA. *Journal of Environmental Quality*, 39, 923–934.

Zeng, R., Zhao, Y.-G., Li, D.-C., Wu, D.-W., Wei, C.-L., & Zhang, G.-L. (2016). Selection of “Local” models for prediction of soil organic matter using a regional soil Vis-NIR Spectral Library. *Soil Science*, 181, 13–19.

Zhao, D., Arshad, M., Li, N., & Triantafyllis, J. (2021). Predicting soil physical and chemical properties using vis-NIR in Australian cotton areas. *Catena*, 196, 104938.

Predicting changes over time of local soil organic carbon contents using a regional spectral library

Ms. Hayfa Zayani^{1,2}, Mr. Youssef Fouad¹, Mr. Didier Michot¹, Mrs. Zeineb Kassouk², Mrs. Zohra Lili-Chabaane², Mr. Christian Walter¹

¹SAS, Institut Agro, INRAE, Rennes, France, ²Institut National Agronomique de Tunisie, Université de Carthage, LR 7AGR01 GREEN-TEAM, Tunis, Tunisia

14 Division 1 Commission 1.2: Soil geography: basic science and new technologies:

Chairperson: Professor Thomas Scholten, Lomond Auditorium, August 1, 2022, 17:30 - 19:30

Providing soil spectral information describing soil variation at a global scale is a continuing challenge which induced the development of soil spectral libraries. With the perspective to increase the spatial and temporal sampling density, these libraries involved scales ranging from local to national and even beyond. This has stimulated worldwide research within a community of soil scientists aiming to calibrate spectral models from regional scale soil spectral libraries for the prediction of soil properties at a local scale.

We explore a regional spectral database (RSD) to evaluate its ability to predict soil organic carbon (SOC) content changes over time of the top soil layer (0-25 cm) in the 12 Km² agricultural watershed of Naizin (ORE AgrHys) located in Brittany (Western France). The RSD contains over 1000 spectra of soil samples mainly collected from top soil layer over Brittany. Naizin soil samples were collected during two field campaigns with 5-year interval. A total of 394 samples were collected in 2013 at two depths (0-15 and 15-25cm). In 2018, 222 sampling points out of 2013 points were selected and soil samples were collected at the same both depths. Prediction models were built using partial least squares regression and support vector machine regression in order to better cope the non-linear dependencies between Vis-NIR spectra and SOC contents.

Predicting SOC contents of samples collected, in 2013 and 2018, from the same points allowed us to evaluate the ability of the regional dataset to predict SOC content changes (Δ SOC) by comparing predicted and observed Δ SOC

Viscarra Rossel, R.A., Behrens, T., Ben-dor, E., et al., 2016. A global spectral library to characterize the world's soil. *Earth-Science Rev.* 155, 198-230. <https://doi.org/10.1016/j.earscirev.2016.01.012>
 Gogé, F., Gomez, C., Jolivet, C., Joffre, R., 2014. Which strategy is best to predict soil properties of a local site from a national Vis-NIR database? *Geoderma* 213, 1-9.
<https://doi.org/10.1016/j.geoderma.2013.07.016>

Feminine Psycho-Spiritual-Social Constructs of Nature, Land, Earth, and Soil

Professor Sabine Grunwald¹

¹*University Of Florida, Gainesville, United States*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

Spiritualized feminism is grounded in spiritualized understanding to foster non-violent social transformation and social equality, specifically for oppressed and marginalized women. Despite the historically rich multiplicities of spiritualities and femininities, it is unclear whether spirituality informs the feminine and brings forth social transformation, or vice versa. In this study historic and contemporary psycho-spiritual-social constructs associated with femininities as expressions of soil, land, nature, or Earth were explored. As numerous contemporary cultures are striving to recognize the importance of diversity, inclusivity, and equity for human flourishing there is still ample scientific evidence of genderism and sexism in addition to kyriarchal power structures that have contributed to internalized inequalities and even oppression of femininities. It depends on the cultural context whether feminine refers to a principle, energy, archetype, spiritual power, natural trait (biological sex), identity, orientation, quality, essentialized sacredness, psychological inner feeling, social-construct (e.g., gender or matriarchy), behavior (e.g., nurture, loving, compassionate), healing modality, or polarity (masculine-feminine). Historically, femininities have been expressed cross-culturally through stories, myths, images, poetry, personifications, interpretations, and phenomenological, meditative, or spiritual experiences. In this talk, various feminine ancestral psycho-spiritual-social constructs of nature, land, earth, and soil that are culturally contextualized will be juxtaposed to discern commonalities and differences. Among them are Pachamama as Earth Mother in Andean culture; Demeter in Greek mythology; Machig Labdrön as Tibetan Buddhist yogini and female deity; the Earth Goddess Parvati as a Hindu deity. Psycho-spiritual femininities with emancipatory and social transformative power will be given special attention.

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Outer and Inner Soil

Dr Nikola Patzel¹

¹*Iuss&dbg, Überlingen, Germany*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

When looking at soil, consider what is in front of your eyes and what is behind-the-eyes.

When humans perceive soil and soil data, there is no way to deny that they are living beings who perceive soil. Humans are not machines and there is a mental dimension to such beings; as well as nature as a whole is not a clockwork. The "inner soil" of human consciousness und unconscious psyche is triggered by and clings to the outer soil when we observe it.

The "outer soil" is composed of the physically graspable natural objects, which farmers, natural scientists etc. interact with in their daily work, even though most of nature – think of soil microbiota! – remains unknown and hardly "graspable". A core element of the theory of inner soil presented here is that it is not only subjective, but basically as objective as the outer soil. Just of a different kind of objectivity. Even before maybe considering a fundamental unity of matter and mind, it is not evident that "objectivity" and "subjectivity" can just be attributed to "matter" and "mind", respectively. The objectivity or subjectivity of the inner soil may be experienced and described at different levels.

IUSS book on Cultural Understanding of Soils, Springer Publisher, 2022

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Philosophy and economy of soil science and soil scientists

Dr. Andrei Rozanov¹

¹*Stellenbosch University, Stellenbosch, South Africa*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

History, sociology, and philosophy of soil science are intertwined (Brevik and Hartemink, 2010). Throughout the 20th century soil science was largely developing as a material science following the materialistic study of soils: their composition, evolution and interaction with ecosystems and man. Soil science provided a unique and diverse material to study, while adopting methods and instrumentation from physics, chemistry, geology, and biology.

The epistemological ambition to accurately represent soil is faced by the obvious “measurement problem” associated with observation. In the recent decades the developments in digital soil mapping have offered new alternatives to classical reasoning in soil geography

In the middle of the 20th century soil science made a rather successful attempt to “industrialize” soil science by providing services to agriculture and forestry. However, growth in scientific services was limited by the level of innovation.

Another avenue of recent exploration by soil scientists is in the field of government policy. The ecologists of the 1960s have found ways of influencing government and profiting from it. The natural conservatism and religious persuasions of the public played a role. It took decades of soil degradation studies to create a genuine wide-spread popular concern about the fate of soils. Hence, it became possible to use the issue in the power play: tap the government and private donor funds, and in return assist governments in formulating policies that may boost government popularity. Here the soil science contribution probably remains minor, but in a competition for power in a democratic society, every vote counts.

Brevik, E. C., & Hartemink, A. E. (2010). History, philosophy, and sociology of soil science. *Soils, Plant Growth and Crop Production: Encyclopedia of Life Support Systems*. Oxford, UK: EOLSS Publishers.

PEDO: Citizen Assisted Science-Based Digital Android Application for Omani soils

Mr. Yousuf Al-Rawahy¹, Mr. Abdullah Al-Shibli¹, Ms. Noof Al-Mukhaini¹, Mr. Ashraf Al-Subhi¹, Ms. Maimuna Al-Wahaibi¹, Mr. Ishaq Al-Naabi¹, Mr. Al-Husain Al-Thuhli¹, Ms. Salha Al-Balushi¹, Mr. Ahmed Al-Mayahi¹, **Dr. Said Al-Ismaily¹**

¹*Sultan Qaboos University, Oman*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

Although there is increasing recognition of citizen-assisted science in different disciplines (e.g. social sciences, medicine, environmental sciences, astronomy, etc.) due to its role to narrow the knowledge gap between science and society, its application to soil science is still limited. Therefore, this study introduced the first citizen-science-based mobile app “PEDO” for the Omani soils. The app is designed to stimulate environmental monitoring, data, and knowledge sharing of the Omani soils for joint decision-making, and cooperative planning that can support informed and demand-driven policy responses. Our work incorporates (i) collection of field data via pedological study, (ii) physicochemical analyses of the collected soil samples, (iii) visitation and documentation of soil-related information from selected historical, industrial, and hereditary attractions, (iv) creation and launch of the smartphone android application, and (v) evaluation of users’ perceptions toward the app using a questionnaire. We anticipate unveiling the socio-economical and hereditary values and promoting potential research opportunities of the Omani soils to the national and international scientific communities. Respondents to the questionnaire study (n=70) illustrated wide potential uses of the app by various disciplines (e.g. monitoring, suitability of soil for agriculture/construction, research, etc.). The majority (87%) believe that the app fosters the ecological appreciation of the Omani soils in the mindset of citizens and stimulates environmental monitoring, data, and knowledge sharing of the Omani soils among the users and decision-makers.

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Al-Ismaily, S. S. A. I., & Al-Maktoumi, A. K. (2011). Studying soil catena in arid-zone environment: Case study for soil science students. *Atlas Journal of Science Education*, 1(2), 24-28.

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The history of soil and human health

Professor Margaret Oliver¹, Professor Eric Brevik²

¹*University of Reading, Reading, United Kingdom*, ²*College of Agricultural, Life, and Physical Sciences, Southern Illinois University, Carbondale, IL, United States*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

The history of soil and human health

People have long known that the environment affects their health either directly or indirectly through their food, drinking water and the air they breathe. Several early civilizations referred to relations between the environment and human health; they drew inferences from repeated observations of conditions rather than scientific investigation. Nevertheless, they arrived at some logical conclusions about human health. For example, goitre was prevalent in ancient China, Greece, Egypt and later the Inca state of Peru. It was often treated with seaweed, although people at the time did not know why the treatment was effective. Archaeologists and medical historians have noted poor health from prehistoric tissues and mummies that they have linked to environmental conditions. Rural people have known for centuries that the health of domesticated animals is affected by the water and food ingested, which in turn depend on the soil. The effects of soil in particular on human health depend on trace elements that are either deficient, adequate, or present in toxic amounts, on pollution from 'heavy' metals and organic chemicals, and on soil microorganisms, some of which are beneficial whilst others are pathogenic. Despite early observations, however, most of these effects remained unexplained until the twentieth century, and some still remain so. Scientific study of the role of the soil on animal and human health is little more than 100–200 years old, but the notion that soil has such a role goes back to at least 1400 BC.

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Oliver, M.A., and Gregory, P.J. 2015. Soil, food security and human health. *European Journal of Soil Science* 66: 257–276.

Ethics and law in forensic soil science and forensic geology: developing a global White Paper

Professor Lorna Dawson¹, Prof. Silvia Peppoloni², Prof. Rosa Maria Di Maggio³, Prof. Ruth Morgan⁴, Prof. Jennifer McKinley⁵

¹James Hutton Institute, Aberdeen, UK, ²Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy, ³Geoscienze Forensi Italia, Rome, Italy, ⁴Crime and Forensic Science, UCL, London, UK, ⁵Queens University, Belfast, N Ireland, UK

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

Forensic soil science is an increasingly important discipline, involving the use of soils, minerals, dusts & plants to determine provenance and provide a chronology of an exhibit's ownership, custody/location. Such traces are extremely useful in a forensic context, because of their environmental specificity; their high levels of transferability; their ability to persist on items such as clothing, footwear, tools/vehicles; and their high levels of preservation after long periods of time.

Significant advances over the past decade, including the development of analytical approaches, miniaturisation of analytical tools, and also in understanding the behaviour, transfer, persistence and preservation of sediments, soils and plant material, have widened their applicability for crime reconstruction.

It is evident that forensic geology has a function and utility of extreme importance in social terms, as the results of its analyses inevitably touch ethical aspects of strong impact, both for those who put it into practice and for those who suffer the consequences of its application.

Forensic soil scientists are usually accredited, and should act in a fully professional and ethical manner at all times, from the first call to crime scene to the presentation of evidence in court. A White Paper on ethical and social implications of forensic geology has been developed; a document that provides an orienting framework of reference values able to guide forensic soil scientists/geologists in conducting their activity. This paper will discuss ways in which we can further promote good ethical practice across the world and for generations of future forensic soil scientists.

Dawson, LA et al., 2020. A proposal for a White Paper on Geoethics in Forensic Geology. Geological Society, London, Special Publications(2021),508(1):115. <http://dx.doi.org/10.1144/SP508-2020-80>

Soilkin: Relational exercises with soil and stones

(Jun.) Prof. Dr. Alex R. Toland¹

¹*Bauhaus Universität Weimar, Weimar, Germany*

24 Division 4 Commission 4.5: History, philosophy and sociology of soil science, Forth, August 1, 2022, 17:30 - 19:30

In the essay *About a Stone: Some Notes on Geologic Conviviality*, Hugo Reinert (2016) poses the question: “What modes of passionate immersion – or love could a stone afford?” Drawing on ideas from multispecies ethnography and the history and philosophy of soil science, this paper responds to Reinert’s research in the far north by tracing the journey of kindred stones from Sámi lands in Norway to the end moraine landscape and sandy soils of the Biosphere Reservation Schorfheide-Chorin, located north of Berlin. The project proposes a series of relational, performative exercises that reflect on the individual and collective agency of mineral and more-than mineral intimacies and the boundaries of what it means to be alive. The paper is structured around three basic propositions: 1) a non-normative understanding of soil subjectivity could lead to kinship – soil kinship – with appreciable social and phenomenological qualities that expand current human-soil relationships; 2) soil formation (pedogenesis) can be interpreted as a process of learning and becoming rather than simply weathering and ageing; and 3) soil agency is situated within a framework of resistance and consent, demanding the terms of kinship between humans and soils be mutually beneficial and appropriate to the slowed-down timescale in which soil beings live and operate. The paper integrates theoretical provocations with performative scores, situating the project at the interface between soil science, environmental humanities, and artistic research. Certini, G., & Ugolini, F. C. (2013). An updated, expanded, universal definition of soil. *Geoderma*, 192 (pp. 378–379).

Krzywoszynska, A. (2019). *Caring for soil life in the Anthropocene: The role of attentiveness in more-than-human ethics*, *Transactions of the Institute of British Geographers* (open access).

Povinelli, E. A. (2017). *Geontologies: The Concept and Its Territories*. Online article in *Eflux* based on the first chapter of Povinelli, E. A. (2016) *Geontologies: A Requiem to Late Liberalism*. Duke University Press.

Puig de la Bellacasa, M. (2015). *Making time for soil: Technoscientific futurity and the pace of care*. *Social Studies of Science*, Vol. 45(5) (pp. 691–716).

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A Field Guide as an annex of the WRB 2022

MSc Vincent Bunes¹, Dr. Peter Schad², MSc Margaretha Rau²

¹Bavarian State Institute of Forestry, Freising, Germany, ²Technical University of Munich, Freising, Germany

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

The classification of a soil according to the World Reference Base for Soil Resources (WRB) requires field and lab data. For field description, the WRB recommends the FAO Guidelines for Soil Description (2006). In practice, three main problems occur:

- The Guidelines are not sufficiently precise.
- In many cases, the Guidelines and the WRB apply different limit values, and some characteristics required by the WRB are completely missing in the Guidelines.
- The Guidelines are rarely used.

But the difficulties go even deeper: The FAO classification (1974, 1988) and the WRB (1998, 2006, 2015) adopted numerous definitions from the US Soil Taxonomy, which descend from the US Soil Survey Manual (e.g., weakly cemented to indurated horizon) and are neither defined in the WRB nor in the FAO Guidelines.

Furthermore, site and soil description is relevant for the interpretation of laboratory results and the evaluation of soil functions.

Therefore, the new edition of the WRB (2022) shall be supplemented with a Field Guide. It contains all definitions of field characteristics that are needed for the WRB and allows a systematic description of site and soil conditions worldwide. Among the characteristics are soil-forming factors (e.g., climate, topography, vegetation), surface characteristics (e.g., rock outcrops, surface sealings, technical surface alterations), and a detailed examination of the horizons (e.g., identification of horizons, texture, structure, redoximorphic features). For the determination of the texture, we developed a simple, yet precise flowchart. This Field Guide offers practical instructions for the correct reporting of soil and site characteristics.

FAO (2006) Guidelines for soil description, 4th edition. Eds: Jahn, R., Blume, H.-P., Asio, V.B., Spaargaaren, O.C & Schad P. FAO, Rome, Italy.

IUSS Working Group WRB (2015) World reference base for soil resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. Eds: Schad, P., van Huyssteen, C.W. & Michéli, E. World Soil Resources Reports 106, FAO, Rome, Italy.

Soil Science Division Staff (2017) Soil survey manual. US Department of Agriculture Handboo No. 18, Washington, DC, USA.

Semi-detailed survey and mapping of WRB soil resources in Ethiopia using different pathways to optimise between accuracy and precision

Ir. Johan Leenaars¹, Ir Ali Ashenafi², Ir Maria Ruiperez Gonzalez¹, Dr Bas Kempen¹, Ir Stephan Mantel¹, Dr Gudeta Kiflu³

¹ISRIC - World Soil Information, Wageningen, Netherlands, ²Geography and Environmental Studies, Addis Ababa University, Addis Ababa, Ethiopia, ³Soil Resource Information and Mapping Directorate, Ministry of Agriculture, Addis Ababa, Ethiopia

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

Scaling agricultural management recommendations in Ethiopia requires understanding of its soil-resources. Objective of this study was a semi-detailed soil-class map for 15 food-insecure woredas ($\pm 12,500\text{km}^2$). First, a geomorphic basemap was prepared at 50m resolution countrywide and intersected with geology to guide a survey conducted by five teams. 3440 profiles including 322 representative pits were classified according to the World Reference Base (WRB2015) as Reference-Soil-Group (RSG) with varying numbers of principal and supplementary qualifiers (PQ & SQ). Spatial soil-class distribution was modelled at 50m resolution by random-forest. Four pathways, to optimise between consistency, detail and accuracy, were tested at 16 levels of precision (RSG, 0-3PQ, 0-4SQ). Pathway1 spatially predicted classes with one multiclass model. Pathway2 constructed these from three separate predictions of RSGs, PQs and SQs. Pathway3 from multiple single-class predictions. Pathway4 deconstructed RSGs into diagnostics, adding to the qualifiers, and reconstructed classes according to the key from single-class predictions of diagnostics (probability >0.3) and applicable, most-probable but not contradicting, qualifiers. Out-of-bag cross-validation of individual class-elements showed purities that were similar in each pathway for RSGs (0.57) and decreased with increasing qualifier detail; most in pathway1 and least in pathways3-4 and more prominently for PQs than SQs. Pathway4 was retained because it corrects for possible inconsistencies in classifying soils among survey teams. Evaluated optimal was RSG+1PQ+3SQ with 0.47 accuracy (>0.50 at lesser detail). Final polygons, generalised at target scale, matched 48% of observations (74% for RSGs). We conclude by suggesting a simplified system pragmatically tailored to national soil classification and mapping initiatives.

IUSS WG WRB, 2015. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Leenaars J.G.B., E. Elias, J.H.M. Wösten, M. Ruiperez González, and B. Kempen, 2020. Mapping the major soil-landscape resources of the Ethiopian Highlands using random forest. *Geoderma* 361.

Marsman B. A. and J.J. de Gruijter, 1986. Quality of soil maps : a comparison of soil survey methods in a sandy area. Soil survey papers No. 15, Soil Survey Institute, Wageningen. (<https://edepot.wur.nl/302705>).

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WRB and Soil Information Systems - steps to harmonized world soil information

Dr. Einar Eberhardt¹

¹*Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Germany*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

The new edition of the World Reference Base of Soil Resources (IUSS WG WRB, in prep.) includes tailor-made soil description rules in an annex that improves the FAO Guidelines for Soil Description (FAO 2006) with elements also from further soil description guidelines (e. g. Schoeneberger et al. 2012, Ad-hoc AG Boden 2005).

As part of the worldwide ongoing efforts of soil data harmonization, a further step is to record these data in a technically similar way. We present a simple data model for WRB 2022 soil data that can be used for harmonized soil data acquisition and storage as well as for data exchange. This includes the soil and horizon descriptive data as well as presence of WRB diagnostics. Such a clear data structure also enhances data import in existing soil and land information systems or other, more complex data structures for data exchange. It also improves possibilities for subsequent use of the data for evaluations not yet intended during primary data acquisition. The structure could be completed with those analytical data parameters that are necessary for WRB classification. Ad-hoc-AG Boden (2005). *Bodenkundliche Kartieranleitung* (5. Aufl.). Hannover: Schweizerbart (in Komm.).

FAO (2006). *Guidelines for soil description* (4th, rev. ed.). Rome: FAO.

IUSS Working Group WRB (in prep.). *World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps* (4th ed.).

Schoeneberger, P. J., Wysocki, D. A., Benham, E.C., & Soil Survey Staff (2012). *Field Book for Describing and Sampling Soils* (Version 3.0). Lincoln, Nebraska: Natural Resources Conservation Service, National Soil Survey Center. Retrieved from http://library.wur.nl/WebQuery/file/isric/fulltext/isricu_i33776_001.pdf

Taxonomic distance studies of the units of the modernized Hungarian Soil Classification with WRB RSGs.

Prof Erika Micheli¹, Dr. Adam Csorba, Dr. Yuri Andrei Gelsleichter Yuri Andre, Dr Endre Dobos, Dr. Marta Fuchs

¹*Hungarian University of Agriculture and Life Sciences, Godollo, Hungary*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

The traditional genetic-based Hungarian Soil Classification System was elaborated during the 1960s. The central units are the soil types (39) that are groups of soils formed under similar soil forming factors and processes, resulting in similar morphogenetic properties. The concept and the definitions were units developed before sufficient data and modern data processing tools became available. The allocation of soils in the system included some subjective elements, even with substantial knowledge and experience of the classifier. A modernized “diagnostic” system was developed based on the accumulated data and experiences with the genetic system as well on the application of new pedometric tools. The definitions and limits of the diagnostic categories (horizons and properties) mostly correspond with the World reference base for soil resources (WRB), but are not identical, they are much simpler, and adopted for the environmental setting of the Carpathian Basin. The 15 soil types (central units) are defined by the newly introduced classification key, based on diagnostic criteria, assuring a more objective result of the classification process. This paper is presenting the rationale of the diagnostic system, gives a summary description of the 15 new soil types and discusses the results of the taxonomic distance studies between the 15 types and the Reference Soil Groups of the WRB. The study is based on the centroid-based approach using legacy data of the Hungarian Soil Monitoring System and ISRIC-WISE Harmonized Database. Conclusions on expected and unexpected matches will be discussed as part of the evaluation the WRB 2015 edition.

ISRIC-WISE Harmonized Global Soil Profile Database (Batjes, 2008, Batjes, 2009)

B. Minasny, A.B. McBratney, A.E. Hartemink. Global pedodiversity, taxonomic distance, and the world reference base *Geoderma*, 155 (2009), pp. 132-139

P. Stefanovits. *The Soils of Hungary*. (2nd ed.), Akadémiai Kiadó, Budapest (1963) (224 pp. (in Hungarian)).

TIM (Soil Monitoring and Information System) Guidelines and Data Base. Hungarian Ministry of Agriculture. 1995, 2020.

How to identify soil diagnostic horizons? A key to the diagnostic features of the World Reference Base for soil resources

Dr Stefaan Dondeyne¹, Mr H. Edward M. Russell Jr.^{2,3}, Dr Anders Bjørn Møller³, Dr Peter Finke²
¹*Department of Geography, Ghent University, Ghent, Belgium,* ²*Department of Environment, Ghent University, Ghent, Belgium,* ³*Department of Agroecology, Soil Physics and Hydropedology, Aarhus University, Aarhus, Denmark*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

Internationally, the most widely used soil classification systems Soil Taxonomy (Soil Survey Staff, 2014), developed by the USDA and the ‘World Reference Base for soil resources’ (WRB), developed by an IUSS working group (IUSS Working Group, 2015), both hinge on the recognition of diagnostic horizons, properties, and materials. Once the diagnostic features of each horizon are established, a name can be attributed to the considered pedon by following a determination key. However, so far, no determination key exists for identifying in a systematic and efficient way the diagnostic features of soil profiles. Developing such a key would facilitate naming soils correctly and should be helpful for automating the classification of legacy soil data. We therefore aimed at developing a determination key applicable for identifying diagnostic horizons according to WRB and propose this as a contribution to a future version of WRB.

In a first instance, all the criteria pertaining to the diagnostic features are listed to create a “0/1 matrix” indicating their applicability. Subsequently, a cluster analysis is performed on this matrix to group features such that a logic and efficient determination key can be developed. The determination key is tested and validated using data of soil profiles in our own collection and databases as well as of the international soil museum ISRIC in Wageningen, The Netherlands. Developing this identification key also brings to light ambiguities and contradictions in the current definition of diagnostics features, based on which suggestions are made for improving WRB.

IUSS Working Group WRB. (2015). World Reference Base for soil resources 2014. Update 2015. International soil classification system for naming soils and creating legends for soil maps. Update 2015. FAO.

Soil Survey Staff. (2014). Keys to Soil Taxonomy. Twelfth Edition, 2014. USDA, Natural Resources Conservation Service.

War and peace - complementary factors of urban soil formation in Central Europe

Prof. Dr. Cezary Kabala¹

¹*Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

Although the present soil properties are crucial for soil classification, knowledge of soil formation factors and conditions may help researchers understand the specific composition of soil profiles and spatial combinations of various soils. Among soil groups, the soils of urbanized areas are particularly dependent on the kind of anthropogenic parent materials and interventions. The area of the present-day botanical garden in Wroclaw (Poland, Central Europe) was situated at least twice in the fortress. The original alluvial soils of the area were first destroyed due to the construction of large-scale fortifications during the Prussian-Austrian wars (18th century). After Napoleon wars, the earthen material from the fortifications was used to fulfil the channels and level the land surface, i.e. became the construction material of the new soil cover (free of artefacts in terms of WRB). Heavy bombing at the end of 2nd World War (1945) has demolished the existing soil surface and neighbouring buildings; the latter produced a large volume of construction debris. Post-war reclamation created variable soils containing these debris throughout or at various depths of soil profile. In addition, external soil material was transported to create 'productive soils'. Although probably all soils in the area were constructed more or less intentionally by humans, only those enriched with artefacts meet the criteria of Technosols, while soils formed from relocated and mixed earthen materials have to be classified among 'natural' soils (eg Phaeozems), which encourages discussion of definition and classification of 'anthropogenic soils'.

1. IUSS Working Group WRB (2015). World Reference Base for Soil Resources 2014, Update 2015. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. World Soil Resources Reports 106, Food and Agriculture Organization of the United Nations (FAO), Rome.
2. Kabala, C., Charzyński, P., Chodorowski, J., Drewnik, M., Glina, B., Greinert, A., ... & Waroszewski, J. (2019). Polish Soil Classification: principles, classification scheme and correlations. *Soil Science Annual*, 70(2).

Improving accuracy assessment of global WRB predictions using taxonomic distance

Mr David Rossiter¹, **Mr Luis Duque Moreira de Sousa¹, Mr Stephan Mantel¹**

¹*Isric World Soil Information, Wageningen, Netherlands*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

With map predictions of soil classes, it is obvious that not all prediction errors are equally serious. Reporting accuracy as binary correct/incorrect can be misleading. As explained in the paper by Rossiter et al.1, most evaluations of classification accuracy consider all misallocations, represented by the off-diagonal entries of the cross-classification matrix, to be equally serious errors. The consequences of a misallocation for someone using the prediction can differ widely depending on the relation between the allocated class and the actual class. The method for creation of a "partial credit" matrix, by Rossiter et al.2 will be applied. It uses the same structure as the cross-classification matrix, with the off-diagonals some partial credit from 0 (as in the naive approach) to 1 (no penalty for this error). This matrix is then used in the accuracy assessment, so that the reported accuracy should better reflect the actual usability of the map. To fill in the weights matrix we consider an "expert opinion" method, which in this case is the expert opinion of the WRB Working Group. Experts are asked to assess any misclassification of the 32 RSGs to be given a partial credit, and if so, how much? We foresee an iterative process in which discrepancies between estimates of experts on partial credits will be discussed, so that the final partial credit matrix is a consensus of the WRB Working Group expert consultation. New global WRB map RSG estimates in SoilGrids3 will report both the naive and weighted accuracies.

1. Rossiter, D. G., Zeng, R., & Zhang, G.-L. (2017). Accounting for taxonomic distance in accuracy assessment of soil class predictions. *Geoderma*, 292, 118–127.

<https://doi.org/10.1016/j.geoderma.2017.01.012>

2. IUSS Working Group WRB. (2015). World Reference Base for Soil Resources 2014; Update 2015. International soil classification system for naming soils and creating legends for soil maps.

Retrieved from <http://www.fao.org/3/i3794en/i3794en.pdf>

3. Poggio, L., de Sousa, L. M., Batjes, N. H., Heuvelink, G. B. M., Kempen, B., Ribeiro, E., and Rossiter, D.: SoilGrids 2.0: producing soil information for the globe with quantified spatial uncertainty, *SOIL*, 7, 217–240, <https://doi.org/10.5194/soil-7-217-2021>, 2021.

The 4th edition of the WRB (2022)

Dr. Peter Schad¹

¹*Technical University of Munich, Freising, Germany*

35 WG1.9 – Advances in understanding soils as reflected by the 4th edition of the WRB, Alsh 1, August 1, 2022, 17:30 - 19:30

The IUSS Working Group WRB releases every second World Congress a new edition of the international soil classification system World Reference Base for Soil Resources. After 1998, 2006, 2014 (update 2015), the edition of 2022 is the fourth.

The 4th edition will have some additional annexes: Field Guide, Horizon Designations (both together replacing the FAO Guidelines for Soil Description), Soil Description Sheet, Colour Symbols for Reference Soil Group Maps, Database Instructions. The wordings of main text and field guide annex will be harmonized.

Many definitions will be refined, reflecting the discussions during field and indoor workshops and the suggestions coming from many colleagues. Examples:

- alternatives for recognizing a cambic horizon without comparing it against over- or underlying layers,
- a better distinction of the various anthropogenic horizons,
- consider chernic horizons intensely altered by agriculture,
- a better and more quantitative description of yermic properties,
- a better and more quantitative description of secondary carbonates in protocalcic properties and the calcic horizon,
- a more precise definition of stagnic properties, Stagnosols and Planosols.

Some diagnostics will be abolished and some new diagnostics introduced, e.g.:

- a horizon describing the carater coeso (Brazil), apedal B horizon (South Africa), Kandosol B horizon (Australia),
- a horizon rich in Fe oxides that accumulated in reduced form by lateral water flow
- a cemented horizon with gleyic properties.

The system of the depth-related specifiers will be improved.

IUSS Working Group WRB (2015) World reference base for soil resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports 106, FAO, Rome, Italy.

Hairs matter at field scale for shoot growth and nutrient uptake, but root trait plasticity is primarily triggered by texture

Prof. Doris Vetterlein^{1,3}, Maxime Phalempin¹, Eva Lippold¹, Steffen Schlüter¹, Susanne Schreiter¹, Ahmed Mutez³, Andrea Carminati⁴, Patrick Duddek⁴, Helena Jorda⁵, Jan Vanderborgh⁵, Mathieu Javaux⁵, Patrick Bienert⁶, Desiree Bienert⁶, Mika Tarkka¹, Minh Ganther¹

¹Helmholtz Centre for Environmental Research - UFZ, Halle, Germany, ²Martin Luther University Halle-Wittenberg, Halle, Germany, ³University of Bayreuth, Bayreuth, Germany, ⁴ETH Zürich, Zürich, Switzerland, ⁵FZJ, Jülich, Germany, ⁶TUM, Munich, Germany

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Root hairs are important for nutrient uptake, especially for those with low mobility. This has often been demonstrated in laboratory, but rarely under field conditions. Contribution of hairs to uptake is expected to be higher in soils with high sorption capacity (1). Root hair defective mutants are expected to show lower nutrient uptake or compensation in terms of altered root traits. This is equivalent to higher investment in root growth. As root hairs can also contribute to plant water acquisition (2), their importance may change during a growing season.

Zea mays root hair mutant (*rth3*) and the corresponding wild-type (WT) were grown in two years under field conditions on two substrates with contrasting texture (loam, sand) (3,4).

Shoot growth and plant P and K uptake were promoted by the presence of hairs. Differences between genotypes were greater for loam than for sand. Compensation for the absence of root hairs in terms of increased root growth was not observed. However, root:shoot ratio was higher for *rth3* compared to WT. Root traits showed high plasticity in response to texture independent of genotype. Increases in root length density in sand were explained by a larger need for exploration versus exploitation. The mechanism that causes the increase in root diameter for sand as compared to loam is still unknown. These changes could not be explained by differences in mechanical resistance. The larger investment into root growth on sand as compared to loam is expected to change long-term carbon balance.

Lippold, E., Phalempin, M., Schlüter, S., & Vetterlein, D. (2021). Does the lack of root hairs alter root system architecture of *Zea mays*? *Plant and Soil*, 467(1), 267-286. DOI 10.1007/s11104-021-05084-8

Carminati, A., Passioura, J. B., Zarebanadkouki, M., Ahmed, M. A., Ryan, P. R., Watt, M., & Delhaize, E. (2017). Root hairs enable high transpiration rates in drying soils. *New Phytologist*, 216(3), 1-11. DOI:10.1111/nph.14715

Vetterlein, D., Lippold, E., Schreiter, S., Phalempin, M., Fahrenkamp, T., Hochholdinger, F., . . . Schlüter, S. (2021). Experimental platforms for the investigation of spatiotemporal patterns in the rhizosphere – laboratory and field scale. *Journal of Plant Nutrition and Soil Science*. DOI: 10.1002/jpln.202000079

Vetterlein, D., Carminati, A., Kögel-Knabner, I., Bienert, G. P., Smalla, K., Oburger, E., . . . Schlüter, S. (2021). Rhizosphere spatiotemporal organization - a key to rhizosphere functions. *Frontiers in Agronomy*, 2, 21. DOI:10.3389/fargro.2020.00008

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Root foraging and mining strategies shape ecosystem services – a focus on biogeochemical cycling and soil formation in low-input agroecosystems

Dr Philippe Hinsinger¹, Dr Esther Guillot¹, Dr Christophe Jourdan², Dr Jean-Paul Laclau², Dr Céline Pradier², Dr Elisa Taschen¹

¹INRAE, UMR Eco&Sols, Montpellier, France, ²CIRAD, UMR Eco&Sols, Montpellier, France

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Producing more food, feed and fiber with less impact on ecosystem services such as the biogeochemical cycles of carbon and nutrients is a major challenge for achieving the agroecological transition of agriculture. To this end, further understanding the rather unique rhizosphere biogeochemistry related to both root foraging and mining strategies is needed. When foraging for resource acquisition, roots indeed release large amounts of organic compounds and considerably alter nutrient concentrations and soil pH. Roots have thus evolved diverse mining strategies that rely on combinations of such rhizosphere processes occurring over short spatial and temporal scales around living roots. These ultimately shape the fate of soil organic carbon and organic matter, the dissolution/precipitation of soil minerals, the adsorption/desorption of both anions (e.g. phosphate) and cations (e.g. potassium) and hence, support services such as soil formation, carbon and nutrient cycling (Hinsinger, 2013). These root foraging and mining strategies considerably vary amongst plant genotypes, as exemplified for crops and plantation trees in low-input temperate and tropical agroecosystems (Erel et al., 2016; Pradier et al., 2017; Battie-Laclau et al., 2020). In the context of climate change, one also needs to account for rhizosphere processes occurring at depth, not just in the topsoil (Thorup-Kristensen et al., 2020). In this talk, we draw exciting perspectives for breeding crops and trees that most efficiently contribute to carbon sequestration at depth and acquire or cycle nutrients to improve nutrient use efficiency for tomorrow's agroecosystems.

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Organic matter modulates the influence of different earthworms species on plant-soil interactions

Mr José Rocha Araujo¹, Dr Anne Pando¹, Ms Lisa Meyer¹, Dr Lise Dupont¹, Dr Thomas Z Lerch¹

¹IEES-Paris, Paris, France

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Plant roots can modify soil physico-chemical properties and microbial communities [1]. In turn plant depend on soils abiotic and biotic factors. Whilst they represent a very diverse group of organisms, little is known on the specific effects of different earthworms on plant roots yet, and even less about the role of the soil OM on these interactions. The objectives of this study was 1) to evaluate the effects of different functional groups of earthworms on plant biomass and roots morphology, and 2) to estimate the influence of OM on the earthworms impact. Here, we used constructed Technosol composed of deep horizons of soil and different doses of compost (10, 20 and 30%) compost as experimental model [3], in which we inoculated different earthworm species (*L. castaneus*, *L. terrestris* and *A. chlorotica*) separately or together. Control soils were not inoculated. Half of the pots were sowed with ryegrass seeds. After 4 months in controlled conditions, we analysed plant biomass, roots morphology and the soil structure. Surprisingly, the relative amount of OM in soils has no influence on the plant biomass, while earthworms affected plant shoot biomass (specifically with *L. terrestris*). Each earthworm species influenced differently the roots morphology and those effects were stronger with increasing amounts of OM.

Earthworms altered significantly the soil structure but only in the absence of plants, suggesting that roots may reshape earthworms structure. This study shows that plant-soil interactions also depends on earthworms diversity, whose effect is modulated by soil OM.

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A pore scale characterisation of extracellular polymeric substances to describe biofilms and plant exudates - integrating imaging, NMR, and modelling

Dr Siul Ruiz¹, Dr. Katherine Williams², Dr. Chiara Petroselli¹, Ms Nancy Walker¹, Dr. Daniel McKay Fletcher¹, Dr. Giuseppe Pileio¹, Dr. Tiina Roose¹

¹University of Southampton, Southampton, United Kingdom, ²University of Portsmouth, Portsmouth, United Kingdom

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Root-secreted mucilage and microbial produced extracellular polymeric substances modify soil physical and biogeochemical processes. Most studies infer the effects of these polymeric substances from soil bulk behaviour rather than investigating the pore scale processes. This investigation quantified the isolated physical behaviour of mucilage in a simplified pore-scale setup. We placed drops of plant derived mucilage at different concentrations between two flat surfaces to form liquid bridges and monitored their drying using optical imaging and magnetic resonance imaging (MRI). We used our observations to validate a polymer-based multi-phase model that characterises the gel-water-air interactions. In the experiments, while pure water liquid bridges rupture, the mucilage buckles under drying, but it maintains a connection between the surfaces. MRI shows more water was lost from the central region in the middle of the two plates. In the model, mucilage gel accumulated near the boundaries where surface adhesion occurs. The modelled accumulation times overlapped with monitored bridge buckling for the different concentrations, showing the model can predict the observed transition at which the mixture no longer behaves like a pure liquid. Results suggest that the earlier phase transitions observed for higher mucilage concentrations show a potential mechanism for greater drought tolerance for plant roots and increases the soil water holding capacity. Furthermore, we discuss potential applications of our model for describing the impacts that microbial biofilms may have on soil structure along with impacts of soil fauna on soil physical functions.

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Modelling the spatial and temporal evolution of rhizodeposition as a function of plant's carbon balance and soil properties

Dr. Frederic Rees¹, Dr. Christophe Pradal^{2,3}, Dr. Romain Barillot⁴, Dr. Marion Gauthier^{1,5}, Dr. Loïc Pagès⁶, Dr. Céline Richard-Molard¹, Pr. Alexandra Jullien¹, Pr. Claire Chenu¹, Dr. Bruno Andrieu¹
¹INRAE, AgroParisTech, Université Paris-Saclay, UMR ECOSYS, Thiverval-Grignon, France, ²INRAE, UR P3F, Lusignan, France, ³ITK, Clapiers, France, ⁴AGAP, CIRAD, INRAE, Montpellier Sup Agro, Univ Montpellier, Montpellier, France, ⁵CIRAD, AGAP and Inria, Zenith, Univ Montpellier, Montpellier, France, ⁶INRAE, UR 1115 PSH, Avignon, France

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Rhizodeposition, i.e. the release of organic material by roots, has been recognized as a major process that controls the short-term dynamics of carbon in the soil and the biological activity in the rhizosphere. Rhizodeposits can be used by microorganisms as a substrate for growth and metabolism, which may drive the build-up of stable soil organic matter (SOM) and/or stimulate an increase in SOM mineralization through the rhizospheric priming effect. This in return may positively affect plant growth by increasing the amount of mineral nutrients available to the plant. So far, our understanding of such processes has been hindered by the lack of reliable estimations of the amount and composition of the organic materials released by roots, e.g. because of the absence of any mechanistic soil-plant models that explicitly integrate such fluxes. RhizoDep is a new plant model that simulates the development of a 3D root system together with physiological processes such as root respiration and rhizodeposition, depending on the amount of carbon available within the root system, and on local soil physical properties. By coupling this plant model to models describing SOM dynamics, we can now recreate a plausible evolution of root growth, soil organic carbon dynamics, or nitrogen mineralization at various soil depths and for contrasted soil profiles. Examples of such outputs for a few crop species will illustrate how this modeling approach can greatly improve our understanding of the influence of root-soil interactions on C and N cycling in cropland.

[No reference]

Shrub-Crop Microbiome and Mycorrhizal Hyphal Interactions: A Novel Rhizosphere Alliance to Mitigate In-Season Drought in the Sahel

Professor Richard Dick¹, Matthew Bright, Spencer Debenport, Nathan Bogie, Ibrahima Diedhiou, Christine Charles, Brian McSpadden-Gardner, Teamrat Ghezzehei, Roger Bayala, Komi Assigbetse
¹*Ohio State University, Columbus, USA*

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

The Sahel is a vulnerable semi-arid environment, with degraded soils where the majority, subsistence farmers routinely face in-season drought. Our development of the Optimized Shrub-intercropping System (OSS) with 2 indigenous shrubs *Guiera senegalensis* and *Piliostigma reticulatum* at elevated densities (~1500) with annual incorporation of coppiced residues addresses this challenge by increasing soil quality and microbial diversity, performing hydraulic lift (HL), and dramatically increasing yields. We report here, recent greenhouse and field research showing how OSS induces drought resistance in pearl millet. A simulated drought field study using deuterium (D₂O) as a tracer (applied to shrub roots at 1 m depth) detected a δD signal of > 300‰ over background in shrub-associated millet tissue; confirming Hled water was transferred to millet. Importantly the +OSS enabled millet to produce a harvestable yield in spite of the in-season drought. Using mesocosms (hydrophobic 36 μm mesh allowing only mycorrhizal hyphae penetration) planted to millet showed that the unturned was labeled with D₂O and had much greater tillering/plant biomass than turned microcosms indicating a common mycorrhizal hyphal network (CMN) connected shrub roots with millet roots. Supporting the CMN was greater AMF colonization/FAME-AMF abundance in shrub over non-shrub soil. Microbial metagenomic sequencing showed that shrubs enriched several plant-growth promoting taxa in millet rhizosphere soil. We conclude that shrubs operate as a natural microbial repository that “inoculates” adjacent crop roots; directly reducing drought with CMN “bioirrigating” and by promoting beneficial, drought resisting rhizosphere microorganisms.

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Impact of root hairs on microscale soil physical properties in the field

Dr Maria Marin¹, **Prof PD Hallett**¹, Dr DS Feeney², LK Brown², Dr Muhammad Naveed¹, Dr Siul Ruiz⁴, Dr Nicolai Koebernick⁴, Prof AG Bengough³, Prof Tiina Roose⁴, Dr TS George²

¹University Of Aberdeen, Aberdeen, UK, ²The James Hutton Institute, Dundee, UK, ³University of Dundee, Dundee, UK,

⁴University of Southampton, Southampton, UK

Interdivisional 4: Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 09:00 - 11:00

Root hairs are well-known to expand the zone of influence of plant roots in soil, with recent laboratory studies revealing that root hairs may also alter soil physical behaviour, influencing soil porosity and water retention at the small scale. However, the results are not consistent, and it is not known if structural changes at the small-scale have impacts at larger scale (i.e., open field). Therefore, we evaluated the potential effects of root hairs on soil hydro-mechanical properties in the field using rhizosphere-scale physical measurements. Assessments were conducted in clay loam and sandy loam soils, from plant establishment to harvesting in actual field trials, comparing three barley genotypes representing distinct phenotypic categories in relation to root hair length. Soil hardness and elasticity were measured using a 3-mm-diameter spherical indenter, while water sorptivity and repellency were measured using a miniaturized infiltrometer device with a 0.4-mm tip radius. Over the growing season, plants induced changes in the soil water retention properties, with the plant available water increasing by 21%. Root hairs also drove mechanical and hydraulic changes in the soil. Both soil hardness ($P = 0.031$) and elasticity ($P = 0.048$) decreased significantly in the presence of root hairs in clay loam soil, by 50% and 36%, respectively. Root hairs also led to significantly smaller water repellency ($P = 0.007$) in sandy loam soil vegetated with the hairy genotype (-49%) compared to the hairless mutant. Therefore, there is substantial scope to select root phenotypes for improved soil physical properties and soil health.

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Can smartphone applications revolutionise how we measure aggregate stability?

Miss Munisath Khandoker^{1,2}

¹Rothamsted Research, Harpenden, United Kingdom, ²Lancaster University, Bailrigg, United Kingdom

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

Aggregate stability describes the ability of soil aggregates to remain stable against external forces such as rapid wetting and raindrop impact. Stable aggregates can improve soil structure, water holding capacity, and protect organic matter. Aggregate stability is therefore an important physical indicator of soil health. Current methods to measure aggregate stability often involve disrupting soil aggregates in distilled water. These tests are time consuming, require specialised equipment, and are usually done in laboratories.

The SLAKES: Soil Aggregate Stability smartphone application, developed by the University of Sydney, Australia, quantifies aggregate stability by measuring how quickly soil aggregates disintegrate once submerged in water. The SLAKES application requires three soil aggregates 1-2 cm in diameter to be placed in a petri dish. Water is added and the SLAKES app provides a measurement of aggregate stability within 10 minutes.

To determine the sensitivity of the SLAKES app, we compared its aggregate stability measurements with that of the established Le Bissonnais method. Soil samples of different texture were taken from under fallow, permanent grass, and continuous arable cropping management from four experimental sites. The SLAKES app was able to differentiate between different managements on clayey soil but, compared to Le Bissonnais, it was less sensitive when tested on sandy soil. Despite this, the SLAKES app is a legitimate method to measure aggregate stability. The app offers a simple, fast, and cheap alternative to standard laboratory methods, allowing land managers and non-scientists to actively test the quality of their soils.

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Calibration transfer: a case study using LDSF spectral library

Miss Wartini Ng¹, Leigh Winowiecki², Andrew Sila², Valentine Karari², Elvis Weullow², Tor-Gunnar Vagen², Prof Budiman Minasny¹

¹University of Sydney, Sydney, Australia, ²World Agroforestry Centre, Nairobi, Kenya

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

Infrared spectroscopy has become a viable alternative for the rapid characterization of soil. Multiple properties can be simultaneously predicted from a single spectrum. There is an ongoing development for global spectral libraries. However, the spectral data collected towards the global spectral libraries were often recorded using different spectrometers under different scanning conditions and procedures. These variations in spectra data collection make the conjoint usage of the global spectral library challenging. There is a need to harmonize the global soil spectral libraries to maximize the application of infrared spectroscopy. In this study, mid-infrared spectral data (2500-25,000 nm) collected from ten different regions across Asia and Africa using four different MIR spectrometers were studied. All the samples were collected using the same method as the Land Degradation Surveillance Framework (LDSF). We trained chemometrics models using the LDSF soil spectral library as a central model. We then explore several spectral calibration transfer methods, including direct standardization, piecewise data standardization, spectral space transformation, orthogonal signal correction and transfer by orthogonal projection. These methods require soil samples to be scanned across instruments prior to standardization. We also explore approaches that do not require spectra data collected on common samples. The approaches include transfer learning and universal model. Transfer learning locally recalibrated the model trained on the main instrument. On the other hand, the universal model involves training a model using spectra from different instruments. Comparing these transfer methods will determine the best strategy to apply a global spectral library on different instruments.

Keywords: infrared spectroscopy, spectral library, chemometrics, calibration transfer

X-ray CT analysis of forest root growth on high-pH peaty soils: it's not all black and white

Miss Jill Pitcher Farrell¹, Mr Nicholas E.L. Wragg², Miss Blair Ruffing¹, Dr Saoirse Tracy², Mr Charles Harper², Dr Thomas Cummins², Dr Maarten Nieuwenhuis², Dr Kenneth A. Byrne¹

¹University Of Limerick, Limerick, Ireland, ²University College Dublin, Dublin, Ireland

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

Inhibited growth is observed in many forest stands planted on marl - a calcareous limnic deposit permeated by variable quantities of shells of freshwater molluscs that presents as a subsoil or discontinuous layer predominantly beneath basin peats in Ireland. An investigation was conducted into the presence of marl or other high pH material in soils, the success of forest stands on these soils, the soil properties, and the penetration of the tree roots into the calcareous layer. A soil-coring survey sampled the boundary between the calcareous layer and the soil above to distinguish between rootable and root-restricting environments. Split-tube undisturbed root cores of 40 cm length and 7 cm diameter were collected and subjected to X-ray Computed Tomography (CT) scanning. This captures 3D images which were analysed to identify whether roots penetrate the marl and characterise details of the root–mineral interface and if it affects penetration success. Analysis of root scanning images shows the ability of some roots to penetrate marl layers in certain circumstances. The results from the scanning were verified using the core break method, root washing and WinRHIZO™ 2D scanning and software. This is one of the first studies to apply X-ray CT technology to in-situ observations of tree roots in forests on peatland soils. Soil samples were also collected at each site and pH, acid-neutralising capacity, organic matter, and soil water content were analysed. Full analysis was completed on 19 forest stands with species including; alder, sycamore, Sitka spruce, Norway spruce, Scots pine and birch.

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FTIR-ATR: A Method Giving Unique Insights into the Composition of Soil

Dr A H Jean Robertson¹, Mrs Angela M Main¹, Dr Reza K Haghi¹

¹*The James Hutton Institute, Aberdeen, Scotland*

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

In recent years the use of soil spectroscopy, in the mid and near infrared regions, has gained in popularity for the prediction of soil properties using chemometric approaches. However, the interpretation of spectra to gain insight into soil composition and changes in soil has been almost entirely neglected. Infrared spectra in the mid infrared region give an overall chemical profile or “fingerprint” of the soil which importantly includes both the organic and mineral components present. The FTIR-ATR (Fourier Transform Infrared-Attenuated Total Reflectance) method for producing infrared spectra of soils does not require preparation of KBR discs as Transmission does, nor suffer from the inversions and artefacts that can be present in Diffuse Reflectance spectra of neat soils. In this presentation we will describe the recording of FTIR-ATR spectra and the information which can be gained from their interpretation. This includes compositional information on the soil organic matter (SOM) present, the nature of the clay minerals and relative proportions of both. Examples of studies relating to the nature of SOM under long-term addition of organic amendments, changes in the mineralogy of machair soils as you go inland from the sea, and changes in peat with depth will be described.

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Novel insights into Fe and Al co-ordination in soils from STEM-EELS and laboratory-based ST-XAS

Dr Alastair Marsh¹, Prof Susan Bernal¹, Dr Andy Brown², Dr Helen Freeman¹, Prof Mark Hodson³, Ms Vicky Leadley⁴, Dr Rob Mills³, Dr Anke Neumann⁵, Ms Helen Pendlowski⁶, Dr Martin Stennett⁷, Dr Brant Walkley⁸, Ms Amy Wright³

¹*School of Civil Engineering, University Of Leeds, Leeds, United Kingdom*, ²*School of Chemical and Process Engineering, University of Leeds, Leeds, United Kingdom*, ³*Department of Environment and Geography, University of York, York, United Kingdom*, ⁴*Department of Chemistry, University of York, York, United Kingdom*, ⁵*School of Engineering, Newcastle University, Newcastle upon Tyne, United Kingdom*, ⁶*The James Hutton Institute, Craigiebuckler, United Kingdom*, ⁷*Department of Materials Science and Engineering, The University of Sheffield, Sheffield, United Kingdom*, ⁸*Department of Chemical and Biological Engineering, The University of Sheffield, Sheffield, United Kingdom*

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

The co-ordination states of aluminium and iron in soils are of importance for numerous applications. Two applications of current interest are: enhanced carbon sequestration in soils through the addition of mineral additives; and, the production of calcined clays for use in blended Portland-based cements in order to lower their embodied carbon. Here, we explore the possibility of describing spatial variation of the chemical environments of Al and Fe at the microscale using STEM-EELS (Scanning Transmission Electron Microscopy with Electron Energy Loss Spectroscopy) and laboratory-based ST-XAS (Scanning Transmission X-ray Absorption Spectroscopy). The two materials investigated were a sandy clay loam agricultural soil from York, England, and a kaolinite-rich lithomarge from the Interbasaltic Formation in Co. Antrim, Northern Ireland. A cross-characterisation bulk-analysis was first conducted by: XRD to assess phase composition; dithionite citrate, acid ammonium oxalate and sodium pyrophosphate extractions to characterise the chemical forms of Fe; ²⁷Al MAS-NMR to assess Al coordination states; and, ⁵⁷Fe Mossbauer spectroscopy to assess Fe oxidation states. Laboratory-based ST-XAS then gives direct measures of the chemical environments of Fe and association with C bonding, whilst STEM-EELS is able to confirm the source of the C bonding in the Fe-rich soils and show how Al co-ordination is locally affected by iron oxide fine particle contamination of kaolinite. These initial findings demonstrate that STEM-EELS and laboratory-based ST-XAS can provide microscale insight beyond the standard range of laboratory-based tests available for the study of soils.

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Biofunctool: An in-field package to assess soil quality based on soil functioning

Dr. Alain Brauman¹, Dr. Alexis Thoumazeau²

¹IRD, UMR ECO&SOLS, Montpellier, France, ²CIRAD, UMR ABSys, Kaselsart University, Bangkok, Thailand

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

The concepts and methods to assess soil health, quality and functions are widely debated in the literature. The question on how to include the role of soil biota that drives soil processes is in the spotlight of current soil assessment approaches. We developed a new operational framework to assess soil functions accounting for the complex interactions between soil physico-chemical properties and soil biological activity, namely Biofunctool®. Biofunctool® follows an integrative approach based on the measurement of soil dynamic functions driven by soil biota rather than stocks. It consists of nine in-field, time- and cost- effective indicators that assess three main soil functions: carbon transformation, nutrient cycling and structure maintenance. The results of the indicators are then aggregated to propose a quantified assessment of the impact of land management on the soil functions. This presentation will present different application of Biofunctool® in different agricultural systems (conservation agriculture, tree plantations, agroecological practices) and soil and climate context (Cambodia New Caledonia, Iviory coast, France). The results prove the relevance and robustness of the method to understand the impacts of agricultural practices on soil multi-functionality; trade-offs between functions will especially be highlighted. In addition to assessments, Biofunctool® may be a useful approach to guide land managers to implement favorable practices to preserve or improve soil health.

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Inner organization of soil crusts: new insights from two-dimensional X-ray microdiffraction

Mr Vincent Geoffroy¹, Dr Fabien Hubert¹, Dr Baptiste Dazas¹, Dr Eric Ferrage¹, Dr Thomas Dabat¹, Dr Brian Grégoire¹, Pr Emmanuel Tertre¹, Pr Richard Giot¹, Dr Laurent Michot², Dr Folkert van Oort³, Dr Felisa Berenguer⁴

¹IC2MP, Université de Poitiers, Poitiers, FRANCE, ²PHENIX, UPMC, Paris, FRANCE, ³UMR ECOSYS, Université de Paris-Saclay, INRAE AgroParisTech, Versailles, FRANCE, ⁴CRISTAL, SOLEIL, Saint-Aubin, FRANCE

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

Water erosion ranks as one of the major environmental issues threatening soil fertility. Formation of crust at the topsoil surface plays a key role in favoring the erosion by controlling the balance between water infiltration and runoff. Crust formation results from reorganization of fine particles such as clays¹. However, their mineralogy as well as their organization cannot be both clearly identified based on conventional micromorphological observations. In order to increase our general understanding about the key role played by clays in soil crusting, our work aims at providing spatialized insight into mineralogical and orientational features of soil clay particles using two-dimensional X-ray microdiffraction (2D μ XRD).

Undisturbed soil crust samples were collected at the “42 plots” long-term experimental site of INRAE Versailles that offers a unique opportunity to study soil crusting². Vertical sections were analyzed at the CRISTAL beamline, SOLEIL synchrotron, to obtain 2D μ XRD data mappings of 20 mm² with a resolution of 65x65 μ m. The specific data treatment developed allows to extract from 2D μ XRD patterns: (i) the different types of clays, (ii) their intrinsic local preferential orientation³ and (iii) the angular deviation of their preferential orientation.

First the methodology of 2D μ XRD data treatment and associated extracted output parameters are assessed using a synthetic clay porous medium constituted by monomineralic clay beds differing in terms of mineralogy and particle orientation. Then, mappings of soil crusts formed under various fertilizers are used to illustrate the role of physico-chemical conditions on spatial organization of clay particles in soil crusts.

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Vienna Soil Organic Matter Modeler 2 (VSOMM2) –computational microscope for SOM systems

Prof. Dr. Chris Oostenbrink¹, Yerko Escalona¹, **Dr. Drazen Petrov**¹

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

Interdivisional 9: Novel methods and techniques, Lomond Auditorium, August 2, 2022, 09:00 - 11:00

Soil Organic Matter (SOM) plays an important role in several biogeochemical processes by directly affecting the microbial activity, soil aggregation, plant growth and carbon storage. Our understanding of its composition and structure is still incomplete. Several experiments using elemental analysis, nuclear magnetic resonance (NMR) and mass spectrometry (MS) shed light on the structure of organic matter. In this context, the Vienna Soil-Organic-Matter Modeler 2 (VSOMM2; <https://somm.boku.ac.at/>), is a website that generates condensed phase computer models of Soil-Organic-Matter (SOM). Most of the data comes from standardized samples by the International Humic Substances Association (IHSS), which uses a specific methodology to extract organic compounds from soil, called humic substances.

The modeler uses an extensive pool of elemental units that compose our SOM molecules called Building Blocks, and utilizes a genetic algorithm that increases the chemical and geometric diversity of generated models. This allowed us to create models of different types and compositions of soil organic matter, including all standardized samples provided by IHSS.

Importantly, these representative condensed-phase models of SOM samples can be subjected to molecular dynamics simulations, providing us with detailed characterization of structure, dynamics and interactions of such systems at the atomistic level. We are confident that these advances in molecular modelling related to SOM systems will lead to new insights into behavior of such systems and thus deepen our understanding of relevant biogeochemical processes.

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Visualizing Soil Landscapes by Mining Soil Survey Taxonomic Data

Dr. Darrell Schulze¹

¹*Purdue University, West Lafayette, USA*

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

Soil taxonomic systems are the languages of soil science. They allow us to organize and make sense of the large number of soil properties that describe any one type of soil, and they allow us to understand how different soils relate to each other. It is easy to think of soils only in terms of the differences in their one-dimensional, vertical soil profiles. Soils, however, are three-dimensional, and soils and soil properties vary spatially across landscapes as well as vertically. In the US, soils have been mapped over large areas, often at scales that allow delineations as small as ~1 ha, and the soils within each delineation have been classified in Soil Taxonomy. Thus, the US Soil Survey Geographic Database (SSURGO) is deep in terms of the kinds and numbers of attributes it contains, quantitative in the way that the soils have been classified, and wide spatially in its coverage. The Soil Explorer app for iPhone/iPad and Android devices and the SoilExplorer.net website combine thematic maps of soil properties with high resolution hillshade base maps to allow users to explore the spatial aspects of soil properties. These maps reflect the concepts imbedded within Soil Taxonomy, as well as the application of Soil Taxonomy during soil mapping. This presentation will provide examples of the insights and questions that arise from thematic maps of soil properties based on Soil Taxonomy, as well as how the process of creating these thematic maps exposes the limitations of what can be obtained from taxonomically-based maps.

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The revised German Soil System - improved structure, new soil types and an alternative diagnostic horizon approach

Dr. Einar Eberhardt¹

¹*Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Germany*

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

German Soil Systematics (part of the soil survey guidelines, current version in the References) has been revised to improve its historically grown structure, to cover very degraded and ameliorated fen and bog soils, to include not yet considered soils (Andosols, Umbrisols and soils affected by lateral translation processes of iron or lime). Because the units of the soil system have been defined by horizon sequences, the link between soil system and horizon designations of the soil description and definition is close. Therefore, horizon designations have been revised to stress main soil forming processes and their expression in the soil horizons. Because horizon sequence definitions of soil systematic units are prone to incomplete or overlapping definitions, they have been changed to diagnostic definitions that make direct use of the horizon designations that in turn explicitly express a wide range of soil morphologic features, deviating from the diagnostic horizon approach of e.g. WRB.

The German soil system covers pedogenesis; it has a complementing soil material classification that considers geogenetic process of the parent material formation, fine earth texture, coarse fragments, lime, lithogenic carbon content and the rock types in three hierarchal levels.

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Classification of paleosols: needs, concepts, and doubts

Prof. Dr. Cezary Kabala¹

¹*Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland*

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

Scientists agree in general that the naming of paleosols should follow the classification systems of modern/surface soils, to stress similar relationships between environmental conditions and soil cover in the past and modern times. However, buried soils often are incomplete (truncated) and altered by post-burial compaction, decomposition of organic matter, weathering of minerals, saturation, and cementation with carbonates, gypsum, soluble salts, etc. Due to these alterations, buried soils commonly do not meet crucial criteria for diagnostic horizons and properties of modern soils, thus the modifications of existing classification systems (WRB in particular) were suggested to classify paleosols. However, the diagnostic criteria are adaptable to relatively young paleosols, while they cannot be applied to soils/rocks after diagenesis. Alternatively, separate classifications for paleosols were developed, based particularly on modified Soil Taxonomy, but the use of standard pedological terminology was questioned as leading to chaos in diagnostic criteria, while the application of specific paleosol names was questioned as nonunderstandable and incomparable with modern soil classifications. Finally, no single taxonomy has been accepted to classify paleosols until now, and most researchers try to apply the existing (modern) soil taxonomies, which provide limited options for buried soils. The Paleopedology Group could discuss the need and possibility for the development of a single separate classification for all paleosols (buried, subburied, fossilised, diagenesed, etc.) or support any of the existing adaptations of international systems. The threat of divergent further development of separate or modified classifications for modern soils and paleosols must be considered.

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Practical evaluation of Soil Taxonomy, Hungarian classification and WRB in terms of NDVI and elevation, inside a salt-affected alluvial plot

Professor Tibor Tóth¹, Bence Gallai², Dr. Tibor Novák³, Dr Szabolcs Czigány⁴, Professor András Makó¹, Dr. Mátyás Árvai¹, Dr János Mészáros¹, Dr Péter László¹, Dr Sándor Koós¹, Dr Mihály Kocsis¹, Dr Kitti Balog¹

¹Institute For Soil Sciences, Centre For Agricultural Research, Budapest, Hungary, ²University of Sopron, Faculty of Forestry, Inst. of Geomatics and Civil Engineering, Dept. of Surveying and Remote Sensing, Sopron, Hungary, ³University of Debrecen, Department for Landscape Protection and Environmental Geography, Debrecen, Hungary, ⁴University of Pécs, Department of Physical and Environmental Geography, Institute of Geography and Earth Sciences, Pécs, Hungary

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

In a salt-affected alluvial plot, increased biomass is associated with increasing elevation and decreasing salt concentration. All four levels of three classification systems, the Soil Taxonomy (ST), the Hungarian classification (HU) and the WRB were evaluated in a 100 m regular grid of 85 profiles for their suitability on biomass (using 10-year average NDVI as proxy) estimation and their correlation with ground elevation.

NDVI values reflecting the soil formation chronological sequences (from least to most developed) were found on the first (least detailed) level of the classification systems. By analysing the aspects of practical applicability, mainly at the detailed levels 3 and 4, HU performed the best in terms of class separability, WRB showed most homogeneous classes, HU provided the closest correlation to the main environmental variable, elevation; and ST operated with the lowest number of classes. Since ST was present with a relatively low number of classes, their homogeneity was lower and revealed a low correlation with elevation. Both HU and WRB performed well in most aspects, but the latter showed greater homogeneity. WRB had twice as many classes as HU and four times as many compared to ST; thus their homogeneity increased accordingly.

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Tóth, T. et al. 2022. Practical evaluation of four classification levels of Soil Taxonomy, Hungarian classification and WRB in terms of NDVI and elevation, inside a salt-affected alluvial plot.

Geoderma (under evaluation)

1855

Paleoclimate, land use and geomorphic changes recorded in archaeological and natural Holocene soils and paleosols of Italy

Prof. Dr. Fabio Scarciglia¹

¹*University of Calabria, Rende (CS), Italy*

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

Paleosols from archaeological and natural sites across Italy provide an overview of Holocene paleoclimate, land use and geomorphic changes in the central Mediterranean region. Different methods contribute to discriminate the role of natural and anthropogenic factors on landscape dynamics. Several paleosols from coastal and inland areas showed a varying volcanic input from Pleistocene and Holocene eruptions, hidden as micrometric cryptotephra in the pedogenic matrix. The volcanic input contributed to the development of andic properties, derived from the weathering of volcanic glass and neogenesis of short-range order minerals. The post-glacial climate amelioration, the Holocene climatic optimum and the late Holocene are marked by different amounts of such poorly crystalline clay minerals in respect of phyllosilicate clays. Their coexistence during the late early to middle Holocene marks a moisture increase with shifts towards drier or seasonally contrasted conditions, confirmed by the recurrence of clay coatings. These pedofeatures are typical of the climatic optimum, prone to forest growth up to Neolithic times (in places supported by charcoal content or $\delta^{13}C$), to soil development and humus accumulation. Erosion, sedimentary aggradation and paleosol burial record a geomorphic instability at 5-3 ka BP in response to short-lived dry phases, possibly amplified by anthropogenic impact since Late Neolithic to Bronze Age and historical times. Forest clearance and a shift from oak to pine forest is recorded by charcoal data in some inland mountain sites. Varying field and microscale features (lithic tools, postholes, ceramics, plow furrows, charcoals, coprolites and bones) record human occupation and activities.

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sequence to a landscape evolution model: Late Pleistocene and Holocene volcanism, soil formation and land use in the shade of Mount Vesuvius (Italy). *Quat. Int.* 394, 155–179.

Open-source Tools for U.S. Soil Taxonomy Applications

Mr. Andrew Brown¹

¹*USDA-NRCS Soil and Plant Science Division, Sonora, United States of America*

12 Division: 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 09:00 - 11:00

Recently there has been a focus on curating taxonomic dictionaries, formative element lists, and computer code for maintenance, development, and application of U.S. Soil Taxonomy.

New open datasets and computational routines using the R programming language are based on official sources including the latest edition of the Keys to Soil Taxonomy and Soil Series Classification databases. Related descriptions and metadata have been aggregated from the U.S. National Soil Information System (NASIS) and Soil Survey Geographic databases to enhance the ability for users to reason over the hierarchical structure of Soil Taxonomy and connect those concepts to their data.

These soil taxonomy related tools are part of a broader effort to promote understanding of core concepts in the U.S. Soil Taxonomic System. Most of the current utilities are for working with taxonomic concepts at the "higher" taxonomic levels: Order, Suborder, Great Group, and Subgroup where a major focus is on bioclimatic properties and diagnostic soil features. Changes to criteria that affect fundamental diagnostic features in Soil Taxonomy can have large influences on classification and, by association, grouping of soil concepts that are similar for use and management in soil surveys. New tools covered in this presentation offer new approaches for understanding the sensitivity of soil class concepts to changes in their underlying criteria. Formalizing the structures of Soil Taxonomy in open-source computer code has the benefit of making reasoning more transparent and accessible to a broad group of end users.

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Soil properties as predictors of biodiversity in forests: Is there a Critical Soil Depth?

Dr. Steffen Seitz¹, Dr. Philipp Goebes¹, Dr. Karsten Schmidt², Dr. Sabine Both³, Prof. Dr. Helge Bruelheide^{4,5}, Prof. Dr. Alexandra Erfmeier^{6,5}, Prof. Dr. Thomas Scholten¹, Dr. Peter Kühn¹

¹*Institute of Geography, University Of Tübingen, Tübingen, Germany*, ²*eScience Center, University of Tübingen, Tübingen, Germany*, ³*Environmental and Rural Science, University of New England, Armidale, Australia*, ⁴*Institute of Biology / Geobotany and Botanical Garden, Martin-Luther University Halle-Wittenberg, Halle, Germany*, ⁵*German Center for Integrative Biodiversity Research (iDiv), Leipzig, Germany*, ⁶*Institute for Ecosystem Research, Kiel University, Kiel, Germany*

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Soils are of particular interest in ecology and particularly in biodiversity research. Soils and topography both are important covariates that have to be taken into account to explain biodiversity effects on ecosystem functions such as productivity. The specific interaction of soil properties and relief positions can positively or negatively affect this relationship. These effects are often non-linear because of specific stable and unstable soil properties and, in consequence, the correlation strength of various biodiversity variables varies with soil depth.

The subtropical forest experiment BEF China was used to investigate how specific sampling depths affect the relationship between soil properties and biodiversity effects, with the aim to determine a "Critical Soil Depth", defined as the depth with the strongest correlation to the ecological variables analysed. These variables such as tree age and species richness were related to pedological variables such as soil texture and soil carbon measured at different depth levels. In addition, topographic information was derived from an elevation model and 66 linear models were calculated.

In this particular forest ecosystem, our analysis revealed the strongest relationship between pedological and topographical information on most ecological variables using a soil column of 0-16 cm (adj. $R^2 \sim 0.7$). The results showed a strong impact of soil depth on soil and biodiversity variables and confirmed the assumption that for specific soil-plant relationships the corresponding sampling depth has a high relevance. This site-specific, optimal sampling depth or "Critical Soil Depth" could thus be set at 16 cm for the BEF China experiment.

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1003

Stimulation of soil nitrogen cycling processes after three years of Free Air CO₂ Enrichment of mature temperate forests at BIFoR-FACE

Professor Sami Ullah¹, Dr Fotis Sgouridis², Dr Suparat Cotchim³, Miss Manon Rumeau¹, Dr Michaela Reay², Dr Jiaojiao Ma¹, Dr Angeliki Kourmouli¹

¹University of Birmingham, Birmingham, United Kingdom, ²University of Bristol, United Kingdom, ³Prince of Songkla University, Thailand

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Increasing atmospheric CO₂ concentrations in temperate forests may affect soil nitrogen (N) cycling processes due to the increased demand for nitrogen by trees to support enhanced CO₂ uptake. The Birmingham Institute of Forest Research (BIFoR) at the University of Birmingham established a Free-Air CO₂ Enrichment (FACE) facility in a mature temperate forest in Staffordshire, UK, where fumigation of three woodland plots with elevated CO₂ (+150 ppm above the ambient) was started in 2017 and continues to date during the growing season. In 2018, 2019 and 2020, we collected soil samples from the three elevated CO₂ (eCO₂) and three control plots to investigate changes and/or shifts in key N cycle processes. Soils were amended in the laboratory with 98 at % ¹⁵N-NH₄⁺ and ¹⁵N-NO₃⁻ and were incubated for 24 hours. Whilst gross N mineralisation and N₂O emission were only marginally higher in eCO₂ compared to controls plots over the three years, there was a significant stimulation of N cycling in 2019 that led to more pronounced differences. Overall, gross N mineralisation, nitrification, and microbial immobilization increased in soils under eCO₂ by a factor of 1.22, 1.25 and 1.22, respectively. Similarly, denitrification and nitrification source N₂O production under eCO₂ increased by a factor of 1.72 and 2.47, respectively, pointing to an overall upregulation of N cycling under eCO₂. BIFoR-FACE is a decadal fumigation experiment, these early responses are further evaluated under in situ conditions to fully account for the role of nutrient availability in constraining CO₂ uptake by trees under future climates.

Soil forest C N P dynamics and pools altered after deciduous native forest conversion to pine plantations.

Ph.D. Felipe Aburto Guerrero¹, MSc. Oscar Crovo², Dr. Pamela Castillo², Ph.D. Susan Trumbore³, Ph.D. Carlos Sierra³, Ph.D. Claudia Czimczik⁴

¹Texas A&M University, College Station, United States, ²Universidad de Concepción, Concepción, Chile, ³Max Planck Institute for Biogeochemistry, Jena, Germany, ⁴University of California Irvine, Irvine, USA

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Even though various studies have highlighted the effects of forest substitution on C sequestration, the role of soil type modulating the impact of forest conversion on ecosystem stoichiometry and biogeochemical cycling has not been well assessed. The sites considered in this study encompass the main forest soil types found in south-central Chile, representing a range of soil properties and mineralogy types (crystalline to amorphous ash derived soils). Two independent plots were established at adjacent Native Forests (NF) and Pine Plantations (PL). We determined the C:N:P inventories of the whole ecosystem (Aboveground and belowground pools) and monitored principal ecosystem C input and output fluxes such as litterfall, litter decomposition, root input, CO₂ efflux, and leachates (DOC/DON/DOP) for almost four years. In addition, we studied cross-litter soil incubations and installed a new system for passive trapping CO₂ for ¹⁴C was established at five additional plots in one of the sites.

Overall, total ecosystem C was significantly higher ($p < 0.05$) in NF. NF has significantly higher C inputs by roots ($p < 0.05$) while PL showed higher litterfall and litter accumulation, although not significant. NF showed higher losses by CO₂ efflux, while PL showed higher losses by DOC.

When comparing each soil type individually, disregarding forest type, the Young Ash soil displayed significantly higher C and N than all the other studied soils. In addition, the Recent Ash soil showed the most extensive changes in soil C:N:P stoichiometry. Soil type greatly determines the expanse of biogeochemical pools and C dynamic alterations derived from native forest conversion.

Crovo, O.; Aburto, F*.; Alborno, M. F.; Southard, R. Soil type modulates the response of C, N, P stocks and stoichiometry after native forest substitution by exotic plantations *Catena*. Quantile: Q1, IF: 4.333, H Index: 106.
<https://doi.org/10.1016/j.catena.2020.104997>

Savanna Soil Carbon: interactive impacts of fire, grazing and climate on soil resilience

Ms Mary Hodgson^{1,2}, Professor Kate Parr³, Dr Jeanette Whitaker², Professor Sally Archibald⁴, Dr Sivu Situngu⁴, Professor Robert McCleery⁵, Professor Nick Ostle¹

¹Lancaster Environment Centre, Lancaster, United Kingdom, ²UK Centre for Ecology and Hydrology, Lancaster, United Kingdom, ³University of Liverpool, Liverpool, United Kingdom, ⁴University of the Witwatersrand, Johannesburg, South Africa, ⁵University of Florida, Gainesville, United States of America

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Fire, herbivory and climate influence savanna vegetation dynamics but their interactive effects on soil properties are poorly understood. These ecosystems are under increasing pressure from human activity and over-exploitation, with changes in fire and climatic regimes. These drivers have the capacity to significantly alter savanna biodiversity and biogeochemical function with implications for dependent human welfare. Specifically, there is considerable uncertainty regarding the potential individual and interactive impacts of these phenomena on the biological and biogeochemical resilience of the underlying soils. A limitation in the literature has been a lack of fire-herbivory manipulations and experiments investigating both above-belowground processes. The consequences of fire-herbivory interactions on soil and grass communities are difficult to differentiate due to their synergistic nature. We present research from fire-herbivory manipulation experiments in Kruger National Park, South Africa. These experiments are being utilised to quantify effects of fire, herbivory and their interactions on soil carbon, nutrient concentrations and microbial communities under different grass species. Using these experiments, we aim to determine the variability in savanna soil properties across gradients and to test whether the biogeochemical resilience of soil is altered by interactions between fire, herbivory and grass species.

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Peatlands spectral data influence in global spectral modelling of soil organic carbon and total nitrogen using diffuse reflectance spectroscopy

Dr Wanderson de Sousa Mendes¹, Professor Dr Michael Sommer¹, Dr Sylvia Koszinski¹, Marc Wehrhan¹

¹*Leibniz Centre for Agricultural Landscape Research, Müncheberg, Germany*

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Peatlands ecosystem is one of the largest global terrestrial carbon pools. However, there is a shortness of its characterisation through proximal sensing. A solution for this can be the diffuse reflectance spectroscopy (DRS), which is a quick, non-invasive, and low-cost analysis. Despite that, there is another current issue in using DRS for creating global models, which is how it can retrieve local characteristics such as soil organic carbon (SOC) and total nitrogen (TN) in peatlands ecosystems. The aims in this study were to: (i) create a local model for quantifying SOC and TN finding the best pre-processing and machine learning methods in peatlands, and (ii) evaluate the contribution of SOC and TN data collected in that ecosystem to global models in European Union. The soil and spectral datasets were retrieved from the Land Use/Cover Area frame Statistical Survey with 21771 observations at 0–20 cm depth and 63 soil cores in a degraded peatland in Germany with 262 observations up to 2 m depth. We evaluated four spectral pre-processing techniques with the Partial Least Square Regression, Random Forest, and Cubist machine learning algorithms. The best pre-processing technique was achieved applying Savitzky-Golay smoothing with Cubist algorithm for both SOC and TN predictions. Merging the local with global data for global modelling improved SOC and TN predictions because of the local data representativeness and quality. The SOC and TN data sampled in peatlands can improve quantification of those soil properties, which are proxies for greenhouse gases emissions and climate change.

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Soil Carbon Stocks as Affected by Land Use Changes in the Pampas of Southern Brazil

Dr Carlos Tornquist¹, Ms Jessica Machado Maciel¹, Mr Jonathas Carvalhedo Johnson¹, Ms Bruna Raquel Winck¹, Ms Elena Polto Taborda¹

¹*UFRGS, Porto Alegre, Brazil*

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

The grasslands of Rio Grande do Sul in Southern Brazil, part of the Pampas ecoregion of South America, have been historically neglected from a conservation stand point (Overbeck et al., 2007). Land use change is accelerating-- approximately 50% of these grasslands have been converted to agriculture and silviculture in the last 35 years (MapBiomass, 2021). Within the Nexus Project "Scenarios for conversion of native vegetation and the sustainability of agroecosystems in the Pampas", we evaluated changes in soil properties (C and N) after conversion of native grasslands (GRAS) under livestock production to cropland (SOY) and Eucalyptus plantations (EUC). We adopted the FAO guidelines for assessment of SOC in livestock systems (FAO, 2019) to conduct our study. Soil samples were collected in pits (to 30 cm depth) within 250m linear plots, allocated to paired sites: grasslands x Eucalyptus x cropland (soybeans-summer x ryegrass-black oats-winter) in 8 representative areas of the Pampas. Samples were analyzed for particle size distribution, soil bulk density (Ds), soil organic C (SOC) and N. SOC stocks were calculated cumulatively to 3 depths (0-10, 0-20 and 0-30cm). Soil C was higher only in the topsoil of GRAS as compared to EUC sites, but not in SOY. Some differences between sites notwithstanding, in general conversion of GRAS to SOY and EUC did not result in reduction of SOC and soil N stocks. The lack of difference observed were likely related to the short time since conversion (10 yrs) and adequate soil management such as no-till or conservation soil practices in Eucalyptus silviculture.

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Long-Term Trends in Calcium and Soil Acidity in Forest Soils After Whole-Watershed Application of Calcium Silicate

Dr. Chris Johnson¹

¹*Syracuse University, Syracuse, United States*

41 WG3.2: Advances in innovative technologies and methods for quantifying biogeochemical cycles of carbon and nutrients in forest soils, Alsh 1, August 2, 2022, 09:00 - 11:00

Chronic acidic deposition resulted in the leaching of calcium from base-poor soils in the northeastern United States. In 1999, wollastonite (CaSiO_3) was experimentally added to a watershed at the Hubbard Brook Experimental Forest in New Hampshire in an attempt to restore the base saturation of the soil to its estimated pre-acidification level. We measured the total Ca in the O horizon and the top 10 cm of mineral soil to track the fate of the added Ca. We also measured soil pH and exchangeable cations to assess the impact of the treatment on soil acidity. By year 19, more than 750 kg/ha of the 1028 kg/ha of Ca that was added to the watershed was no longer in the O horizon or the top 10 cm of mineral soil. Soil pH and exchangeable Ca concentrations increased significantly in organic and mineral soils after treatment. Exchangeable H and Al concentrations decreased significantly. The pool of exchangeable Ca increased significantly after treatment, peaking in the O horizons three years after treatment and in the upper mineral soil seven years after treatment. Soil Al became more tightly bound after treatment. Less than 5% of the added Ca was exported from the watershed in stream water after 19 years, indicating that most of the added Ca remains in soils and forest vegetation. Wollastonite treatment has been an effective means of increasing available pools of Ca in this forest ecosystem.

None

Residual chlorinated organic pollutants in paddy soil may induce methane release as revealed by coupling between methanogenesis and reductive dechlorination

Dr Yan He¹, Dr Jing Yuan¹, Dr Jie Cheng¹, Dr Xueling Yang¹, Dr Jianming Xu¹

¹*Institute of Soil and Water Resources and Environmental Science, College of Environmental and Resource Sciences, Zhejiang University, Hangzhou, China*

44 WG3.4: Mitigation and adaptation strategies for climate change in rice-based systems, Alsh 2, August 2, 2022, 09:00 - 11:00

Residues of chlorinated organic pollutants (COPs) in environment is still a major public concern. Reductive dechlorination is the most efficient way for depletion of COPs in paddy soil, where the methanogenesis is usually mass-produced. Both processes are essentially microbial-mediated electron accepting processes and received much attention in last decades, due to their great importance for soil remediation polluted by COPs, and the effect of global warming, respectively. In this study, we applied meta-analyses, incubation experiment and quantum modelling to investigate the associations between reductive dechlorination and methanogenesis. Results indicated the accelerated methanogenesis were commonly synergistically coupled with the accelerated removal of COPs. Some methanogens were showed as the core taxa co-occurring with dechlorinators in the microbial networks of COP-polluted environments. Also, methanogenic species could promote some COP dechlorination by regulating cell metabolic functions, e.g., the coenzyme F430 could reduce the activation barrier of reductive dechlorination. Further regulation based on a mixed culture through microbial electrolysis cell verified the possibility to synchronously regulate these two processes via the application of suitable electrostimulation. Collectively, our work provides a novel insight into the multiple environmental function of methanogens that likely contribute to COP dechlorination, and the associations between dechlorination and methanogenesis may occurred and can be modified in COP residual paddy soil. Caution is thus necessary to be paid on the potential risk of increased methane release from paddy soil polluted with COPs.

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Under global warming: More organic amendment is essential to compensate soil carbon loss

Hyeon-ji Song¹, Pil Joo Kim Pil Joo Kim^{1,2}

¹*Division of Applied Life Science, Gyeongsang National University, Jinju-si, Republic of Korea,* ²*Institute of Agriculture and Life Sciences, Gyeongsang National University, Jinju-si, Republic of Korea*

44 WG3.4: Mitigation and adaptation strategies for climate change in rice-based systems, Alsh 2, August 2, 2022, 09:00 - 11:00

Since the elevated air temperature and carbon dioxide (CO₂) concentration might simultaneously increase the net primary production (NPP) of plants as a carbon (C) input source and soil respiration rate in the future climate condition, the impact of global warming on soil organic carbon (SOC) stock changes was not clearly concluded. Here we show that open-top chamber experiment in rice paddy to investigate the changes of SOC stock under global warming condition. Three types of atmospheric conditions were installed for a whole year as main treatments: present (14.4°C, 475ppm), after 50 years (16.3°C, 590ppm), and after 100 years (16.3°C, 690ppm). Conventional (NPK) and organic fertilizer treatments which were fertilized by only chemical fertilizer and green manure, respectively, for rice cultivation were additionally placed under each different atmospheric condition. Soil C stock change was estimated by analyzing net ecosystem C balance (NECB) which indicates the difference between C input and output. Under global warming, atmospheric CO₂ enhancement increased the NPP of rice with a quadratic relationship in both fertilizations. In contrast, the NPP of cover crop (hairy vetch and barley mixture) was apparently increased with increasing CO₂ concentration. Soil respiration rates were significantly increased with increasing atmospheric temperature and CO₂ concentration, particularly in fallow season. Under conventional cropping condition, the decline in NECB which indicates soil C stock depletion was observed. Organic farming showed C much higher net C sequestration potential than conventional farming. We concluded that organic amendment application is inevitable to enhance soil C sequestration in global warming era.

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Rice Husk/Biochar Amendment Increases Soil Carbon and Alters Greenhouse Gas Emissions in an Ultisol Paddy Soil

Mr. Frank Linam¹, Dr. Matt Limmer¹, Dr. Angelia Seyfferth¹

¹*University of Delaware, Newark, United States of America*

44 WG3.4: Mitigation and adaptation strategies for climate change in rice-based systems, Alsh 2, August 2, 2022, 09:00 - 11:00

Rice feeds over half the world and its consumption is increasing annually(1,2). The flooded conditions (low Eh) used in rice production results in it being responsible for 12-26% of anthropogenic methane (CH₄) emissions(3,4), which increase with organic amendments(5-9). At higher Eh, nitrous oxide (N₂O) and carbon dioxide (CO₂) are also emitted(3,10-12). Carbon can be sequestered through crop residue incorporation(7,8,13), but greenhouse gas (GHG) emission can outweigh soil organic matter (SOM) buildup in paddy soils(12). Residue management and irrigation also strongly impact dissolved organic carbon (DOC) dynamics in paddy soils(14,15). Rice residue and irrigation must be managed to maximize SOM while minimizing DOC loss and GHG emission. We applied rice husk to Ultisol paddy mesocosms as fresh Husk, low-temperature (450C) Biochar, or CharSil—a product derived from burning husk at >1000C. GHG flux, DOC, and SOM measurements were taken for 3 years following amendment. In addition, a pot study was conducted in tandem using the same soil amendments and including irrigation treatments of flooded, alternate wetting and drying (AWD), and non-flooded. Results suggest that only fresh husk increased CH₄ emissions. Emission of CO₂ was increased slightly with amendments in non-flooded conditions. Emission of N₂O was only seen in non-flooded treatments. Amendments increased SOM by 0.23-0.63% (11-31% relative increase) and changed DOC from -18% to +25% with Husk>Biochar>CharSil. Amendments also caused a change in SOM chemistry seen using FTIR and C-NEXAFS. Results suggest that moderate drainage along with amendment of Husk and Biochar can sequester C.

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Soil saturation degree in rice paddy: the key factor to determine biomass application rate for minimizing global warming impact

Hyeon-ji Song¹, Pil Joo Kim Pil Joo Kim^{1,2}

¹*Division of Applied Life Science, Gyeongsang National University, Jinju-si, Republic of Korea,* ²*Institute of Agriculture and Life Sciences, Gyeongsang National University, Jinju-si, Republic of Korea*

44 WG3.4: Mitigation and adaptation strategies for climate change in rice-based systems, Alsh 2, August 2, 2022, 09:00 - 11:00

Soil organic carbon (SOC) stock plays a crucial role to improve soil quality and mitigate global warming. In a temperate mono-cropping system, cover cropping during long fallow season and its biomass recycling was strongly recommended to increase SOC stock. However, since each soil has its own C saturation potential, continuous biomass application might increase labile organic C stock and then enhance mineralized C loss. In rice paddy, the increased CH₄ emission might make more seriously global warming, comparing with a C sink's effect via soil C sequestration. To investigate the effect of continuous biomass application on labile C accumulation and mineralized C loss in mono-rice paddy, cover crop was cultivated during fallow season and its biomass as green manure was annually applied with different levels (0, 25, 50 and 100%) of aboveground biomass. In the 9th year after the installation, SOC stock was clearly increased with increasing biomass application but maximized at approximately 70% of soil C saturation degree. SOC stock increase was not proportional with biomass application level, but it was changed with exponential rise to maximum. Labile C fraction (non-protected) in soil was significantly increased with increasing biomass application level and soil C saturation degree. In comparison, mineralized C loss was significantly increased with increasing labile C fraction in soil, but the contribution of CH₄ emission on C mineralized loss was more highly increased with increasing biomass application. In conclusion, continuous biomass application without consideration on soil saturation degree can accelerate global warming.

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Rice Root Fe Plaque Formation in North American Paddy Soils

Mr. Frank Linam¹, Dr. Matt Limmer¹, Dr. Angelia Seyfferth¹

¹*University Of Delaware, Newark, United States of America*

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Rice is a staple for over half the world population and has annually increasing consumption(1,2), particularly in the developing world. Unfortunately, rice is also uniquely prone to contamination by toxic arsenic (As)(3,4) due to As mobilization by soil flooding and plant uptake via a highly efficient Si pathway. Rice plants have aerenchyma that supply O₂ to their roots but also result in radial oxygen loss (ROL) into the rhizosphere. ROL allows for oxidation of reduced iron (Fe) to iron oxide minerals (FeOx)(5), which form reddish-orange plaque on the root exterior(6,7). This process can be simulated using O₂-permeable silicone tubing as an “artificial” root(8). Because FeOx are strong adsorbents of As(9,10), this Fe plaque is thought to somewhat protect rice from As uptake(11-18), but its effects on As and nutrient uptake in divergent soils have not been investigated. We grew rice in a pot study using five paddy soils from Arkansas and Delaware (USA) that vary greatly in their extent of weathering to examine the effects of root plaque formation and mineral composition on As and nutrient uptake by rice. Porewater chemistry, temporal “artificial” root plaque composition, mature root plaque composition/mineralogy, and plant chemistry were examined. Results suggest that soil type plays a large role in determining root plaque Fe mineralogy, and that plaque mineralogy greatly impacts retention of oxyanions outside the root. These findings, along with previous work, show that water and nutrient management alter the roles Fe plaque plays in rice nutrition and safety.

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Crop diversity decreases soil organic matter decomposition in the rhizosphere

Mx Imelda Uwase^{1,2}, Prof. Liz Baggs², Dr Kate Buckeridge³, Dr Tim George¹, Dr Eric Paterson¹
¹*The James Hutton Institute, Aberdeen, United Kingdom*, ²*University of Edinburgh, Edinburgh, United Kingdom*, ³*Institute of Science and Technology, Luxembourg, Luxembourg*

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Intercropping is a millennia old practice of growing multiple crops together in the same field. Studies have reported that intercropping can change rhizosphere microbial communities. It is still unclear whether changes in the microbial community structure substantially alter soil processes. Rhizosphere microbes consume root-derived substrates to fuel their activities, including the decomposition of in soil organic matter (SOM) into plant available forms. Roots can indirectly increase or decrease the rates of SOM decomposition.

This experiment was designed to determine whether barley-pea intercropping modifies SOM decomposition rates relative to barley and pea monocultures. The plants were grown in an experimental chamber for 7 weeks. The chamber was continuously supplied with CO₂ enriched with a tracer isotope (¹³C). This labelling approach allowed us to quantify soil respiration and partition it into CO₂ emitted from root activity and microbial utilisation of root compounds and CO₂ emitted from SOM decomposition.

Results showed that throughout the experiment, the temporal dynamics of SOM priming in barley-pea intercrops differs to that of the sum of its parts. Overall, barley-pea intercrops and pea monocrop reduced the decomposition of SOM. An analysis of the phospholipid fatty acid (PLFA) profile of rhizosphere microbes revealed that the rhizosphere microbial community of barley-pea intercropping was like that of the monocrops. In barley-pea intercropping, rhizosphere microbes assimilated more root-derived C relative to the average of the monocrops. This experiment demonstrated that cereal-legume intercropping has the potential to build up SOM through increased microbial utilisation of root substrates and decreased SOM decomposition.

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Drought alters the influence of functional rhizosphere traits on soil aggregation and soil organic carbon dynamics under different maize cultivars

M.sc. Franziska Steiner¹, Andreas J. Wild², Nicolas Tyborski³, Shu-Yin Tung⁴, Tina Köhler^{5,6}, Franz Buegger⁷, Johanna Pausch², Tillmann Lüders³, Sebastian Wolfrum⁴, Andrea Carminati⁶, Carsten W. Mueller⁸, Alix Vidal⁹

¹Soil Science, Technical University of Munich, Freising, Germany, ²Agroecology, Bayreuth Center of Ecology and Environmental Research BayCEER, University of Bayreuth, Bayreuth, Germany, ³Ecological Microbiology, Bayreuth Center of Ecology and Environmental Research BayCEER, University of Bayreuth, Bayreuth, Germany, ⁴Institut für Organische Landwirtschaft, Soil and Resource Management, Bavarian State Research Center for Agriculture, Freising, Germany, ⁵Soil Physics, Bayreuth Center of Ecology and Environmental Research BayCEER, University of Bayreuth, Bayreuth, Germany, ⁶Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland, ⁷Institute of Biochemical Plant Pathology, Helmholtz Zentrum München (GmbH), German Research Center for Environmental Health, Neuherberg, Germany, ⁸Department for Geoscience and Natural Resource Management, University of Copenhagen, Denmark, ⁹Soil Biology Group, Wageningen University, Wageningen, Netherlands

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

The formation of soil structure in the rhizosphere is a multifactorial process determined by complex interactions between root properties, the (micro)biome and physicochemical soil processes. However, the expression of rhizosphere traits is specific to individual plant and crop varieties and is modified under drought to reduce water stress (Klein et al.,2020). These intraspecific variations influence rhizosphere soil structure and offer potential for trait-based crop breeding, as soil aggregation can improve plant resource acquisition under drought and increase soil organic carbon (SOC) stabilization (Mawodza et al.,2020; Poirier et al.,2018). Thus, a deeper understanding of the processes linking rhizosphere traits to soil structure formation under drought is crucial.

We investigated which rhizosphere traits drive soil aggregation and the distribution of SOC in the maize rhizosphere and how this is altered by drought. Therefore, we measured morphological root properties, soil aggregation, SOC distribution, natural ¹³C abundance and microbial enzyme activities in the rhizosphere of 38 maize genotypes. The experiment was conducted in an automated phenotyping facility, where four replicates of each cultivar were grown under well-watered and drought-stressed conditions.

The initial results indicate that soil aggregation in the rhizosphere was partly controlled by physical processes and modified by the individual maize genotypes depending on the expression of specific functional root traits. Drought resulted in an overall reduction of aggregate stability and increased concentrations of maize-derived carbon in the rhizosphere soil of most cultivars. Our data will deepen the understanding of how certain rhizosphere traits can be used to maintain soil functionality under drought.

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Evaluation of Arabian Desert Ornamental Native Plant Species for long-term Impact on Soil Properties, Water Use Efficiency and Mycorrhizal Association

Miss Ayesha Alam¹, Dr. Elke Neumann¹

¹*Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, PO Box #. 15551, District Al Asharej, Al Ain City, United Arab Emirates*

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Public parks and gardens greatly complement the residential and touristic value of cities of the Gulf Region, but maintenance of exotic plant stands requires substantial quantities of irrigation water and fertilizers under the prevailing soil and climatic settings. In recent years, some Arabian desert floral species have been introduced as components of ornamental urban plantations to urban spaces of the Gulf Region, mainly with the intention of plummeting irrigation water expenditure. In a field trial, eight native and four extensively used exotic ornamental plant species were comparatively evaluated for their ornamental values, water use efficiencies, and long-term impacts on properties of a virgin Arenosol in Al Ain, UAE. Native plants i.e., *Convolvulus virgatus*, *Senna italica*, *Tephrosia apollinea*, *Moringa peregrina* and *Tamarix nilotica* had the highest ornamental values and water use efficiencies significantly. After one year of cultivation (2020- 2021), *C. virgatus*, *S. italica*, and *T. apollinea* had left much higher amounts of litter and root biomass behind than the tree species *T. nilotica* and *M. peregrina*, or the exotic plant species. All mycotrophic plants had formed associations with arbuscular mycorrhizal fungi (AMF) under limited resources input levels. Based on obtained results of the analyses of soil organic matter content (SOM), cation exchange capacity (CEC) and water holding capacity (WHC) it can be concluded that integration of ornamental desert native plants into public urban greenery can be a resource-saving strategy to improve the physical and chemical properties of saline and dry sandy soils of the Arabian Desert.

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Using roots to bio-engineer soil: The multi-functional role of cover crop roots to mitigate soil degradation

Dr Csilla Hudek^{1,2}, Dr Zoltan Kevei¹, Cristinel Putinica¹, Lynne Roxbee Cox¹, Dr Lynda Deeks¹, Ceri Dawson¹, Dr Sarah De Baets³, Professor Wilfred Otten¹

¹Cranfield University, Cranfield, United Kingdom, ²Lancaster University, Lancaster, United Kingdom, ³KU Leuven, Leuven, Belgium

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

The study focussed on identifying the role of plant roots of selected cover crop species, in providing soil functions that will reduce or reverse soil degradation and aimed to design cover crop mixtures which maximised soil multi-functionality. A microcosm experiment was carried out using 1m³ lysimeters, growing a variety of cover crops in loam soil for 90 days. Cover crop mixtures comprised of species such as Oat, Rye, Mustard, Buckwheat and Phacelia, were designed based on prior experimentation, studying the individual species' root functional identity and by evaluating their performance on 4 soil ecosystem services. During the growing period dynamic root development was monitored using mini-rhizotrons (CI-600 digital root imager). After harvest roots were cored in four different soil layers at 15 cm intervals and root traits were determined. Root biomass of each plant species in each cover crop combination was quantified using DNA profiling. Soil physical parameters: penetration resistance, bulk density and infiltration were measured. Soil pore networks were determined by using CT imagery and root induced soil aggregate stability by wet sieving.

The Oat based mixtures had a more dynamic root development in the sub soil layer compared to the Rye based mixtures. All mixtures had significantly higher infiltration rate compared to the monoculture cereals. The highest aggregate stability was measured for Oat+Mustard+Buckwheat and the lowest for Rye+Mustard+Buckwheat. Species distribution in the top layer showed the dominance of Rye biomass, in the Rye based mixtures and of the tap rooted species in the Oat based mixtures.

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Hudek, C., Putinica, C., Otten, W., & De Baets, S. (2021). Functional root trait-based classification of cover crops to improve soil physical properties. *European Journal of Soil Science*, 1– 16.

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Response of root development of leaf vegetables to soil heterogeneous fertilization by combined application of phosphorus and water-soluble organic matter

Mr Yutaro Takahashi¹, Masahiko Katoh¹

¹*Meiji University, Kawasaki, Japan*

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Phosphorus (P) immobilization in soils reduces the P use efficiency. It has been known that the application of water-soluble organic matter (WSOM) derived by animal manure compost could suppress P immobilization, resulting in the improvement of the P use efficiency from Brassica Rapa. In the soil, P and WSOM are not homogeneously but heterogeneously distributed in the root zone. The aim of this study was to understand the root development and P-uptake strategy in a plant in the case of heterogeneous P and WSOM distribution. This study designed the plant growth pot with three compartments: one cultivation and two root compartments. The P fertilization treatments could be applied in the root compartments: single P, combined application of P and WSOM, and control. Heterogeneous P application in the root compartment could improve P use efficiency with the root development. However, P combined with WSOM induced the reduction in the root development, suggesting that B. Rapa could absorb sufficient P under the minimal root development due to the high level of available P in the presence of WSOM. The P supply by the combined application of WSOM was high when the available P level was low in the root compartment. In contrast, the P supply by the combined application of WSOM became weak when the available P level in the root compartment was high. This study suggests that B. Rapa can efficiently use P by allocating the root development even under the soil heterogeneously applied P and WSOM.

Takahashi Y., Katoh M., (2021), Suppression of phosphorus immobilization in soil amended with water soluble organic matter derived from different unused biomass resources, Geneva Eurosoil.

Root traits for soil organic matter mineralization: The route to breeding for sustainability

Professor Liz Baggs¹, Dr Jill Cairns², Dr Christian Thierfelder², Dr Manje Gowda³, Professor Tim Daniell⁴, Dr Blessing Mhlanga⁵, Dr Lumbani Mwafulirwa¹, Dr Eric Paterson⁶

¹University of Edinburgh, , UK, ²CIMMYT, Harare, Zimbabwe, ³CIMMYT, Nairobi, Kenya, ⁴University of Sheffield, , UK, ⁵Scuola Superiore Sant'Anna, Pisa, Italy, ⁶The James Hutton Institute, , UK

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Crop varieties with enhanced ability to source nutrients from soil organic matter (SOM) may help to improve nutrient supply in systems where SOM is replenished through management. Using stable isotope approaches and genome-wide association mapping, we demonstrate genotypic variation in a set of maize lines to influence SOM mineralization rates, and we identify the root traits and maize candidate genes associated with this mineralization. We show root length, root diameter and root-derived C mineralization to be strong predictors of SOM-C mineralization. Based on their phenotypic performance, maize lines cluster distinctly from hybrids. This suggests that exploration of the genetic basis of inbred lines can serve as a viable option for targeted maize breeding for sustainable intensification. In accordance with this we identify two candidate genes associated with enhanced SOM mineralization rates: GRMZM2G114362 with functions for proteolysis and peptidase activity, and GRMZM2G170962 for proton-transporting ATP synthase and ATP synthesis, which are associated with the regulation and active release of root exudates into the rhizosphere. It is promising to target these genes to promote root exudate release and to stimulate the microbial community to release nutrients from SOM for crop nutrition. We discuss our findings in the context of sustainable crop production in systems managed to enhance SOM, and the opportunity to capitalise on root trait influences for breeding for sustainability.

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Gowda, M., Cairns, J.E., Mwafulirwa, L., Daniell, T.J., Thierfelder, C., Paterson, E., Baggs, E.M. (2021). Evidence of a plant genetic basis for maize roots impacting soil organic matter mineralization. *Soil Biology & Biochemistry*, 161, 108402.

Thierfelder, C., Paterson, E., Mwafulirwa, L., Daniell, T., Cairns, J.E., Mhlanga, B., Baggs, E.M. (2021). Toward greater sustainability: how investing in soil health may enhance maize productivity in Southern Africa. *Renewable Agriculture and Food Systems*, doi: 10.1017/S1742170521000442.

Modifying soil hydraulic and mechanical properties with contrasting herbaceous plants

Dr David Boldrin¹, Prof Jonathan A. Knappett², Prof Anthony K. Leung³, Dr Kenneth W. Loades¹, Prof Anthony Glyn Bengough²

¹*The James Hutton Institute, Dundee, UK*, ²*School of Science and Engineering, University of Dundee, Dundee, UK*,

³*Department of Civil and Environmental Engineering, School of Engineering, Hong Kong University of Science and Technology, Hong Kong SAR, China*

Interdivisional 4 - Plant soil interactions and their roles in soil formation and sustainable crop production, M1, August 2, 2022, 13:00 - 15:00

Floods are increasing due to land use change and extreme weather caused by global warming (Barros et al. 2014). Soil and soil-plant interactions have a fundamental role in the development of mitigation and adaptation solutions for climate change (Stokes et al. 2014). These solutions demand the understanding of multiple vegetation effects on soil physical properties.

In this study, contrasting herbaceous species (legumes, grasses, and forbs) were selected and grown as monoculture or species-mix in columns of sandy loam soil (bulk density: 1.4 Mg/m³) for five months. Fallow soil was also tested as the control. Saturated hydraulic conductivity was initially tested for each column, and then the columns were monitored for three-weeks of evapotranspiration. Water loss, matric suction, and penetration resistance were measured. Finally, soil was tested for aggregate stability and water retention curves.

Saturated hydraulic conductivity was significantly different between soil columns vegetated with contrasting species and negatively correlated with specific root length. The water stored in the soil was efficiently removed by transpiration (>60% of evapotranspiration). Interestingly, the evapotranspiration in the species-mixes was greater than the average between the single species (measured in the monocultures). Significant increases in penetration resistance and aggregate stability were observed in vegetated soil compared to the control. Species of the same functional type had consistent effects on soil water retention properties and porosity.

Herbaceous plants differed considerably in their ability to alter soil mechanical and hydraulic properties. Substantial scope exists to choose species mixes to manipulate soil for designing nature-based solutions.

Barros VR, et al. (2014) Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press

Stokes A, et al. (2014) Ecological mitigation of hillslope instability: ten key issues facing researchers and practitioners. *Plant and Soil* 377: 1-23. doi: 10.1007/s11104-014-2044-6.

Mapping molecular composition heterogeneity of particulate organic matter during the decomposition of organic fertilizer at different depths

Dr Julien Guigue¹, Dr Christopher Just¹, Siwei Luo¹, Marta Fogt^{1,2}, Prof. Michael Schloter^{1,2}, Prof. Ingrid Kögel-Knabner^{1,3}, Dr Eleanor Hobley^{1,4}

¹Chair of Soil Science, School of Life Sciences Weihenstephan, Technical University of Munich, Freising, Germany, ²Helmholtz Zentrum München, German Research Center for Environmental Health, Research Unit for Comparative Microbiome Analysis, Neuherberg, Germany, ³Institute for Advanced Study, Technical University of Munich, Garching, Germany, ⁴Zentrale Stelle für Informationstechnik im Sicherheitsbereich, Munich, Germany

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

Particulate organic matter (POM) is the main educt of new inputs of organic matter in soils and its chemical fate corresponds to the first stages of the SOM decomposition cascade ultimately leading to the association of organic and mineral phases. We investigated the POM molecular changes during decomposition at a sub-millimetre scale by combining elemental and molecular measurements of POM with laboratory imaging spectroscopy in the Vis-NIR range. We set up an incubation experiment to compare the molecular composition of straw and composted green manure (contrasting C/N ratio) during their decomposition in reconstituted topsoil or subsoil of a Luvisol, and recorded high resolution hyperspectral images of complete soil cores at the start and end of the incubation.

Hyperspectral imaging was combined with machine learning ensembles to map POM alkyl/O-N alkyl ratio and C/N ratio, revealing the spatial heterogeneity in the composition of straw and green manure. Both types of organic amendment were more degraded in the topsoil than in subsoil and we measured consistent trends in molecular changes undergone by straw, with the alkyl/O-N alkyl ratio slightly increasing from 0.06 to 0.07, and C/N dropping by about 40 units. The green manure was more heterogeneous, with no clear molecular changes detected.

The imaging VNIR spectroscopy approach enables high-resolution mapping of the spatial distribution of the molecular characteristics of organic particles in soil cores, and offers opportunities to disentangle the roles of POM chemistry and morphology during the first steps of their decomposition in soils.

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Steffens, M., Zeh, L., Rogge, D.M. & Buddenbaum, H. 2021. Quantitative mapping and spectroscopic characterization of particulate organic matter fractions in soil profiles with imaging VisNIR spectroscopy. *Scientific Reports*, 11, 16725

Nematode amplicon sequencing is useful to reveal inter- and intraregional (functional) biodiversity differences in conventional and organic farming systems

Mr. Lieven Waeyenberge¹, Dieter Slos¹, Thibault Devolder¹, Kristian K. Brandt², Eva Lloret³, Krista Peltoniemi⁴, Stefan Schrader⁵, Merrit Shanskiy⁶, Raúl Zornoza³, József Dezsó⁷, Igor Dekemati⁸, Nikola Grujić⁹, Barbara Simon¹⁰, David Fernández Calviño¹¹

¹ILVO (Flanders Research Institute for Agriculture, Fisheries and Food), Plant Sciences Unit, Merelbeke, Belgium,

²Section for Microbial Ecology and Biotechnology, Department of Plant and Environmental Sciences, University of Copenhagen, Frederiksberg, Denmark, ³Department of Agricultural Engineering, Universidad Politécnica de Cartagena, Cartagena, Spain, ⁴Natural Resources Institute Luke, Natural resources, Soil ecosystems, Helsinki, Finland, ⁵Thünen Institute of Biodiversity, , Germany, ⁶Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia, ⁷Institute of Geography and Earth Sciences, Faculty of Sciences, University of Pécs, Pécs, Hungary, ⁸Department of Agronomy, Institute of Crop Production Sciences, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary, ⁹Department for Entomology and Agricultural Zoology, Institute for Phytomedicine, Faculty of Agriculture, University of Belgrade, Belgrade-Zemun, Serbia, ¹⁰Department of Soil Science, Institute of Environmental Sciences, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary, ¹¹Section for Soil Science and Agricultural Chemistry, Department of Plant Biology and Soil Science, University of Vigo, Ourense, Spain

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

Assessment of soil health through complete analysis of the soil food web is technically daunting and immensely time consuming. Alternatively, selected biotic indicators reflecting the ecological processes and responding to natural or anthropic changes in soil conditions, can be used. Nematodes are recognized as such indicators, but their use is hampered mainly because their microscopic characterization requires specific expertise. However, replacing the microscopic method with an advanced sequencing technique, could result in a high-throughput method for routine and accurate soil biodiversity assessments for the restoration, sustainable use and protection of soils.

During a survey across nine European pedoclimatic regions, 188 fields of conventional and organic farming systems were sampled. The nematode communities were extracted by zonal centrifugation and from each an amplicon sequencing library was constructed (490 bp, 18S rRNA gene). All libraries were sequenced (Illumina MiSeq 2x300bp) and compared with an in-house curated nematode sequence database comprising more than 700 genera (DNA-metabarcoding). Biological and functional biodiversity analyses showed that the nematode biodiversity is directed more by the region than the farming systems (Permanova, $R^2=34\%$ and $<1\%$ respectively). If we investigate the nematode communities per region, the grouping of communities is established only for maximum 23% by the farming systems. Similar results were obtained after analysing prokaryote, fungi, earthworms, and confirms the applicability of nematode amplicon sequencing for the mentioned objectives. This work was funded by the H2020 program through the SoildiverAgro-project grant agreement 817819.

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Probing the nature of soil organic matter: a theory-driven review

Dr Han Weng¹, Professor Johannes Lehmann², Dr Lukas Van Zwieten³, Professor Stephen Joseph⁴, Dr Braulio S. Archanjo⁵, Dr Bruce Cowie⁶, Dr Lars Thomsen⁶, Dr Mark J. Tobin⁶, Dr Jitraporn Vongsvivut⁶, Dr Annaleise Klein⁶, Dr Casey L. Doolette⁷, Dr Helen Hou¹, Professor Carsten W. Mueller⁸, Professor Enzo Lombi⁷, Professor Peter M. Kopittke¹

¹*School of Agriculture and Food Sciences, The University of Queensland, St. Lucia, Brisbane, Australia,* ²*Soil and Crop Science, School of Integrative Plant Science, Cornell University, Ithaca, United State,* ³*NSW Department of Primary Industries, Wollongbar Primary Industries Institute, Wollongbar, Australia,* ⁴*University of New South Wales, Sydney, Australia,* ⁵*Divisão de Metrologia de Materiais - DIMAT, Instituto Nacional de Metrologia, Normalização e Qualidade Industrial -INMETRO, Duque de Caxias, Brazil,* ⁶*Australian Synchrotron, Clayton, Australia,* ⁷*Future Industries Institute, University of South Australia, Mawson Lakes, Australia,* ⁸*Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark*

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

Soil organic carbon management is a nature-based carbon dioxide removal technology which removes and sequesters carbon from the atmosphere whilst at the same time contributing to soil health and agricultural productivity. The soil science communities are refuting the traditional assumptions of the nature of soil organic matter (SOM) as based on 'humic substances' that are operationally-defined and have not been observed by contemporary, in situ spectromicroscopic techniques. Instead, new theories suggest that the interactions between molecular diversity of organic compounds, their spatial heterogeneity and temporal variability controls the formation and persistence of SOM. A mechanistic understanding of these processes occurring within organo-mineral and organo-organic assemblages requires non-invasive techniques that minimize any disturbance to the physical and chemical integrity of the sample. Here, we present a theory-driven review where a combination of in situ methods serve as potential solutions to better understand the persistence and dynamics of SOM and its effects on nutrient distribution at a micro- and nano-scale. We explore underlying theories in light of advances in available methodologies, their historical development and future opportunities. Examples of interdisciplinary approaches that have been utilized in other areas of science but not in soils offer both deductive and inductive analytical opportunities. We show how different conceptual methods across scales inform each other, and how important and indispensable high-resolution investigations are to resolving next-generation questions.

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Simulating root exudation processes using microdialysis – examining short-term C supply and N availability in near real-time

Dr Scott Buckley¹

¹*Swedish University of Agricultural Sciences, Umeå, Sweden*

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

Root exudation is a widely studied plant function that has implications for many soil processes. Examining these processes can be challenging with the methods we commonly use, which are prone to artefacts or disturbances that can alter soil conditions unrealistically. We will show work spanning several studies demonstrating the potential for microdialysis to simulate realistic diffusive root exudation release patterns and rates in soil at relevant spatial and temporal scales, whilst simultaneously measuring their influence on N availability and free enzyme activity. We conducted microcosms studies with a boreal organic soil sampled near Rosinedal, Sweden. Sucrose release via microdialysis rapidly reduced daily fluxes of inorganic N but increased fluxes of amino acids over a 7-day period, which suggested that microbes favourably immobilised inorganic N when labile C was available. Diffusive release rates of sucrose varied over time, suggesting exudation rates may be influenced by microbial demand. We also found that in situ oxidative enzyme activity (also sampled with microdialysis) is influenced by sucrose supply – most significantly in N-limited soil – highlighting the hotspot role the rhizosphere may play in C and N cycling under N limitation. We discuss some of the caveats with the technique, but present microdialysis as a useful tool for examining rhizosphere research questions with a new lens. Buckley, S., Brackin, R., Näsholm, T., Schmidt, S., Jämtgård, S. (in press). The influence of sucrose on soil nitrogen availability – a root exudate simulation using microdialysis. *Geoderma*

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Molecular-level characterisation of damaged and restored peat soils using molecular tagging and advanced NMR spectroscopy

Mr Richard York¹, Dr Nicholle Bell¹

¹*School of Chemistry, University of Edinburgh, Edinburgh, United Kingdom*

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

The ecological and environmental importance of peat cannot be understated; it represents the largest terrestrial carbon store worldwide and a home to unique flora and fauna. Its damage threatens habitat destruction and release of carbon into the atmosphere and natural waters. In order to restore damaged peatlands and protect those in near-natural condition, indicators of peat status and quality must be found. The most comprehensive indicator is the molecular composition of peat, but this remains elusive due to the fact that it is an incredibly complex mixture. The most viable analytical tool to achieve this endeavour is NMR spectroscopy, which is capable of assigning resonances to individual compounds. However, even using the most advanced NMR experiments at our disposal, full characterisation is hindered by the presence of thousands of similar molecules. One promising method to enable structure determination of individual molecules in NOM is molecular tagging: chemical modification of the predominant functional groups within the molecules of organic matter, inserting NMR-active nuclei to act as reporters on their chemical environment. When combined with high-resolution NMR, these tags filter out the vast majority of signals of untagged molecules, allowing dramatic simplification of spectra. Here we present the application of previously reported molecular tagging methods to whole peat samples in order to study molecular markers of peat decomposition, as well as the development of further tagging methods and advanced NMR techniques. Samples are drawn from damaged, restored and near-natural Scottish peatlands in order to evaluate restoration efforts at the molecular level.

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The "QuantiSlakeTest", a low-tech technique for assessing structural stability of soils in farming systems

Dr Frédéric Vanwindekens¹, Dr Brieuc Hardy¹

¹*Centre Wallon De Recherches Agronomiques, Gembloux, Belgique*

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

Soils are at the heart of agro-ecosystems. In various parts of Europe, soils, their structure and function are under pressure from intensive farming practices and global changes.

We have developed a low-tech approach to assess the structural stability of soils. The QuantiSlakeTest is based on the principle of a continuous quantitative measurement of the disintegration of a soil sample immersed under water.

To compare the modalities of the different treatments, the curves are normalized and a series of synthetic indicators are calculated based on the analysis of the curves (e.g. relative weights at stabilization, time to reach the maximum relative weight after immersion, different slopes, area under the curve).

The application of the QuantiSlakeTest on samples taken from different long-term trials shows significant differences between the cultivation practices. The most important differences are observed between ploughed and conservation tillage plots. These results obtained under controlled conditions were also observed to compare the practices of a network of farmers in Wallonia.

Our results were compared to those obtained by applying the method of Le Bissonnais (1996) on samle from the plots of the long term trials. Some of our indicators are correlated with the fast-wetting test of Le Bissonnais (1996), which targets soil resistance to slaking. Other indicators are correlated with the slow-wetting test of Le Bissonnais (1996), which indicates that the effect of slaking on soil disaggregation decreases over time whereas that of clay dispersivity increases. Le Bissonnais, Y. (2016), Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. *Eur J Soil Sci*, 67: 11-21. https://doi.org/10.1111/ejss.4_12311

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Space-Time selection of soil samples for local calibration of spectral models

Dr Mario Fajardo¹, MSc Angelo Benvenuto², Dr Osvaldo Salazar²

¹The University of Sydney, Sydney, Australia, ²Universidad de Chile, Santiago, Chile

Interdivisional 9 - Novel methods and techniques, Lomond Auditorium, August 2, 2022, 13:00 - 15:00

A common practice in the creation of predictive models of soil properties (i.e. soil organic carbon) using spectral information is to use global and/or local spectral libraries (Rossel, 2016). The main inconvenient in the use of large spectral libraries in local scenarios is that they tend to perform poorly compared with local datasets. Recent research (Ng, 2022) has tested a way to "localize" models using a combination of both global and local spectral libraries together with promising results while other research has found ways to "augment" spectral models using environmental covariates (Moura-Bueno, 2021).

An important fact in using environmental covariates is that they are highly affected by temporal changes (e.g. global warming), if a spectral model is meant to be "augmented" with environmental data, then special attention needs to be given to an appropriate selection of them.

The hypothesis of this work is that the process of localization can be performed to both the spectra and the environmental covariates, and the selection of an appropriate training dataset can be optimized using an appropriate sample that captures the spectral, the spatial and the time variability, including the time domain as an additional attribute.

The methodology makes use of remotely sensed timeseries of soil temperature and moisture altogether with soil spectra at different locations (global and local) with a non-linear dimensional reduction known as UMAP (McInnes, 2018) that preserves both the global and local variability of the original. The method will be tested in spectral libraries from Australia and Chile.

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Fundamental Changes in Soil Taxonomy

Dr. Mark Stolt¹

¹*University of Rhode Island, Kingston, USA*

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

Soil Taxonomy has become increasingly complex over the past 50 years and the number of taxa has grown almost exponentially. This complexity detracts from the ability of Soil Taxonomy to serve the needs of increasingly diverse users. In this paper we review several proposed fundamental changes to Soil Taxonomy with the intention of creating a system that is less complicated, more user-friendly, and that can serve as an effective and engaging tool for the soil science community to reach other disciplines and communities that use soils information. We are not proposing changes to the general architecture of Soil Taxonomy, but rather changes in definitions, criteria, concepts, and format (what is emphasized within each category). Examples include simplifying the definition of organic soil material, recognizing wet soils at the highest level (order), moving moisture regime from the suborder to the family level, and harmonizing meanings across the hierarchy. We believe that purposeful and well-designed changes to Soil Taxonomy have the potential to make the system easier to use and have more meaningful classes across the various levels of classification.

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Soil formation paths in West-Mediterranean calcareous stone-wall bench terraces

Mr Danny Itkin¹, PhD Rosa M. Poch², PhD Curtis Monger³, PhD Uri Shaanan⁴, PhD Jordi Bolòs², PhD Onn Crouvi⁴, Mrs Nurit Ben Hagai⁵, PhD Haim Goldfus¹

¹*Ben-Gurion University of the Negev, Beer Sheva, Israel*, ²*Universitat de Lleida, Spain, Lleida, Spain*, ³*New Mexico State University, Las Cruces, USA*, ⁴*Geological Survey of Israel, Jerusalem, Israel*, ⁵*Zemach E. Agriculture technologies, N/A = Not Applicable, Israel*

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

Stone-wall bench terraces constitute the most common archaeological landform. However, the soils of man-made terraces are absent from soils textbooks, classification systems and maps. Here, to portray the development of terrace soils in space and time, we examined the morphology, micromorphology and physico-chemistry of five dated terrace soil profiles (1200-1810 CE) from North East Iberia. The examined terrace soils are >1.5 m thick with brownish colours, granular to sub-angular blocky structure, friable consistence, silt loam texture, moderate alkalinity, high CaCO₃ content, low to moderate phosphorus content, very little organic matter, low exchangeable sodium percentage, and cation exchange capacity values typical of illite clays. Significant properties (e.g., organic matter and phosphorous), show irregular trending values across the profiles. Micromorphology indicates cohesively welded peds in a vughy microstructure, groundmass with an open porphyric coarse/fine related distribution, abundant content of charred matter and slight discontinuous carbonate recrystallization, mostly biogenic. We suggest that pedogenesis in these soils involve substantial thickening (expectingly increasing the water holding capacity), inheritance of ex-situ aggregates, structure development under the influence of anthroturbation and bioturbation, and scarce lessivage and calcium carbonate redistribution. We propose to classify the studied soils as archaeological Anthraltic Xerorthents (archaeo-quasi-Terric Anthrosols (Escalic)) and archaeological Typic Haploxerolls archaeo-quasi-Terric Anthromollic Anthrosols (Escalic)) and suggest four morpho-stratigraphic units for terrace fill material. We argue that early stages of terrace soil pedogenesis question past paradigms of 'time zero' and 'soil maturity', and propose a model for the state of entropy and development of terrace soils.

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Relict Charcoal Hearth (RCH) soils – properties and classification

Prof. Dr. Thomas Raab, Dr. Alexandra Raab, M.Sc. Alexander Bonhage, Dr. Anna Schneider

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

Relict Charcoal Hearths (RCHs) are remnants of past anthropogenic activity and are extensively found in Europe and North America. In the last decade a rising number of studies have revealed the significance of RCH soils for the field of pedology, as well as archaeology, geomorphology and ecology. This emerging topic urgently requires better harmonization between disciplines and researchers. Important steps are needed to better understand RCHs in tandem with a promotion of interdisciplinary research in the proper classification of RCH soils in national and international soil taxonomies. Described hereafter are the main properties of RCH soils used referentially to establish a widely applicable classification scheme. The most distinct feature of RCH soils is the charcoal-rich technogenic substrate resulting in higher C-contents. In addition, their most prominent characteristics are the low bulk density and high porosity. The typical porosity of RCH soils results in differing water infiltration patterns and rates, water retention, and heat transfer. RCHs in sloped terrain often have multiple technogenic layers separated by intermediate mineral colluvial substrate, all with a varying thickness depending on the slope position at the platform. The topsoil horizons below RCHs are modified to varying degrees, mainly depending on the type and terrain position of the sites. Buried A horizons below the technogenic layers often show slightly reduced SOM contents, and at some sites soil below the technogenic substrate is further influenced by thermally-induced transformation of iron (hydr-) oxides and the formation of hematite, apparent in a reddish colour of the buried substrate.

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Paleoenvironmental signification of Late Pleistocene Palustrine calcretes in the Maipo basin, Central Chile

Mr Marco Pfeiffer¹, Ms. Pilar Vargas², Dr. Valentina Flores-Aqueveque², Dr Maria Laura Carrevedo³, DR. Moisés Valladares⁴, Dr. Tania Villaseñor⁵

¹*Departamento de Ingeniería y Suelos, Facultad de Ciencias Agronómicas, Universidad de Chile, Santiago, Chile,*

²*Departamento de Geología, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Santiago, Chile,*

³*Institute of Ecology and Biodiversity (IEB), Sanitago, Chile, , Chile,* ⁴*Grupo de Investigación en Biodiversidad y Cambio Global (GBCG), Universidad del Bío-Bío, Chillán, Chile, Chillan, Chile,* ⁵*Instituto de Ciencias de la Ingeniería, Universidad de O'Higgins, Rancagua, Chile*

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

On the western edge of the Maipo basin, where the alluvial fill meets the foothills of the Coastal Range, exist a series of localized but widely distributed patches with cemented calcium carbonate soils. These surface calcic rich deposits, gave origin to the locally known Agua del Gato soil series, which is of variable thickness and is covered by an organic deposit (peat). This soil represents one of the few examples that exist worldwide of recently formed wetland calcretes. Their particular location close to modern water flows, suggests that they are deposits formed in riparian wetland environments. The macrofacies and microfacies found suggest a wetland environment with fluctuations in the phreatic level that allow to indicate subaerial and flooded environments of shallow depth, with sporadic episodes of fluvial deposition. The presence of gastropods, ostracods, carophytes and diatoms account for a very productive environment, which would have formed after the Last Glacial Maximum, according to preliminary radiocarbon dating in gastropods shells. The Agua del Gato calcrete provides valuable palaeoenvironmental information of the late Pleistocene in the area, contributing to the scarce record existing to date at this latitude, while also presenting itself as an analogue for the few recent records of existing palustrine calcretes worldwide.

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The paleo-environmental reconstruction of a central-southern Apennine peat bog and the implications in the climate changes

Dr Erika Di Iorio, PhD Luana Circelli, Prof Claudio Massimo Colombo

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

The peat bogs represent an important sink full of paleo-environmental information and play a decisive role in determining the future carbon balances under changing climatic conditions. Since peatlands in the Alpine region have been largely studied, up to now, no systematic paleo-environmental studies have been carried out in one of the southern Apennine peat bogs. For this purpose, a fen, located in Molise region in central Apennines, was studied.

High-resolution and systematic geochemical studies, combined with magnetic, palynological and clay mineralogy data, were carried on 4 m undisturbed peat cores, sampled into 10 cm sections. Our measurements showed an important variation of the physical and chemical properties along the 400 cm of the peat column.

The results suggested that the peat bog sequence could be separated into three units, according to pedo-climatic environments.

The first two units (0-199 and 200-300cm) were characterized by a low magnetic susceptibility degree, suggesting that detrital input signals were affected by anaerobic dissolution processes, and a first geochemical anomaly (Be, Rb), probably due to eolian deposits of volcanic ash, and the presence of *Abies alba* pollen (6000 cal BP).

Lastly, the unit 3 (300–400 cm) is characterized by the greatest value of para-magnetic properties, the clay assembly dominated by smectite, index of dry climate, forest succession dominated by *Abies/Fagus sylvatica*.

In conclusion, combination of magnetic properties, trace elements, palynological and mineralogical data is a viable framework for reconstructing the paleo-environmental changes of this sequence.

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Could Vertisols record geomorphic history in volcanic landscapes of Mexico?

Dr. Elizabeth Solleiro-Rebolledo¹, Dr. Sergey Sedov, MSc Thania Garcia-Zeferino

¹UNAM, Mexico, Mexico

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

Vertisols are present in almost every climatic zone of the world and constitute a nearly continuous soil cover in flat areas and depressions. In volcanic landscapes, the influence of the basic-andesitic lavas together with climates of strong seasonality, seems to be crucial factors for their development, while the time span for their formation is several thousand years. In the volcanic environments of Mexico, Vertisols can be found in different relief positions, conforming a continuous and homogeneous mantle. They can occupy areas in the top of volcanoes, at the slope positions and at the valley bottoms. It is common to find Vertisols associated to pre-Hispanic structures, therefore they form in only hundred years. Which factor controls the evolution of Vertisols in the volcanic landscape of Mexico? Studies in the western sector of Mexico, where the Guanajuato-Michoacan volcanic field is located, have shown the contribution of re-worked, pre-weathered materials, for a more rapid pedogenesis. In this area, we constructed a catena from the top of volcanic structures to the alluvial plain of the Lerma River. Micromorphological observations reveal that soils in different geomorphic positions contain soil fragments with vertic features in a dark groundmass. Particularly, a mixture of reworked Vertisols with fresh volcanic glass over an ancient “house” dated to the Classic (around 500 AD) evidence the effect of geomorphic processes which produce mudflows downslopes. In this way, these Vertisols can store information about past catastrophic events.

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K-Ar dating and oxygen isotopic analysis for tracing Asian dust inclusion in aeolian depositions during the last glacier period

Dr Atsushi Nakao¹, Ms Mai Terashima¹, Dr Crawford Elliott², Dr Marion Wampler², Prof Ryoji Tanaka³, Prof Junta Yanai¹, Prof Takashi Kosaki⁴

¹Kyoto Prefectural University, Kyoto, Japan, ²Georgia State University, Atlanta, United States, ³Okayama University, Misasa, Japan, ⁴Aichi University, Hiraike-cho, Japan

12 Division - 1 Commission 1.4, Commission 1.6 – Soil classification and palaeopedology, Boisdale 1, August 2, 2022, 13:00 - 15:00

Aeolian mantles consisting of mixtures of Quaternary volcanic ash and Asian dust widely cover land surfaces in Japan. Although minerals in Asian dust has paid less attention than those derived from volcanic ash because of smaller impacts on major soil physicochemical properties, nowadays has seen renewed interest in mica-vermiculite in Asian dust, since they are a limited source of permanent negative charges to selectively adsorb monovalent cations as K^+ , NH_4^+ and Cs^+ . To clarify the origin of mica-vermiculite in eolian mantles to be Asian dust, a combinational use of two fingerprinting methods was proposed in this study.

Fifteen soil samples were vertically collected from > 3 m of stratified layers of aeolian deposits on the uplifted Pleistocene marine terrace, located at 30 km east of Quaternary volcano Mt. Sanbe (Shimane, Japan) and 20 km south of the Sea of Japan. The 2-20 μm particles were fractionated from these soils. The $^{18}O/^{16}O$ ratio in quartz isolated from the 2-20 μm particles was determined to obtain $\delta^{18}O$ values. The concentrations of ^{40}K and ^{40}Ar in the 2-20 μm particles were determined to obtain the value of K-Ar age.

Both $\delta^{18}O$ and K-Ar age took a wide range between volcanic and Asian dust endmember values ($\delta^{18}O$; 8.6 - 15.1‰, K-Ar age; 12 - 400 Ma) and they were positively correlated ($r = 0.79$, $p < 0.01$). These values enabled us to clarify the presence of ca. 1 m of Asian-dust-derived layers that had deposited in this region during the last glacier period.

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Anthropogenic and climatic stressors interact to disrupt soil communities and nutrient cycling

Dr. Jane Lucas¹, Dr. Michael Strickland²

¹*Cary Institute of Ecosystem Studies, Millbrook, USA*, ²*University of Idaho, Moscow, 83843*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Soils contain immense diversity and support terrestrial ecosystem functions, but they face both anthropogenic and environmental stressors. While many studies have examined the influence of individual stressors on soils, how these perturbations will interact to shape soil communities and their ability to cycle nutrients is far less resolved. Here, we hypothesized that when soils experience multiple stressors their ability to maintain connected and stable communities is disrupted, leading to shifts in C and N pools. To test this, we maintained soils across three temperatures representative of seasonal variability (15, 20 and 30 °C) and introduced high or low doses of the common livestock antibiotic Monensin. We monitored respiration and examined changes to microbial communities through amplicon sequencing and network analyses. We also examined soil C and N pools to understand how temperature and antibiotics shape ecosystem function. We found that antibiotics and rising soil temperatures interacted to disrupt bacterial assemblages and network structure, allowing for a rise in fungal dominance and change in soil nutrient stoichiometry. Antibiotics alone decreased bacterial diversity, abundance, total extractable N, and microbial carbon use efficiency, while increasing bioavailable C. Higher temperatures independently homogenized fungal community composition, decreased dissolved organic C and increased soil respiration rates. These results emphasize that as soils encounter multiple stressors, ecosystem efficiency, stability and resilience may be diminished.

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Microbial inputs at the litter layer translate climate into altered organic matter properties

Dr. Lukas Kohl^{1,2,3}, Dr. Allison Myers-Pigg¹, Dr. Kate A. Edwards², Prof. Sharon A. Billings³, Mr. Jamie Warren, Ms. Frances A. Podrebarac¹, Prof. Susan E. Ziegler¹

¹Department of Earth Sciences, Memorial University, St. John's, Canada, ²Department of Agricultural Sciences, Helsinki University, Helsinki, Finland Institute for Atmospheric and Earth System Research/Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland, ³Institute for Atmospheric and Earth System Research/Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland, ⁴Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, Corner Brook, Canada, ⁵Department of Ecology and Evolutionary Biology, Kansas Biological Survey, University of Kansas, Lawrence, USA

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Plant litter chemistry is altered during decomposition but it remains unknown if these alterations, and thus the composition of residual litter, will change in response to climate. Selective microbial mineralization of litter components and the accumulation of microbial necromass can drive litter compositional change, but the extent to which these mechanisms respond to climate remains poorly understood. We studied litter decomposition along a boreal forest climate transect to investigate how the composition and/or metabolism of the decomposer community varies with climate, and if that variation is associated with distinct modifications of litter chemistry during decomposition. Changes in litter chemistry and $\delta^{13}\text{C}$ values were measured in litterbag experiments conducted at each transect site. A warmer climate was associated with higher litter nitrogen concentrations as well as altered microbial community structure (lower fungi:bacteria ratios) and microbial metabolism (higher $\delta^{13}\text{C}_{\text{PLFA}}$). Litter in warmer transect regions accumulated less aliphatic-C (lipids, waxes) and retained more O-alkyl-C (carbohydrates), consistent with enhanced ^{13}C -enrichment in residual litter. These results suggest that chemical changes during litter decomposition will change with climate, driven primarily by indirect climate effects rather than direct temperature effects. A positive correlation between microbial biomass $\delta^{13}\text{C}$ values and ^{13}C -enrichment during decomposition suggests that change in litter chemistry is driven more by distinct microbial necromass inputs than differences in the selective removal of litter components. Our study highlights the role that microbial inputs during early litter decomposition can play in shaping surface litter contribution to soil organic matter as it responds to climate warming.

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Biochar and co-inoculated plant growth promoting bacteria enhanced Inorganic NPK fertilizer uptake and use efficiency by maize

Dr Christian Adler Phares¹

¹*University of Cape Coast, Ghana, Ghana*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Field research was conducted to investigate the effect of biochar and co-inoculation with plant growth promoting bacteria on the uptake and use efficiency of inorganic NPK fertilizer applied to nutrient deficient dry coastal savannah tropical soil in Ghana. The study was conducted in the major cropping seasons of 2020 and 2021 with seven treatments including: control, NPK (half rate (HR): 60: 30:30 kg ha⁻¹), NPK (full rate (FR): 120-60-60 kg ha⁻¹), NPK (FR) + biochar (1500 kg ha⁻¹), NPK (HR) + biochar (1500 kg ha⁻¹), NPK (FR) + biochar (1500 kg ha⁻¹) + P + B, NPK (HR) + biochar (1500 kg ha⁻¹) + P + B.

The inclusion of PGPB species showed a significant increase in nitrogen, phosphorus and potassium uptake and use efficiency relative to the use of NPK fertilizer or biochar alone. Additionally, the uptake and use efficiency of inorganic fertilizer at both half rate and full rate were not significantly different due to the presence of PGPB. This is an indication that farmers could apply inorganic NPK fertilizer at half rate and outcome similar to that of full rate of application. The soil pH significantly decreased in sole inorganic NPK plots but increased in NPK + biochar plots. Moreover, organic C, dehydrogenase activity and metabolic quotient were significantly higher in plots amended with NPK+ biochar with PGPB compared with sole NPK or NPK+ biochar plots. The use of PGPB in combination with biochar is a promising strategy to enhance use efficiency of inorganic NPK fertilizer.

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Energetic Return on Investment Determines Overall Soil Microbial Activity

Louis J.P. Dufour¹, Anke Herrmann¹, Julie Leloup², Cédric Przybylski³, Ludovic Foti², Luc Abbadie², Naoise Nunan²

¹Department of Soil and Environment, Swedish University of Agricultural Sciences, P.O. Box 7014, SE-75007, Uppsala, Sweden, ²Institute of Ecology and Environmental Sciences, iEES Paris, Sorbonne Université, CNRS, IRD, INRA, UPEC, Univ Paris Diderot, 4 place Jussieu, 75005, Paris, France, ³Sorbonne Université, CNRS, Institut Parisien de Chimie Moléculaire, IPCM, 4 Place Jussieu, 75005, Paris, France

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Microbial communities are a critical component of the soil carbon (C) cycle as they are responsible for the decomposition of both organic inputs from plants and of soil organic C. However, there is still no consensus about how to explicitly represent their role in terrestrial C cycling. The objective of the study was to determine, using a bioenergetics approach, how the properties of organic matter affect the metabolic response of the resident microbial communities in soils. This was achieved by cross-amending six soils with excess water-soluble organic matter extracted from the same six soils and measuring heat dissipated due to the increase in microbial metabolic activity, in order to replicate conditions in activity hotspots.

Microbial metabolic activity was measured as heat dissipation following the addition of soil organic matter by isothermal calorimetry during a 24 h incubation period. The soil bacterial community structure was determined by 16S rRNA gene sequencing. The energetic return on investment that microorganisms acquire from the available organic C was determined experimentally using Fourier transform ion cyclotron resonance mass spectrometry and bomb calorimetry.

Here, we show that the energetic return on investment was positively related to the overall metabolic response of microbial decomposers. However, the observed temporal differences in metabolism across soils indicate that bacterial communities do not exploit energetic return-on-investment in the same ways. Overall, this suggests that soil microorganisms preferentially transform substrates with higher energetic return on investment. We will present this bioenergetics framework and evaluate its significance for terrestrial carbon cycling in soils.

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Bioprospection and sentinel organisms as monitoring tools for assessing the impact of climate warming on soils in the Canadian North

Dr Paul George^{1,2,3}, Dr Anne Jungblut⁴, Dr Alexander Culley^{3,5}, Dr Jacques Corbeil^{1,2}

¹Département de médecine moléculaire, Université Laval, Québec, Canada, ²Centre de recherche en données massives, Université Laval, Québec, Canada, ³Centre d'études nordiques, Université Laval, Québec, Canada, ⁴Life Sciences Department, Natural History Museum, London, United Kingdom, ⁵Département de biochimie, de microbiologie et de bio-informatique, Université Laval, Québec, Canada

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Climate warming is causing significant changes at higher latitudes. Largely hidden from growing public awareness, rising temperatures destabilize soils in the Arctic and sub-Arctic, causing rapid and profound shifts in microbial biodiversity (1). As a result, there are concerns that undescribed microbes will go extinct as their unique habitats are lost, and others will be selected as new vegetation regimes take hold. Here, we characterise the soil communities from various habitats of Canada's North. We apply modern sequencing techniques and a novel isolation method, the EcoChip (2), to identify sentinel microorganisms and producers of potential biomedical compounds. Soils were collected around Whapmagoostui-Kuujuuarapik, Québec, Canada. Three soil cores of 30 cm depth x 10 cm diameter were collected from 5 habitats. Cores were frozen and transported to Université Laval for homogenisation. Samples were incubated at different elevated temperatures (+2 and +4 °C), after which DNA will be extracted 2 weeks after each step. Communities were compared to a baseline composition under natural conditions. We also present results of a parallel experiment using the EcoChip, a novel platform for the in situ isolation, monitoring, and culturing of bacteria in the field. Here, we attempted to isolate microbes under the same incubation conditions. Data are still being analysed but we expect to see different organisms isolated at each temperature treatment. Together, our results present a potential trajectory for northern microorganisms under climate warming. These will guide urgently needed field assessments and bioprospecting initiatives to promote sustainable policies in Canada's North.

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Molecular approaches to examine microbial diversity (long-term experimental sites)

Mr Matias Fernandez², Dr John Elphinstone, Proff. Matthew Goddard, Dr Ian Adams, Dr Joana Vicente

¹Fera Science, York, United Kingdom, ²University of Lincoln, Lincoln, United Kingdom

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Biological communities have been described as an important factor in Soil Health, whether recycling nutrients, improving plant growth, suppressing plant pathogenic organisms or forming beneficial symbiotic associations with plants. The present study aims to improve understanding of the diversity of soil biology and how it responds to common management practices within the agricultural sector so that soils can be managed to safeguard essential biological functions that ensure crop productivity as well as ecological and human sustainability. A combination of six experimental sites as part of the SBSH Partnership was under investigation to study long-term effects of different organic soil amendments, drainage treatments, tillage approaches, pH levels and fertilizer applications. Soil biodiversity has been analysed using metabarcoding procedures following PCR amplification of 16S and ITS rRNA markers to assess bacterial and fungal community diversity. Analyses were performed using the open-source software pipeline QIIME2 to assess the main changes in soil microbiome arising from difference in soil management. The data show a significant effect of pH on fungal and bacterial communities. Different fertiliser, cropping sequence, organic amendments, soil compaction, drainage and tillage applications also affected soil microbes, but the sizes of these effects were much smaller than for pH. However, the striking observation was that agronomic soil managements had less impact on soil microbial diversity than the effects of geographical location or season: where you are affects soil biology more than what you do.

<https://ahdb.org.uk/soil-biology-and-soil-health-partnership>

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Impacts of soil properties and farming practice on prokaryotic microbiomes across nine European pedoclimatic regions

Mr Simon Bo Lassen¹, Kai Ding², Lieven Waeyenberge³, Raúl Zornoza⁴, Eva Lloret⁴, Krista Peltoniemi⁵, Stefan Schrader⁶, Merrit Shanskiy⁷, David Fernández Calviño⁸, **Phd Kristian Koefoed Brandt^{1,9}**

¹Department of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark, ²Key Laboratory of Urban Environment and Health, Institute of Urban Environment, Chinese Academy of Sciences, 1799 Jimei Road, Xiamen 361021, China, , , ³ILVO (Flanders Research Institute for Agriculture, Fisheries and Food), Plant Sciences Unit, Burg. Van Gansberghelaan 96, B-9820 Merelbeke, Belgium. , , , ⁴Department of Agricultural Engineering, Universidad Politécnica de Cartagena, Paseo Alfonso XIII 48, 30203 Cartagena, Spain , , , ⁵Natural Resources Institute Finland (Luke), Natural resources, Soil ecosystems, Latokartanonkaari 9, FI-00790 Helsinki, Finland , , , ⁶Thünen Institute of Biodiversity, Bundesallee 65, D-38116 Braunschweig (Germany) , , , ⁷Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, 5 Fr. R. Kreutzwaldi St., 51006 Tartu, Estonia , , , ⁸Section for Soil Science and Agricultural Chemistry, Department of Plant Biology and Soil Science, University of Vigo, As Lagoas s/n, 32004 Ourense, Spain , , , ⁹Sino-Danish Center for Education and Research (SDC), University of Chinese Academy of Sciences, 380 Huaibeizhuang, Beijing, China., ,

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Prokaryotes (Bacteria and Archaea) are crucial for the stability and productivity of agroecosystems. However, factors shaping the prokaryotic microbiome in soil and the impact that various farming practices (e.g., conventional and organic farming) may have on it are still incompletely understood. Here we explore the prokaryotic microbiome of 188 soil samples collected from agricultural fields across nine pedoclimatic regions of Europe using Illumina 16s ribosomal RNA gene amplicon sequencing. Links between soil physicochemical properties, farming practice, and the prokaryotic microbiome were investigated using multivariate statistical analyses. The pedoclimatic region was found to be the key determinant of the prokaryotic microbiome, and this could be attributed to various soil physicochemical parameters, including pH, soil texture, field moisture, and concentrations of bioavailable nutrients. A core microbiome consisting of 5730 operational taxonomic units (OTUs) belonging to 30 different phyla was detected in all pedoclimatic regions. The majority of the core OTUs belonged to Proteobacteria (30%), Actinobacteria (18%), Acidobacteria (11%), Planctomycetes (9%), Bacteroidetes (7%), and Chloroflexi (5%). Impacts of farming practice on the prokaryotic microbiome differed between pedoclimatic regions and were only significant in the Atlantic North and Boreal pedoclimatic regions. Overall, our study provides insights into the prokaryotic microbiome in European agricultural soils and highlights key factors shaping it.

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<http://soildiveragro.eu/>

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High rainfall disturbs soil microbial structure and function in a mature temperate forest under elevated carbon dioxide

Miss Katy Faulkner¹, Mr Simon Oakley³, Ms Kelly Mason³, Dr Sally Hilton¹, Professor Chris van der Gast⁴, Professor Niall McNamara³, Professor Sami Ullah², Professor Gary Bending¹

¹University Of Warwick, Coventry, England, ²Birmingham Institute of Forest Research, England, ³UK Centre for Ecology & Hydrology, Lancaster, England, ⁴Manchester Metropolitan University, Manchester, England

19 Division 2 Commission 2.3: Soil microorganisms under changing environment, Forth, August 2, 2022, 13:00 - 15:00

Climate change is expected to alter global precipitation patterns, with unknown impacts on biodiversity and ecosystem functioning. Temperate forests are one of the largest terrestrial carbon stocks, acting as sinks for greenhouse gases such as methane thus playing a major role in ameliorating global warming. Predicted changes to precipitation intensity and duration under future climates are likely to alter soil moisture dynamics in forest soils and the consequent impacts on the terrestrial carbon balance under future atmospheric carbon dioxide levels is not known. Here, we use a novel in situ approach to simulate high rainfall in soil plots within a mature temperate oak-dominated (*Quercus robur*) forest in Staffordshire, UK (Birmingham Institute of Forest Research Free-Air Carbon Dioxide Enrichment facility) where atmospheric CO₂ levels are elevated 150 ppm above ambient levels. We show that an 8-week period of elevated rainfall and soil moisture had significant impacts on soil functioning. The forest soil methane sink was significantly reduced in the high rainfall treated soils by ~ 21-67%, resulting in greater methane accumulation in the atmosphere. Using molecular approaches, we show how the bacteria and archaea communities, specifically methanotrophic and methanogenic taxa, are impacted by these climate stressors. The activities of soil extracellular enzymes, involved in the breakdown of organic carbon, nitrogen, and phosphorus compounds, were reduced during the high rainfall treatment. Our results demonstrate that important soil functional changes occur during high precipitation events and potential impacts of multiple climate stressors cannot necessarily be determined by the study of single stressors alone.

Green manuring can reduce Chinese dependence on fertilizer nitrogen by 40% in rice production system

Dr. Songjuan Gao¹, Dr. Guopeng Zhou², Dr. Danna Chang², **Dr. Robert M Rees**³, Dr. Kristian Thorup-Kristensen⁴, Dr. Weidong Cao², **Prof Bob Rees**

¹Nanjing Agricultural University, Nanjing, China, ²Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, China, ³Scotland's Rural College (SRUC), Edinburgh, UK, ⁴Department of Plant and Environmental Sciences, University of Copenhagen, Frederiksberg, Denmark

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

Rice production in China has increased continuously over the past 4 decades, but this change has been accompanied by significant environmental burdens, leading to pollution of air, water and soils. There is therefore a renewed interest in role of traditional practices of green manuring, in supporting more sustainable food production. The increased use of nitrogen (N) fertilizers has reduced the prevalence of green manuring but at a significant environmental cost. In a new analysis of a nationwide experimental network of green manuring, the results of 192 site-year field experiments from 38 green manure experiments located at 14 sites during 2008 to 2020 showed that rice yields increased when combined with 100% or 80% of conventional amount of N fertilizer, and maintained or even increased following a 40% reduction of fertilizer N input in green manure-rice rotations. The positive effects of green manure on yields increasing with the application years of green manure. Crop N uptake and N fertilizer use efficiency were enhanced, and soil C and N pools were increased by green manuring despite reduced N fertilization. The potential area available for green manure utilization is about 10 million ha in south China, correspondingly to a saving of 0.6 million t of N fertilizer each year without loss of yield. Thus, green manuring is an effective and practicable tool towards sustainable agriculture in China.

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Long-term changes in paddy soil fertility in tropical Asia under the Green Revolution from 1960s to 2010s

Prof. Junta Yanai¹, Prof. Sota Tanaka², Dr. Shin Abe³, Dr. Atsushi Nakao¹

¹Kyoto Prefectural University, Kyoto, Japan, ²Kochi University, Nankoku, Japan, ³Kindai University, Arida, Japan

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

Over 50 years of the Green Revolution since the 1960s, the global population has increased by 2.5 times, cereal production by 3.3 times, and the use of N, P and K fertilizers by 9.4, 4.2, and 4.3 times, respectively. Information is still limited on the influence of these impacts on the fertility status of agricultural soils. We therefore investigated the influence of the Green Revolution on 142 paddy soils in three tropical Asian countries, i.e., Thailand, the Philippines and Malaysia, by repeated soil sampling in the 1960s and 2010s at or near the same locations. We revealed that the phytoavailability indices of three macronutrients, i.e., available P, exchangeable K, and total N showed 743% ($p < 0.01$), 12%, and 1% increase on average, respectively, while total C showed 9% decline. Comprehensive investigation of overall fertility status by factor analysis using 11 soil parameters suggested that only the factor scores associated with “available P status” increased drastically in all the three countries ($p < 0.01$) whereas those associated with “organic matter and N contents” and “inherent potentiality” did not exhibit any consistent changes. In conclusion, intensive soil/fertilizer management systems under the Green Revolution have successfully improved the nutrient status, especially P status, of paddy soils with slight decrease of total C, while a large amount of N and K applied has been released to the outer environments. Conversion to a high-efficiency system of external nutrient inputs with organic matter-conserving strategies is required to secure sustainable food production while restoring the environment during the coming decades.

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Is rice field a nitrogen source or sink for the environment?

Mr. Weichen Huang¹

¹Laboratory for Earth Surface Processes of the Ministry of Education, College of Urban and Environmental Sciences, Peking University, P.R.China

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

Rice field has been traditionally considered as a nonpoint source of reactive nitrogen (N) for the environment, while it, with surrounding ditches and ponds, also contributes to receiving N inputs from atmosphere and waterbodies and intercepting N outputs from rice field. However, a comprehensive assessment of the N source or sink of rice field for the environment is lacking. Based on systematic observations and process-based simulations of N budget, we identified the roles of rice field and evaluated the opportunities for shifting its role from N source (i.e., outputs > inputs) to sink (i.e., outputs < inputs). Rice field was found to be a N source for waterbodies (including surface and ground waters), but a N sink for the atmosphere for the wet and normal year. The “4R-nutrient stewardship” (i.e., using the right type of N fertilizers, at right rate, right time, and in right place) applied in rice field was sufficient for the source-to-sink shift for the atmosphere for dry year, but needed to implement together with improvements of irrigation and drainage for waterbodies. Furthermore, with the combination of various technologies, rice field played a role as a N sink of up to 22.8 kg N ha⁻¹ for the atmosphere and up to 2.0 kg N ha⁻¹ for waterbodies, along with 24% decrease in irrigation water use and 21% decrease in N application rate without affecting rice yield and soil fertility. Together these findings highlight a possibility to achieve an environmental-friendly rice field by improving agricultural management technologies. Jiang WJ , Huang WC , Liang H, et al. Is rice field a nitrogen source or sink for the environment? *Environmental Pollution*, 2021:117122. DOI: 10.1016/j.envpol.2021.117122

Exploration of soil macropores in a compacted plough pan by rice genotypes

Mr Md Dhin Islam¹

¹University of Aberdeen, Aberdeen, United Kingdom, ²Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

Long-term puddling in paddy systems, or tillage in upland systems, often creates a hard layer below the plough layer called the plough pan. Plough pans inhibit deep rooting by affecting porosity, bulk density and penetration resistance of soil. Therefore, deep leached nutrients and water becomes less accessible. Macropores such as cracks and biopores in hard soil could help deep rooting, mitigating constraints to root growth for rice production. So the aim of this research was to investigate how soil macropores through a plough pan affects rice root growth. Deep rooting Black Gora and shallow rooting IR64 rice varieties were grown in packed cores of unsaturated soil in a greenhouse. Artificial biopores and cracks were inserted through plough pan to form different treatments. Plough pans with macropores had 25-32 % more roots than with no macropores. RLD was 55 % greater in the plough pan layer if cracks were present compared to biopores. Conversely, RLD was 26 % less in subsoil if the plough pan had cracks compared to biopores. Deep-rooted Black Gora produced 81% greater RLD, 30 % more root numbers and 103 % more branching than the shallow rooted rice genotype IR64 within the plough pan layer. Cracks were found to be far better than biopores for rice root growth through plough pans, with a deep rooting variety being far more responsive to macropore presence. This research suggests that simple quantification of macroporosity may be insufficient, and that macropore shape has a large impact on root access and branching.

Changes in soil properties and soil quality in long-term rice-based cropping system under conservation agriculture.

Dr Ram Prakash Tata¹, Dr Madhavi Molluru¹, Ms Srinika Sheela¹

¹*Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hydeabad, Hyderabad, India*

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

A six-year field experiment was conducted in Hyderabad, India, on Vertic Haplustept with a rice-maize-Sesbania cropping system to study the impact of tillage combinations and weed management practices on soil properties and soil health. Climate of the experimental site was semi-arid. Tillage treatments included combinations of conventional tillage (CT) and zero-tillage (ZT) with/without crop residues (R) in dry direct-seeded rice (DSR)/transplanted rice during South-west monsoon and maize in winter. The weed management options were chemical weed management, IWM (Integrated Weed Management with chemical and mechanical methods) and unweeded control.

Adopting ZT has improved soil aggregation, hydraulic conductivity, bulk density, penetration resistance. Better macro-aggregation and improved soil properties with retention of crop residues was reported by Bandyopadhyay et al., 2010 and Choudhury et al., 2014).

Total organic carbon and organic carbon fractions (very-labile, labile, less-labile and non-labile) were significantly higher under ZT treatments than CT treatments. Retention of crop residues in ZT treatments enhanced soil enzyme activities (dehydrogenase, urease, acid/alkaline phosphatase and catalase) over conventional tillage. Tillage practices and consequent soil aeration status influenced the on soil microbial populations significantly (bacteria, fungi, actinomycetes, Azotobacter and Azospirillum). Weed management practices did not affect soil physical and chemical properties. Herbicide application caused a transient reduction in soil microbial counts and enzyme activities.

Soil quality index, computed by principal component analysis, was highest with unweeded control in ZT+R-ZT+R (60.0). Mohanty et al. (2007) reported that higher SQI under zero tillage. The lowest SQI was observed under IWM under CT-CT (35.6) among all treatment combinations.

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Cultivating flooded rice as a treatment technology to mitigate nutrient loads and improve soil quality from agricultural watersheds

Dr. Jehangir Bhadha¹, Dr. Abul Rabbany¹, Dr. Naba Amgain¹, Dr. Yuchuan Fan¹, D. Matthew VanWeelden¹

¹*University Of Florida, Belle Glade, United States*

43 WG 3.4: Recent advances in nutritional, biological and physical processes in paddy soils, Alsh 1, August 2, 2022, 13:00 - 15:00

During summer more than 202 km² of fallow sugarcane land is available for rice production in South Florida. The net value of growing flooded rice in the region as a rotational crop with sugarcane far exceeds its monetary return. Soil conservation, pest control, and nutrient load reduction are only some of the benefits. With no phosphorus (P) fertilizer applied, rice cultivation in Florida can potentially function as a sink for P as a result of particulate settling and plant P-uptake, while harvested whole grain rice can effectively remove P from a rice field per growing season. A controlled experimental plot was designed to quantify reduction in P concentration and loads between inflow and outflow over a 110-day rice cultivation cycle. Daily water samples were collected from inflow and outflow over a six-week period once a steady flood was established. Inflow water P concentration was manipulated weekly, from 0, 0.075, 0.22, 0.50, 0.22, and 0.075 mg/L P concentration. Approximately 160 L of water was treated daily. On average 28% reduction in TP concentration and 51% reduction in SRP was observed between inflow and outflow, corresponding to significant P load reductions using this treatment technology. Soil health benefits include increased water holding capacity, and reduced active carbon compared to fallow fields. Future research work includes (i) evaluating P use efficiency in crop management by identifying and selecting rice varieties tolerant to low P inputs; and (ii) effect of varying flood depth on P loads from rice fields.

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Piping formation and distribution in a semi-arid environment: A new conceptual model

Mr Ariel Nahalieli^{1,2}, Prof Tal Svoray¹, PhD Eli Argaman²

¹Department of Geography and Environmental Development, Ben-Gurion University of the Negev, ²Soil Erosion Research Station, Soil Conservation & Drainage Division. Ministry of Agriculture & Rural Development

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Piping is a complex erosion process caused by subsurface water flow. This paper studies the effect of soil cracks and hillslope aspect on piping development and the spatial distribution of soil pipes. It introduces a conceptual model of piping development in semi-arid environments. The model addresses factors that substantially influence the piping formation. Including rainfall regime, solar radiation, soil properties, and geospatial characteristics extracted from unmanned aerial vehicle aerial scans. Three hundred and twenty-two pipes were sampled and measured in the field to provide evidence to the ideas presented in the conceptual model. Soil texture, sodium, calcium magnesium, organic matter, and SAR were analyzed using standard laboratory methods for all these soil samples. Our results demonstrate how differences in subsurface soil properties profoundly affect piping formation processes but do not fully explain substantial differences in spatial distribution between north- and south-facing aspects. However, the synergy of soil properties, rainfall data, and simulated differences in heat flux between aspects led to the development of a landscape with considerably more pipes in the south-facing aspects. Despite many studies from around the world on the development of piping, our proposed conceptual model of the process is unique to semi-arid climates due to the nature of the rainfall. However, we are convinced that much can be learned from this process in many areas of the world.

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Predicting nutrient loss due to water and wind erosion across New South Wales, Australia

Dr Xihua Yang¹

¹*NSW Department of Planning, Industry and Environment, Sydney, Australia*

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Nutrient loss from soils not only threat agricultural productivity and food security but also causes degradation of water quality and environment in many parts of the world. However, nutrient loss through soil erosion is often ignored in the nutrient cycle studies, there is little understanding of how much nutrient lost through water and wind erosion. In this study, we assessed soil nutrient depletion due to both water and wind erosion and its spatial and temporal variability across New South Wales (NSW), Australia. We estimated the mass fraction (%) of total nitrogen (N), total phosphorus (P) and soil organic carbon (SOC) in the eroded soil, and the total stock of nutrient for the soil depths of 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm and 100-200 cm. The estimated average N, P and SOC stocks in NSW soils are 11.2, 6.7 and 134.5 t ha⁻¹ respectively. There are great variations in the loss of nutrients by erosion in space and time. The average total nutrient loss rate is about 4.5% in NSW due to both water and wind erosion, and the total cost is estimated \$2.3 million per year. The areas with highest nutrient loss are the North Coast and Hunter regions due to relatively high hillslope erosion and nutrient content of the soils. Nutrient loss from water erosion is about 87 times higher, on average, than that from wind erosion. The findings and methodology contribute to knowledge of nutrient loss due to erosion in broad nutrient circle studies.

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A crop phenology-based approach to quantify the C-factor at the field-parcel scale in Europe

Mr Francis Matthews^{1,2}, Dr Panos Panagos², Prof. Gert Verstraeten¹

¹Department of Earth and Environmental Sciences KU Leuven, Leuven, Belgium, ²Joint Research Centre, Ispra, Italy

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

As environmental data abundance increases, targeting the management-relevant spatial and temporal scale of soil erosion requires model parameterisation techniques capable of capturing the dynamics of the dominant driving (rainfall erosivity) and resisting ((non-)photosynthetic vegetation cover) factors influencing the system through time. Modern large-scale data sources (e.g. Sentinel-2 optical data, rainfall datasets, EU-scale land survey (LUCAS) and administrative data) potentially offer a unified approach to parametrise soil erosion models across the EU, however their capability to overcome the intensive parameterisation demand of dynamic models remains relatively unexplored. We utilise the available integrated administration and control system (IACS) parcel-vector and crop declaration data from EU member states to provide the spatial backbone of the approach. Using the RUSLE framework, we present a field parcel-specific approach to soil erosion risk assessment and model parameterisation by considering the crop phenology and post-harvest crop residue management practices (C-factor) derived from Sentinel-2 observation timeseries. By combining the area-specific rainfall dynamics (R-factor) we give a parcel-specific and temporally explicit risk indicator of soil erosion based on the (a)synchronicity between the seasonal rainfall erosivity regime and the crop canopy cover status. This approach provides new opportunities to understand the variation in erosion risk and target better mitigation measures (e.g. the implementation of cover crops and reduced tillage). Future work will seek to integrate these dynamic C-factor measurements into a dynamic model to consider the full suite of influencing factors driving episodic soil loss.

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Off-site economic costs induced by soil erosion in the northwestern European loess belt for the last two decades (Normandy, France)

Dr Olivier Cerdan¹, Dr Edouard Patault², Ing Jerome Ledun³, Dr Valentin Landemaine¹, Dr Arnaud Soulignac¹, Ing Jean-Baptiste Richet³, Pr Matthieu Fournier⁴, Dr Jean-François Ouvry³, Pr Benoit Laignel⁴

¹Brgm, Orléans France, Orléans, France, ²ALTEREO, Venelles, France, ³AREAS, Saint-Valery-en-Caux, France, ⁴University of Normandy, Rouen, France

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

While soil erosion physical processes and socio-environmental impacts are widely addressed in the literature, few studies have focused on the economical dimension. However, it is essential to consider this dimension to conduct appropriate land use management policies. Erosion and runoff are known to result into on-site and off-site impacts. A fully exhaustive analysis of erosion and runoff economic costs may be difficult and ambitious due to the low availability of the data and considering that some issues are still not evaluated in the literature (cost of public policies to prevent erosion and runoff impacts, prohibition of drinking water due to turbidity, etc.). In this study, we chose to analyze the main off-site economic costs induced by these processes in a region located in the northwestern European loess belt (Normandy, France). We quantified avoidance and social damages over the last 25 years through a global and retrospective analysis of financial databases provided by regional or local authorities (water agencies, departmental councils, reinsurance, drinking water companies, transport infrastructures managers) and literature review (scientific articles and technical reports).

Our analysis suggested that from 1995 to 2017, the total damages cost ranged from 611 to 721 M€. Off-site avoidance damage costs accounted for almost 2/3 of the total expenditure. In the Seine-Maritime area, the mean cost was evaluated to 4 319 € yr⁻¹ km⁻² and to 868 € yr⁻¹ km⁻² in the Eure area. Even if we tried to be as exhaustive as possible some off-site economic costs remained unknown.

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Disentangling prolonged rainfall and land use change interactions on catchment sediment source dynamics from multi-biotracers isotope composition

Dr Hari Ram Upadhayay¹, DR Yusheng Zhang¹, Dr Steven J. Granger¹, Mafalda Micale¹, Prof Adrian L. Collins¹

¹*Rothamsted Research, North Wyke, Okehampton, United Kingdom*

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Excessive sediment degrades freshwater quality and is prone to further increased due to the combined effect of extreme wet weather and differing land uses. To quantify erosion and sediment source responses across scales, this study integrated work at both field and catchment scale for two hydrologically contrasting winters (2018-19 and 2019-20). Sediment load was estimated based on sensor data at the field scale (grassland-arable conversion system) on an instrumented farm platform. Sediment source apportionment work was undertaken at the catchment scale (4.5 km²) which used combined alkanes, and both free and bound fatty acids' carbon isotope signature as diagnostic fingerprints with a Bayesian un-mixing model (MixSIAR). Sediment source apportionment based on bound fatty acids revealed a substantial shift in contributions, from stream banks dominating (70 ± 5%) in 2018-19, to arable land dominating (52 ± 7%) in 2019-20. Increased contributions from arable land (~3.9 times) and pasture (~2.4 times) during the extreme wet winter of 2019-20. These losses were consistent with elevated losses measured at the field scale which indicated that low-magnitude high frequency rainfall alone increased sediment loss even from pasture by 350%. Beyond quantifying the shifts in field scale sediment load and catchment scale sediment sources due to the changes in weather patterns, our results demonstrate valuable insight into how fate of biotracers in soil and sediment manifests in the δ¹³C values of homologues and, in turn, their role in information gain for estimating sediment source contributions.

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Integrating biochar into cropping systems reduces soil loss and run-off characteristics in Ghana

Prof Vincent Logah¹, Prof Janvier Bashagaluke, Dr Andrews Opoku, Dr Henry Oppong Tuffour, Prof Joseph Sarkodie-Addo, Prof Charles Quansah

¹*Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Soil loss from arable lands constitutes a major constraint to crop production globally. In Sub-Saharan Africa (SSA), although agronomic and mechanical interventions have been suggested to reduce the menace, soil management options exploiting biochar-inorganic input interactions within the context of climate-smart agriculture, have not received the needed research attention. This study assessed how integrating different crop and soil management practices can affect soil loss characteristics from arable lands in SSA. We conducted field experiments on run-off plots in three consecutive cropping seasons. In the two-factor experiments, soil amendments comprising biochar (BC), inorganic fertilizer (NPK), BC + NPK and control constituted the subplots whereas cropping systems: maize, soybean, cowpea, maize + soybean intercrop constituted the main plot factors. We incorporated a bare plot to serve as soil erosion check. We observed greater soil loss on the bare plots seasonally, ranging from 9.75 to 14.5 Mg ha⁻¹. Under sole cropping systems, cowpea caused 31–40% reductions in soil loss than maize. In addition to their direct role in plant nutrition, the soil management options contributed to significant ($p < 0.05$) reductions in soil loss. The BC+NPK caused the least soil loss of 1.23–2.66 Mg ha⁻¹. Cowpea produced the least seasonal runoff coefficient with the greatest coefficients observed under sole maize. The BC+NPK produced economic returns greater than the threshold ($VCR > 2$) under soybean cropping system but with $VCR < 2$ for other cropping systems. The study shows promise for exploring biochar/NPK interactions in minimizing soil loss on croplands in SSA.

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The legacy of the historic land use/land cover changes after cropland abandonment: effects on soil properties, nutrients, and redistribution processes

Makki Khorchani¹, Dr. Leticia Gaspar², Ms Estela Nadal-Romero¹, Prof. José Arnáez³, Prof. Teodoro Lasanta¹, Prof. Ana Navas²

¹*Instituto Pirenaico de Ecología (IPE-CSIC), Zaragoza, Spain*, ²*Estación Experimental de Aula-Dei (EEAD-CSIC), Spanish National Research Council, Zaragoza, Spain*, ³*Área de Geografía Física, Departamento de Ciencias Humanas, Universidad de La Rioja, Logroño, Spain*

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Mediterranean mountain areas were affected by rapid cropland abandonment during the 20th century. Secondary succession or afforestation are different strategies to restore soil ecosystem services, such as nutrient, conservation and soil carbon sequestration. Studies are limited at catchment scale in Mediterranean mountains, and there is still a debate about which strategy is more appropriate. In addition, it is expected that future scenarios of land use/land cover (LULC) will have direct impacts on land degradation, especially in Mediterranean mountains that are very sensitive to Global Change. This study analyses the effects of cropland abandonment and passive/active restoration on soil properties, and redistribution rates using fallout ¹³⁷Cs measurements in the Araguás catchment (Central Spanish Pyrenees). A total of 52-grid soil samples from the first 40 cm and 9 sectioned reference samples were collected and their physico-chemical properties were analysed. ¹³⁷Cs inventories were used to estimate soil erosion and deposition rates. Results show that LULC changes and active restoration had significant impacts on physico-chemical soil properties and nutrients: soils in the Araguás catchment are prone to degradation, and soil losses have been recorded through the catchment during the last 60 years due to human activity. However, higher values of organic carbon and nitrogen stock in the afforested area suggest that afforestation can reduce soil degradation at long-term scale. These results will help to establish the basis for a sustainable management considering the complexity and fragility of the Mediterranean mountains.

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On the effect of pioneer biocrust communities on soil erosion after disturbances in an European temperate forest ecosystem

M.Sc. Corinna Gall¹, Dr. Martin Nebel², Prof. Dr. Dietmar Quandt², Diplom-Biologe Michael Sauer³, Prof. Dr. Thomas Scholten¹, Dr. Steffen Seitz¹

¹*Soil Science and Geomorphology, University of Tübingen, Rümelinstr. 19-23, 72070 Tübingen, Germany*, ²*Nees-Institute for Biodiversity of Plants, University of Bonn, Meckenheimer Allee 170, 53115 Bonn, Germany*, ³*Esslinger Str. 18, 72124 Pliezhausen, Germany*

Interdivisional 6: Dynamics of soil erosion and land loss under present and future environments, Lomond Auditorium, August 2, 2022, 15:30 - 17:30

Soil erosion remains one of the most severe environmental challenges, which is assumed to further exacerbate with climate change. Even small disturbances in forest ecosystems, such as skid trails, can drastically increase soil losses. Biological soil crusts (biocrusts) play an important role in preventing soil erosion as pioneer soil colonizers known for their soil stabilizing effects. However, research on the influence of biocrust communities on soil erosion in temperate forest ecosystems is scarce.

This study examined the natural succession of biocrusts in skid trails on four soil substrates in a temperate forest in Germany and investigated their influence on sediment discharge and surface runoff, including differences from undisturbed forest floor and track position. Therefore, we used a combined approach of rainfall simulations and small-scale runoff plots (ROPs, 40 x 40 cm), conducted at four time steps after skid trails were established and accompanied by parallel vegetation surveys of biocrust and vascular plant succession.

Sediment discharge was 8.6 times higher in skid trails compared to undisturbed forest and 13.2 times higher in wheel tracks. Maximum soil erosion was measured on bare soil, which was most clearly reduced by initial vegetation in July. During winter, erosion was as intense as on bare soil, despite a protective vegetation cover. Although biocrusts were overtopped by vascular plants during succession, they managed to coexist, as evidenced by the positive correlation between biocrust and vascular plant cover. Moreover, bryophyte-dominated biocrust treatments contributed more to mitigating soil erosion than vascular plant treatments.

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The importance of soil horizons in pedology

Prof Alfred Hartemink, Dr Yakun Zhang

¹*University Of Wisconsin - Madison, Madison, USA*

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Soil horizons reflect soil processes and convey information about past and present soil conditions. The identification and delineation of soil horizons is affected by lateral and vertical variation in soil properties. Here we review studies that investigated variation in the master horizons O, A, E, B, and C. We summarize what is known about soil horizon variation, quantify the variation in different horizons, and investigate its pedological significance. Horizon thickness does not seem to be related to the variation of soil chemical and physical properties within the horizon, i.e. thicker horizons do not necessarily have higher variation in their soil properties. Factors that affect the within-horizon variations include landscape position, parent material, vegetation, fertilization, tillage, drainage, and time. The vertical distribution of soil properties can be quantified using soil depth functions. Digital soil morphometrics techniques can assist in the quantification of two-dimensional soil profile properties and variations.

Disentangling the pedogenic factors controlling active Al and Fe concentrations in soils of the Cameroon volcanic line

Dr. Tetsuhiro Watanabe¹, M.Sc. Shiori Ueda¹, Dr. Atsushi Nakao², Dr. Antoine Mvondo Ze³, Dr. Randy Dahlgren⁴, Dr. Shinya Funakawa¹

¹Kyoto University, Kyoto, Japan, ²Kyoto Prefectural University, Kyoto, Japan, ³Université de Dschang, Dschang, Cameroon, ⁴University of California Davis, Davis, USA

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Active Al and Fe (oxalate extractable Al/Fe: Alo/Feo) strongly affect soil physical, chemical and biological properties (Takahashi & Dahlgren, 2016). This study examined the pedogenic factors affecting Alo and Feo contents across a soil weathering sequence in Cameroon. We investigated the B horizon (~50-cm depth) from 26 soils formed in basalt/trachyte volcanic materials at different elevations (110–2570 m) incorporating a wide range of temperature (14–27°C) and precipitation (1520–3130 mm). The weathering sequence ranged from weakly weathered Andosols in the southwest region grading to strongly weathered Oxisols on the central highlands. We assumed pyrophosphate extractable Al/Fe (Alp/Fep) as organo-Al/Fe, and (Alo – Alp) and (Feo – Fep) as short-range ordered minerals. Factor analysis of climatic (e.g., temperature and precipitation metrics) and soil geochemical properties (e.g., weathering indices) identified three factors representing temperature, precipitation/leaching, and weathering degree as the primary determinants of Alo and Feo concentrations. Organo-metal complexes (Alp and Fep) were negatively correlated with the temperature factor, whereas the short-range ordered mineral phases (Alo – Alp and Feo – Fep) were negatively correlated with weathering degree and positively correlated with precipitation/leaching. Our analysis infers that increased weathering and dryer climate enhance the transformation of short-range-order Al/Fe to more crystalline phases. Further, low temperature promotes the formation and preservation of organo-Al/Fe. Allophanic materials were only evident in weakly weathered soils based on oxalate extractable Si content. In sum, climatic factors and degree of weathering were confirmed to be the primary controls on the active Al and Fe fraction.

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Accelerated soil development due to seasonal water-saturation under hydric conditions¹¹¹

Dr Zoltán Szalai^{1,2}, Ms Marianna Ringer¹, Dr. Tibor Németh^{1,2}, Dr Péter Sipos¹, Dr. Gergely Jakab^{1,2}
¹Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, ²Eötvös Loránd University, ELTE, Budapest, Hungary

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Pedogenesis can be accelerated by periodic water saturation. The exact nature and effectiveness of hydric conditions in the intensification of soil development are not clear yet. Our understanding of the timescales of the mineralogical changes occurring in soils is limited; however, the time frame of soil organic matter accumulation is known. Here, we described soil development over a period of 50 years. The studied Gleysols are located in Hungary. The beginning of the pedogenesis is well documented here; the parent material was deposited during a major flood event in 1963. Therefore, the studied soil profiles represents development over the last 50 years.

We used an elemental analyser to determine SOC and TN content. Selective extractions were also used to determine amorphous and crystalline Fe and Mn content alongside XRD and TEM for mineralogical analysis, XRF for elemental analysis. Eh and pH were measured by a field monitoring station.

Fifty years under hydric conditions resulted in rapid vertical differentiation within the soil profile including SOM enrichment in the topsoil, and the formation of smectites and Fe accumulation in the zone of groundwater fluctuation. A high proportion of amorphous and colloidal phases indicated that very intense processes had taken place in the zone of the redox oscillation. The presence of more crystalline goethite in the bulk soil reflects frequent Eh changes. The source of the pedogenic carbonates in the subsoil is the material of the mollusc shells dissolved in the topsoil. Our results demonstrate that pedogenesis can proceed faster than previously assumed. Szalai et al <https://doi.org/10.1016/j.geoderma.2021.115328>

Age and polygenetic origin of Planosols in postglacial areas of Central Europe

Prof. Dr. Cezary Kabala¹, MSc. Elzbieta Musztyfaga¹

¹*Wroclaw University of Environmental and Life Sciences, Wroclaw, Poland*

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Stagnogleyed, texturally contrasting soils that meet the criteria of Luvic Planosols (WRB 2015) are widespread in the postglacial areas of Central Europe. The different age and origin of the cover sands and underlying tills were evidenced by TL dating, heavy mineral analysis, and the moraine pavement. The presence of a clay-illuvial horizon (argic) in the pre-Eemian till covered with clay-poor sands suggested the Eemian age of the argic horizon and the relic (subburial) nature of the Luvic Planosols (as the remains of eroded Luvisols). However, similar soils (but lacking pavement and periglacial cracking) commonly occur in the zone of the Last Glacial Maximum, where the Eemian age of the illuvial horizon is impossible (as the parent material is younger). Furthermore, the clay skins developed in the 'old' loams do not differ from modern clay cutans, that is, they do not have signs of (periglacial) frost destruction. Moreover, the upper section of the till seems depleted of the clay fraction, which suggests more local clay translocation, i.e. within the till sublayers rather than from cover sand to underlying till. These findings led to the conclusion that similar pedogenic transformations, present in the profiles of Luvic Planosols developed from sediments of various ages, have developed at a similar time, that is, in the Holocene, and irrespectively of both the lithological discontinuity and the periglacial features (f present). The brunification in the cover sands suggests an independent pedogenic development of the upper sandy and underlying loamy parts of the Planosol profiles.

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Toposequence of soils formed in Pleistocene Lake Bonneville deposits, Utah, USA¹

Dr. Janis Boettinger¹

¹*Utah State University, Logan, USA*

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Deposits of Pleistocene pluvial Lake Bonneville derived from calcareous sedimentary rocks in a semiarid basin of the Basin and Range physiographic provide a unique opportunity to study pedogenic processes along a toposequence of soils. Coarse-textured, high rock-fragment, somewhat excessively drained soils on deltas exhibit downward translocation of carbonates, primarily occurring as coatings on rock fragments. Medium-textured, rock fragment-free, well drained soils on medium lake terraces exhibit downward translocation of carbonates as masses and, subsequently, translocation of clay. Fine-textured, somewhat poorly drained soils on low lake terraces exhibit downward translocation of carbonates coupled with upward translocation from the carbonate-charged seasonally high groundwater, resulting in carbonate masses and nodules, and translocation of clay. While redox concentrations of iron masses occur, the alkaline pH of these soils inhibits formation of iron depletions. Fine-textured, somewhat poorly drained soils on low lake terraces subject to slightly saline seasonally high groundwater exhibit downward and upward translocation of carbonates, accumulation of exchangeable sodium, and translocation of clay. The strongly alkaline pH of these soils inhibits formation of iron redoximorphic features, but manganese concentrations occur as coatings and masses. Poorly drained, fine textured soils on the lowest lake terraces and lake plains concentrate carbonates at a shallow depth, inhibiting the translocation of clay. Poorly drained soil subject to the saline water table concentrate salts more soluble than gypsum near the soil surface. Soil classification according to Soil Taxonomy will also be presented.

(no references)

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Soil-forming factors controlling properties of Technosols developed on historical mining and metallurgical sites in the Tatra Mountains, southern Poland

M.Eng. Magdalena Tarnawczyk¹, dr hab. Łukasz Uzarowicz¹, dr Wojciech Kwasowski¹, dr Artur Pędziwiatr¹

¹*Warsaw University of Life Sciences – SGGW (WULS – SGGW), Warsaw, Poland*

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

Alpine soils in the Tatra Mts. are well recognised, however, Technosols in high mountain environments have not been studied in detail. The aim of this study was to determine the most important soil-forming factors controlling properties and pollution degree of technogenic soils (Technosols) developed on historical (15th–19th century) mining and metallurgical sites in the Tatra Mts., southern Poland. Studied soil profiles were located at areas of varying time elapsed since the start and end of mining and metallurgical activity. The sites varied in type of antropogenic parent material (mining wastes and metallurgical slags), vegetation cover, elevation and landform. The study comprised determination of basic physical, chemical and sorption properties, soil mineral composition and total trace elements concentrations. Studied Technosols were poorly developed soil formations with simple morphology (A horizon in the topsoil and C horizons in the subsoil). They contained high content of rock fragments. Soils were characterised by highly variable physical and chemical properties due to the different mineral composition of the parent material. Due to vegetation development, soil organic matter has been accumulated in the topsoils of the examined soil profiles. High concentrations of selected elements (Fe, As, Cd, Cu, Pb, Zn, Cr, Mn, Co, Ni) is related with their occurrence in parent material. Research so far has shown that the properties of Technosols in the Tatras have been controlled primarily by past human activities (mining, metallurgy), parent material properties, and vegetation. Additional soil-forming factors controlling soil properties indirectly were relief and climatic conditions dependent on altitudinal zonation.

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Reconstructing soils from waste: barriers and opportunities

Dr Kate Schofield¹, Mr Nick Willenbrock², Professor Brian Reid³, Dr Naofel Aljafer¹, Dr George Littlejohn¹, Mrs Angela Harrop¹, Professor Mark Fitzsimons¹

¹University Of Plymouth, Plymouth, United Kingdom, ²CL:AIRE, Reading, United Kingdom, ³University of East Anglia, Norwich, United Kingdom

11 Soil Genesis, M1, August 2, 2022, 15:30 - 17:30

The construction of soils from appropriate repurposed materials (e.g. displaced soils and aggregates, agricultural bi-products, dredgings, organic and carbon-rich materials) represents an opportunity to mitigate against some of the negative impacts of soil losses, whilst also reducing the burden on waste disposal systems and lessening the burden on valuable natural soil resources.

New approaches are needed to reduce soil and aggregate displacement and to reuse soil-forming materials. In doing so, this represents an opportunity to create a circular economy, whereby displaced materials can be matched with appropriate receiver sites, and can add value to the displaced soils and aggregates through blending with materials that augment and enhance the properties and performance of the resultant soil composite. Such an approach can be tailored to increase carbon sequestration potential (e.g. stable carbon component addition), enhance textural and hydrological properties (e.g. sand or clay addition) and/or remediate the substrate (e.g. removal or reduction of contaminants).

For such an approach to be effective, appropriate regulation and careful management of all materials throughout the process is required. We will present a protocol for the determination of key physical, chemical and biological characteristics of candidate materials and their carbon off-setting potential so that an appropriate receiver location and remediation strategy can be identified and accounted for through life cycle analysis during the construction planning stages.

Emerging soil microbial-based strategies for restoring biodiversity and enhancing climate resilience of degraded ecosystems

Dr Miriam Muñoz-Rojas^{1,2}, Dr Nathali Machado de Lima¹, Frederick Dadzie¹, Kit King¹, Dr Mark Ooi¹

¹*Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, UNSW Sydney, Sydney, Australia,*

²*Department of Plant Biology and Ecology, University of Seville, Seville, Spain*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

Global environmental changes such as drought, intense fire and land degradation are rapidly transforming the structure and functioning of ecosystems worldwide. These changes are leading to a severe loss of above and belowground biodiversity and increased soil degradation. Soil microorganisms control important ecosystem functions such as nutrient cycling, plant productivity and climate regulation. Thus, microbially assisted conservation and restoration have the potential to reconnect above- and belowground dynamics, creating functional ecosystems that are more resilient to climate change impacts. Our recent research has focused on (i) assessing the responses of soil microbial communities to disturbance, e.g., severe fire, and extractive activities such as mining, and (ii) developing bio inoculants composed of locally sourced soil bacteria from the rhizosphere, and biocrust cyanobacteria, to promote plant growth and soil fertility and enhance ecosystem capacity for global change adaptation. This presentation will showcase some key findings of these studies conducted in contrasting Australian ecosystems (shrubland-grassland in the arid zone, and subtropical/temperate forests). These outcomes include the successful translocation of whole-soil communities for inhibiting weeds, and the effective use of indigenous microbes (rhizobacteria and cyanobacteria combinations) for soil carbon sequestration, nitrogen fixation, and growth promotion of key arid and temperate plant species. We will also discuss the potential applicability of these approaches through emerging seed enhancement technologies such as biopellets, for landscape-scale conservation and restoration programs in the context of climate change.

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Soil microbiome-mediated carbon sequestration: understanding the mechanisms across different ecosystem

Dr Ashish Malik¹, Mr William Pallier¹, Dr Lisa Cole¹, Prof Steven Allison², Dr Robert Griffiths³

¹University of Aberdeen, Aberdeen, United Kingdom, ²University of California, Irvine, USA, ³UK Centre for Ecology and Hydrology, Bangor, United Kingdom

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

Soil organic carbon (SOC) represents the largest store of terrestrial carbon. Intensive land use practices deplete SOC stores; climate warming and shifting precipitation patterns exacerbate uncertainty over its fate. Carbon accrual in soils is imperative in reaching net zero targets but by improving soil health it also aids in sustainable agriculture. Soil microbiomes act as gatekeepers of soil-atmosphere carbon exchange by balancing the rates of decomposition and stabilisation to either release or store carbon. However, we cannot reliably link the physiological response of soil microbes in a changing environment to SOC changes. By analysing microbiome functional traits using omics and stable isotope tracing in soils from different ecosystems, we demonstrate two distinct mechanisms of microbiome-mediated SOC sequestration that are globally applicable. Firstly, higher microbial growth efficiency causes increased channelling of organic matter through the microbial food web leading to increased microbial biomass and necromass that interacts with the soil mineral matrix to produce stable SOC. Our results highlight that reduced land use intensity in grasslands/croplands promotes SOC formation through this mechanism; due to decrease in resource limitation and stress that lowers metabolic constraints on growth. However, this mechanism does not apply in wetlands/peatlands where reduced land use intensity leads to water saturation and anoxia thereby reducing microbial growth and inhibiting decomposition leading to carbon accrual. We conclude that the balance of decomposition and stabilisation processes driven by changes in microbial access to resources, its metabolic transformation and subsequent interactions within soil physical structures determines SOC balance in different ecosystems.

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Understanding antimicrobial resistance in soil-plant system for One Health

Professor Yongguan Zhu¹

¹*Institute Of Urban Environment, Chinese Academy of Sciences, Xiamen, China,* ²*Research Center for Eco-Environment, Chinese Academy of Sciences, Beijing, China*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

The discovery of streptomycin as an effective antibiotic by late Prof S Waksman is not only a milestone in medical science but also a remarkable achievement in soil biology research. Nevertheless, the extensive use and/or abuse of antibiotics in the past few decades have caused significant enrichment of antimicrobial resistance (AMR) in both clinics and the environment. Although soils harbor intrinsic AMR as a result of microbial metabolism and interactions, through irrigation and the use of organic fertilizers (derived from animal manures and/or urban organic waste), soil is increasing becoming a major reservoir of environmental AMR. In parallel to the transport of chemicals/nutrients from soil to crops, AMR can also move from soil to crops, thus impact the safety of agricultural produces. By using genomics tool and high throughput qPCR, this paper will examine the dynamics of AMR in soil-plant continuum, and will delineate the major driving factors affecting the accumulation and spread of AMR in soil-plant systems and associated human health risks. It will also discuss the potential mitigation and remediation approaches that can be used to halt the pollution of AMR in soil-plant system, thus to lessen the risks of soil AMR to human health. As soil is an integral component of ecosystem which contributes to human health in different pathways, this paper will also use AMR as an example to propose that One Health framework should be adopted to broadly link soil to human health.

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Arbuscular Mycorrhizal Fungi in Buriti, Cerrado Cashew and Peki in Cerrado soil

MSC Leidiane Dos Santos Lucas¹, Maria Lucrecia Gerosa Ramos¹, Rodrigo Fernandes de Souza², Sandro Dutra e Silva², José Mateus dos Santos², Jadson Belem de Moura², Aurélio Rubio Neto³
¹Universidade de Brasília, Brasília, Brasil, ²Faceg - Sedmo, Goianésia, Brasil, ³IFGoiano - Instituto Federal de Educação Ciência e Tecnologia Goiano, Rio Verde, Brasil

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

The Cerrado is the second largest biome in Brazil and has a great biodiversity of plants and soil microorganisms. Most of these microorganisms, such as arbuscular mycorrhizal fungi, live in a symbiotic relationship with plants, bringing benefits such as increased absorption of water and nutrients. Some of these plants, such as Buriti, Cashew from the Cerrado and Pequi are of great social and economic importance for the inhabitants of the Cerrado region, as they are an important source of food and income for small farmers, in addition to being part of the food. of the culture of the interior of Brazil. Understanding how the diversity of mycorrhizal fungi in the soil behaves is essential for the development of more efficient management practices for these plants, as well as elucidating information gaps about these organisms in the cerrado region. Thus, this work aimed to survey the biodiversity of arbuscular mycorrhizal fungi associated with *M. flexuosa*, *A. humile* and *C. brasiliense* in cerrado soil. There was no statistical difference between the values of spore density and mycorrhizal colonization rate in the three investigated species. The genera *Acaulospora*, *Claroideglomus*, *Diversispora*, *Scutellospora*, *Sclerocystis*, *Glomus*, *Funneliformis*, *Gigaspora*, *Ambispora* and *Scrobiculata* were identified in the rhizosphere of pequi, cerrado cashew and buriti. With the exception of *Scrobiculata* and *Scutellospora*, all other genera are commonly found in Buriti. In cashew from the cerrado, the genera *Funneliformis*, *Sclerosystis* and *Scutellospora* show less affinity. In the pequi rhizosphere, only the genus *Gigaspora* has low affinity with the plant.

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Effects of a fungal invasion on soil bacteria

Dr Flavia Pinzari¹, Dr Matthew D. Clark¹, Dr Raju Misra³, Dr Darren Chooneea³, Prof Xiangming Xu⁴, Dr Anne D. Jungblut¹

¹*Life Sciences Department, Natural History Museum, London, United Kingdom*, ²*Institute for Biological Systems, Council of National Research of Italy (CNR), Montelibretti (Rome), Italy*, ³*Core Research Laboratories, Molecular Biology, Natural History Museum, London, United Kingdom*, ⁴*National Institute of Agricultural Botany, East Malling Research Station (EMR), East Malling, Kent, United Kingdom*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

Fungal bioinoculants have a vast potential in agriculture because they can help increase crop yields and quality and reduce the application of chemicals. Their effectiveness has been widely tested (Malusà et al., 2016). However, little is known about the effect of bioinoculants on microbial assemblages in non-rhizospheric soil. A sudden introduction of a fungal species into soil could theoretically impact local microbial communities and lead to changes in nutrient availability (van Elsas et al., 2012). We assessed the impact of the introduction of the inoculum of a competitive fungus, the globally-used biofertiliser *Trichoderma afroharzianum* T22, on soil microbiome in microcosms to understand 1) to what extent the resident microbial community richness and relative abundance are influenced by T22; 2) whether microbial taxa are resilient to the disturbance caused by the fungus; 3) to what extent the bioinoculant impacts the functions of soil microorganisms. We used bacterial 16S rRNA gene amplicon sequencing (Illumina) and a shotgun metagenomic analysis (Oxford Nanopore Sequencing) to analyse the microbial communities in bioreactors after seven weeks of incubation with and without T22. The introduction of the fungus had a negative impact on the abundance of some groups of bacteria, such as the genus *Pseudomonas*, and it stimulated the abundance of species metabolically linked to the fungus, including chitin degrading Chitinophagaceae. In conclusion, the results suggest that more than impacting bacteria's overall biodiversity, introducing the fungus has favoured some groups at the expense of others, even creating new food webs and trophic niches.

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Moody microbes! Cycles of soil temperature and pedogenic variations disentangle soil microbiome predictions in Australian soils

Dr Vanessa Pino¹, Dr Mario Fajardo¹, Professor Alex McBratney¹, Dr Budiman Minasny¹, Dr Neil Wilson², Dr Chris Baldock²

¹The University of Sydney, Sydney, Australia, ²Metagenomic Laboratory, Metagen Pty, Ltd, Gatton, Australia

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

Ecosystem multifunctionality relies on the soil microbiomes. Functional redundancy is not globally evident that decay or changes in the soil biome irreversibly alter soils capacity to provide essential services (e.g., food, energy). Toward protection, decision-makers require intensive-expensive insight into the soil microbiome's ecological structure to maximise representative environmental variations even in future soil environments. Machine learning, predictions and mapping support this process by simplifying complexities and associated expenses. However, soil biomes predictions carry high levels of uncertainty and map interpretations of ecological processes can be self-conflicting across studies. We modelled and mapped projections (1,000m resolution) from soil metabarcoding data (16S rRNA and ITS genes) for New South Wales (800,642 km²). A novel combination of soil and environmental variables on a digital soil mapping (DSM) approach using exact sequence variants (ASVs) – instead of OTUs - with UMAP (Uniform Manifold Approximation and Projection) resulted in β -diversity maps concordance correlations between 0.91 – 0.96 and 0.91 – 0.95 for bacteria and fungi, respectively. The soil biomes' dissimilarities were driven by soil chemistry (pH and ECEC) and soil temperature (LST-phase and LST-amplitude). Regionally, spatial microbial patterns showed parallels to the distribution of soil classes, e.g., Vertosols clustered beyond spatial distances. Furthermore, cultivated soils showed lower richness due to decreased rare microbes, potentially compromising soil functions and ecosystems' services over time. Further soil microbiomes studies based on pedogenons and pedophenons as a monitoring approach is proposed from our findings.

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Soil fungal interactions change from negative to positive under lower fertility

Dr Rodica Pena^{1,2}, Dr Abdallah Awad², Dr Yu Shang³, Dr Tesfaye Wubet⁴, Prof Mark Tibbett¹

¹*School of Agriculture, Policy and Development, University of Reading, Reading, UK,* ²*University of Goettingen,*

Goettingen, Germany, ³*Leibniz Institute DSMZ-German Collection of Microorganisms and Cell Cultures, Braunschweig,*

⁴*Helmholtz Centre for Environmental Research, Halle, Germany*

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

In forest ecosystems, soil fungi play a key role in nutrient cycles. Fungal inter-guild interactions may influence their functions. In particular, the interactions between ectomycorrhizal and saprotrophic fungi can significantly affect soil organic matter decomposition. Their competitive interactions may eventually lead to suppression of saprotrophic decomposing activities through the so-called “Gadgil effect” (Gadgil and Gadgil 1971). However, how various fungal guilds, which reside in roots or soil mycelium, influence each other under environmental variation remains unclear. This study determined the direction and strength of one guild’s influence on another guild in soil fungal communities, interrogating how guild interactions change along the soil fertility and root carbon resource gradients. In this way, we tested the stress gradient hypothesis (SGH) in soil and root fungal communities. We found that fungal inter-guild interactions commonly change from negative to symmetrical positive with the decrease in soil fertility and root carbon resources in line with SGH. Saprotrophic and ectomycorrhizal guilds showed a reciprocal negative influence under high soil fertility, confirming the premises for the Gadgil effect, but they positively influence each other, giving rise to facilitative interactions under lower soil fertility. The bidirectional positive interactions between different soil fungal guilds may contribute to maintaining nutrient cycling and ecosystem productivity under mild decreasing soil fertility that is essential under current climate change when forests are prone to lower soil fertility.

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An antique association between fungi and plants that can save the future of agricultural production in the face climate change

Dr Juliana Silva Rodrigues Cabral¹, Me Germanna Gouveia Tavares², Me Letícia Rezende Santana², Lais Noamy da Silva², Edson Luiz Souchie²

¹Universidade de Rio Verde - Unirv, Rio Verde, Brazil, ²Instituto Federal Goiano - Campus Rio Verde, Rio Verde, Brazil

19 Division 2 Commission 2.3: Soil microorganisms under changing environment., Forth, August 2, 2022, 15:30 - 17:30

Climatic conditions interfere in agricultural production, with drought limiting plant growth and development negatively affecting grain production. Arbuscular mycorrhizal fungi (AMF) become an alternative to maximize plant tolerance to drought, because they can associate symbiotically with most plants conferring advantages, among which contribute to increase water use efficiency and maintain greater stomatic conductance, maintaining carbon fixation, even during periods of water deficit. This study aimed to analyze the physiological performance of soybean plants associated with arbuscular mycorrhizal fungi after different intensities of drought. Soybean plants were inoculated at sowing with *Gigaspora margarita* and *Gigaspora gigantea*, separately, being grown in a greenhouse under natural light conditions, with relative humidity of 65-85 % and average temperature of 28 °C. Drought intensities were imposed when the plants reached stage V3, being divided into three groups: control (80% of field capacity), moderate (60% of field capacity) and severe (40% of field capacity). When they had symptoms of water deficit, the plants were reirrigated and after 48 h physiological evaluations were performed. The inoculation of arbuscular mycorrhizal fungi favored the recovery of soybean plants after the dry season, obtaining the best physiological parameters when compared to plants without inoculation. Therefore, mycorrhizal inoculation maximized the tolerance of soybean plants to water deficit, with the fungus *Gigaspora gigantea* providing better functioning of the photosynthetic apparatus of the plants.

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Evaluation of centroid units from Brazilian to Universal Soil Classification System

PhD Yuri Gelsleichter^{1,2}, PhD Erika Michéli¹, PhD Anjos Lúcia Helena Cunha dos², Phd Ádám Csorba¹, PhD Eliane de Paula Clemente Almeida³

¹Hungarian University of Agriculture and Life Sciences, Godollo, Hungary, ²Federal Rural University of Rio de Janeiro, Seropédica - RJ, Brazil, ³Embrapa Soils, Rio de Janeiro, Brazil

34 WG1.8 – Advances in universal soil classification, Alsh 2, August 2, 2022, 15:30 - 17:30

Modern soil classification systems (SCS) started as local and regional efforts of scientists to group individual soils by their attributes and associated environments. Currently, two SCS are accepted as international, the World Reference Base and the Soil Taxonomy. These systems were developed from database mainly from temperate regions of the world and with few tropical soils, especially the ones rich in Fe and Al, such as those dominant in some Brazilian states. Besides, soil information is very difficult to translate across countries and international SCS due to differences in criteria and laboratory methods adopted in the national systems. To hub soil information, a centroidal SCS is under development as part of the proposal of the IUSS working Group to develop the Universal Soil Classification (USC) system. Some of the intermediate steps consist of computing and comparing centroids from national and international systems. Soil data from the Brazilian Agricultural Research Corporation (Embrapa - <https://www.sisolos.cnptia.embrapa.br/>) was used to calculate the Brazilian centroids. The profiles in the dataset are classified according to the Brazilian SCS. The Brazilian centroids were compared with ISRIC-WISE v3.1 ones to understand overlapping/gaps taxa between the two systems. The taxonomic relationships present the possibility to contribute to the development of centroidal system to better express the tropical soils in the USC system. The adoption of a universal SCS can promote a common "soil language" among the global soil science community. Also, data harmonization. The taxonomic relationships comparing Brazilian centroids with the universal system will be presented at the meeting.

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Universal soil classification for soil map legends and soil information systems

Dr. Andrei Rozanov¹, Dr. Trevan Flynn²

¹Stellenbosch University, Stellenbosch, South Africa, ²Biology Centre of the Czech Academy of Sciences, SoWa Research Infrastructure, České Budějovice, Czech Republic

34 WG1.8 – Advances in universal soil classification, Alsh 2, August 2, 2022, 15:30 - 17:30

The work on the Universal Soil Classification (USC) was proposed and extensively discussed at the 19th WCSS in 2010 (Hempel et al., 2013). Since then, the developments in digital terrain analysis (DTA) and digital soil mapping (DSM) have outpaced the developments in soil classification. However, now we can think of a soil classification system that would suit the new era of soil information systems and their spatial presentation and visualisation as maps. We see that informal aggregation of soil classes is of great practical use in various detailed and large-scale maps (e.g. acid or shallow soils). We suggest that the USC should be both data- and purpose-driven taking into account the resolution of final mapping products.

The nature of soil as an assembly of granular and fibrous materials into a vertically-distributed sequence prohibits visual examination of all the soil profiles existing on Earth. The interpolation of point observations using covariate layers is becoming of great importance. To produce polygon maps one has to look at the semantic segmentation of covariate layers and use semantic aggregation of point soil information to classify the segmented surface. In this context one has to optimize the classification itself using at least two optimization parameters, e.g. (a) maximize soil diversity and (b) minimize error. Various sources of error may be present in interpolated soil maps and such errors themselves may be classified into groups (e.g. inaccuracy, mistake and blunder) instead of simply reporting the percentage of match/mismatch between interpolated surface and validation data set.

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Soil Carbon affected by N rates in tropical maize intercropped with forages

Mr. Laudelino Vieira da Mota Neto¹, Mr. Ciro Antonio Rosolem¹

¹São Paulo State University - UNESP, Botucatu, Brazil

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Land-based solutions to climate change mitigation as intercropped systems demand a long-standing understanding upon the interplay of nitrogen (N) crop and forages on carbon (C) sequestration. Soil samples were taken to 40 cm depth from a 5-year experiment where ruzigrass (*Urochloa ruziziensis*), palisadegrass (*Urochloa brizantha*) and Guinea grass (*Megathyrsus maximus*) were intercropped with maize fertilized (270 kg ha⁻¹) or without nitrogen. The C reservoir was not changed at 0,0-0,1 m, but was reduced at 0,1-0,2 and 0,2-0,4 m under unfertilized ruzigrass and palisadegrass. Yet, nitrogen increased C pool by 4.5% (3.33 Mg C ha⁻¹) up to 0,4 m depth, increased particulate C by 11% and mineral-associated organic matter (MAOM, by 4.6%) fractions at the 0,0-0,1m layer, with no effect of the forages. While ruzigrass reduced the original C pool by 13.56% (10.89 Mg C ha⁻¹) the average decrease under Guinea grass and palisade grass was 7.06% (5.7 Mg C ha⁻¹). Nitrogen supplied to ruzigrass reduced POM and MAOM, chiefly in deeper layers, contrary to Guinea grass 2 years from installation. The largest share of the total soil carbon was MAOM, while POM showed the highest potential sink for carbon. Our findings demonstrate that land use change modified C pools and fractions mostly down the soil profile. As expected, Guinea grass depleted soil total N at two and 5-year cropping on N absence, which changed C distribution into fractions but did not affect C pools. In intercropped systems Guinea grass is a good strategy to keep C pools regardless of N supply.

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Shining a light on in situ distribution of soil carbon functional groups in an 8-year Free-Air Carbon Dioxide Enrichment study

Dr Han Weng¹, Professor Peter M. Kopittke¹, Dr Steffen Schweizer³, Ms Yunyun Zheng², Dr Jian Jin², Professor Roger Armstrong⁴, Professor Ashley Franks^{5,6}, Professor Ingrid Kögel-Knabner³, Professor Caixian Tang²

¹*School of Agriculture and Food Sciences, The University of Queensland, Brisbane, Australia,* ²*Department of Animal, Plant & Soil Sciences, Centre for AgriBioscience, La Trobe University, Melbourne, Australia,* ³*School of Life Sciences, Technical University of Munich, Freising, Germany,* ⁴*Agriculture Victoria Research, Department of Jobs, Precincts & Resources, Horsham, Australia,* ⁵*Department of Physiology, Anatomy and Microbiology, La Trobe University, Melbourne, Australia,* ⁶*Centre for Future Landscapes, La Trobe University, Melbourne, Australia*

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Building and protecting soil organic carbon (SOC) is critical to agricultural productivity, soil health and climate change mitigation. We aim to understand how molecular-scale mechanisms in the organo-mineral interfaces influence SOC persistence in three contrasting soils under long-term elevated CO₂ conditions. For the first time, we have provided two-dimensional microscale information of C forms and their distribution in the microaggregate and mineral fraction under long-term elevated CO₂ conditions. Although elevated CO₂ did not change the total SOC content in the microaggregates across three soils, there was a for a 20% decrease in the mineral fraction of the Calcisol. Microaggregates were depleted in plant-derived C whilst the mineral fraction enriched with microbial-derived C. The shift in C forms in various aggregate sizes may undermine the overall steady state of total SOC content under the elevated CO₂ condition. Using synchrotron-based microspectroscopic techniques for in situ analyses, we provide evidence for organo-mineral interactions initiated at the microaggregate scale followed by occlusion of microbial metabolites in the mineral fraction. These organo-mineral interactions can be reversed even in the mineral fraction of a light-texture Calcisol under long-term elevated CO₂. The study provides critical information to advance knowledge of building SOC for productive, sustainable and resilient cropping systems.

Soil protection or nutrient supply? Dual role of litter layer in cacao agroforestry systems

Ms Rika Ratna Sari^{1,2}, Dr Danae MA Rozendaal¹, Mr Danny D Saputra^{1,2}, Dr Kurniatun Hairiah², Dr James M Roshetko³, Dr Meine van Noordwijk^{1,3}

¹Wageningen University and Research, Wageningen, Netherlands, ²Brawijaya University, Malang, Indonesia, ³World Agroforestry, CIFOR-ICRAF, Bogor, Indonesia

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Litter protects the underlying soil, depending on litterfall and decomposition, but dynamics of the standing litter stock in agroforestry systems remain poorly understood. We aimed to unravel effects of litter quality, temporal patterns, microclimate, and a possible home-field advantage (HFA) on standing litter dynamics across a land-use gradient, including its effect on the soil C and N change. We quantified litterfall, standing litter stock, and microclimate during a year in (remnant) forest, cacao-based simple and complex agroforestry, cacao monocultures, and annual crops in Indonesia. We conducted a reciprocal litter transfer experiment and measured soil C and N content below the litterbags. Standing litter stocks during the year matched estimates from monthly litterfall and decomposition rates. Variation in litter quality influenced decomposition rates more strongly than microclimate variation or HFA. Lower litter quality in complex and cacao monoculture decreased the decay rate compared to simple agroforestry; mean litter residence time was over a year. Faster decomposition rates inconsistently increased soil C and N change. Variation of soil C and N content was mostly explained by effects of land-use. However, we surprisingly found that the relative change of soil C and N content under simple agroforestry litter in its original environment was the highest compared to other treatments, supporting the effect of HFA that has been found in simple agroforestry system. The seasonal patterns of litterfall and relatively slow decomposition rates supported permanence of the litter layer in all cacao production systems, protecting the underlying soil with delayed nutrient supply as consequence.

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The effect of salinity on dissolved organic C and nutrients in non-saline soils

Dr. Sunendra Joshi¹, Dr. Donald Sparks¹

¹*Department of Plant and Soil Science, Delaware Environmental Institute (DENIN), University of Delaware, Newark, US*

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Climate change induced flooding and rising seas can significantly enhance seawater intrusion in coastal regions, impacting the biogeochemical properties of soils, particularly those soils which are non-saline. Ion exchange and desorption processes, induced by sea water, causes an increase in the ionic strength, which can affect the release of DOC and nutrients (particularly N and P). We have limited understanding on the effect of salinity on DOC, inorganic P (Pi), and NH₄⁺, and their bioavailability in non-saline soils, that previously have not experienced or adapted to salinity. Non-saline soils were collected from the Agricultural Experimental Stations at the University of Delaware and treated with deionized water and artificial seawaters (ASW). Solution samples were collected at 0.5, 2, 8, 24, 48, and 96 hours, filtered, and analyzed for DOC, Pi, NH₄⁺, and exchangeable cations. Compared to the deionized water, increases in salinity caused a greater release of DOC and NH₄⁺ but lower amounts of Pi into the solution. After addition of ASW, K⁺ was released from the soil, but Ca²⁺ and Na⁺ were absorbed on the soils. These results show that salinity increased the bioavailability of NH₄⁺ but decreased Pi suggesting distinctly different effects of salinity on nutrient release in non-saline soils. Also, the data show an ion exchange induced release of NH₄⁺ and K⁺ which was promoted with increase in salinity. Salinity induced ion exchange studies, combined with redox oscillations experiments, will provide a deeper understanding on how salinity affects biogeochemical processes in non-saline soils.

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The impacts of sea level rise on phosphorus cycling in coastal soils

Dr. Chunhao Gu¹, Dr. Elizabeth Tomaszewski², Dr. Sunendra Joshi¹, Dr. Donald Sparks¹

¹*Delaware Environmental Institute, Department of Plant and Soil Sciences, University of Delaware, Newark, United States*, ²*U.S. Geological Survey, Boulder, United States*

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Climate-driven sea level rise (SLR) has globally led to increasing saltwater intrusion into coastal soils at an increasing rate, which could impact phosphorus (P) dynamics in coastal soils and further affect water quality. However, P molecular speciation, that largely determines its bioavailability and transformation in coastal soils remains unknown. We evaluated the SLR impacts on P transformation using X-ray absorption spectroscopy (XANES) and modified Hedley fractionation using a soil salinity gradient from Delaware Rehoboth Bay. The salinity gradient consisted of five sites, representing different degrees of SLR-induced saltwater intrusion. With decreasing distance to the shore, both soil salinity (29.3 – 0.07 mmhos cm⁻¹) and P concentrations (683.1 – 304.0 mg kg⁻¹) decreased. Sequential fractionation showed that occluded P (i.e., P in residue after 1M HCl [DHCl] extraction) was dominant (86.9 – 89.5% of total P). Non-occluded P (i.e., the sum of water-soluble P, NaHCO₃-P and NaOH-P) and DHCl-P accounted for 6.4 – 10.6% and 4.0 – 1.9% of total P, respectively. DHCl-P, representing presumably Ca-P, increased with increasing salinity. Semi-quantitative analysis of bulk XANES spectra showed that soil P was dominated by Fe-P and Al-P (>80%). Hence, with increasing salinity, soil P became increasingly accumulated in occluded pool mainly as Fe-P and Al-P. Qualitative analysis of μ -XANES spectra revealed that Ca-P existed in hotspots of the highest salinity soil while Fe-P or Al-P existed in hotspots of low salinity soil, demonstrating the interference of SLR-derived Ca²⁺ with P cycling. Results demonstrated that SLR markedly influenced P cycling in coastal soils.

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Modelling soil carbon dynamics under different tillage, crop rotation and climate scenarios in Southeastern Brazil

Dr Marcelo Valadares Galdos⁴, Prof Juliano Calonego², Dr Murilo Vianna¹, Prof Sacha Mooney³, Prof Ciro Rosolem²

¹*Institute for Climate and Atmospheric Science, University of Leeds, Leeds, UK*, ²*Department of Crop Science, Sao Paulo State University, Botucatu, Brazil*, ³*Division of Agricultural & Environmental Science, University of Nottingham, Nottingham, UK*, ⁴*Rothamsted Research*

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Conservation agriculture, comprised of the absence or reduction of soil tillage, diverse crop rotations and permanent soil cover, has been shown to increase soil organic carbon (SOC) stocks, particularly in the surface soil layer. However, little is known about the potential impacts of climate change on SOC stocks in conservation agriculture in tropical regions. In this study, we evaluated the effects of crop rotation, soil tillage and climate scenarios on SOC, using the DayCent model in a long-term experiment in Southeastern Brazil on a Typic Rhodudalf clay soil. The experiment began in 2003 with sunflower in fall/winter followed by pearl millet, forage sorghum, and sunn hemp in spring, and soybeans in the summer. A fallow treatment with chiselling was carried out in 2003 and 2009. Soil samples were collected in 2003, 2013, 2015 and 2017. Site-specific climate, soil and management data was used to calibrate and parameterize the model, and above-ground biomass and SOC were simulated under two climate change scenarios - low emissions (SSP1 – RCP 2.6) and high emissions (SSP5 – RCP 8.5) to 2100. In both scenarios, the use of cover crops, especially a legume crop, led to higher SOC stocks, and the absence of N input and plant residues in the spring in the chisel/fallow treatment reduced the accumulation of SOC. However, SOC sequestration gains were significantly reduced in the long-term (end-of-century) in the high emissions scenario. These results highlight the importance of accounting for climate change scenarios when assessing potential SOC sequestration in conservation agriculture.

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CO₂ retention on wood ashes from different raw materials and CO₂ release after soil mixing

Prof Masahiko Katoh¹, Ms Rika Bitoh¹

¹*Meiji University, Kawasaki, Japan*

40 WG3.2: Carbon and nutrient cycles under intensifying climate change and land management, Alsh 1, August 2, 2022, 15:30 - 17:30

Wood ashes generated from biomass power plants expects to be reused for agriculture. Applying wood ashes that CO₂ retained to soil may simultaneously supply nutrients and CO₂ from ashes. This study investigated CO₂ retention on wood ashes of different raw materials, CO₂ release after soil mixing, and water-soluble nutrients in the ashes before and after CO₂ retention. Three types of wood ashes with different raw material compositions were used for CO₂ retention test. Wet wood ashes were packed in a column, and a mixture of CO₂ and N₂ gas was passed through the column. CO₂-retained ash was mixed with Andosol at 1wt%. CO₂ released during 3 days of incubation was collected with 0.01 M NaOH. Crystalline mineral composition and water-soluble nutrient content of wood ash before and after CO₂ retention were determined. The amount of CO₂ retained varied from 0.39 to 1.35 mmol/g, depending on the type of wood ash. The formation of carbonate minerals in the wood ash was observed after the CO₂ retention. The amount of water-soluble Ca in the wood ash decreased after CO₂ retention while those of water-soluble Mg and Si increased. The amount of CO₂ retained as CaCO₃ was estimated to be 20% to 30% of the total CO₂ retained regardless of the ash type. The amount of CO₂ released was 17% to 22% regardless of ash type. These results suggest that the CO₂ retention capacity varies depending on the ash type. The CO₂ released from the ashes was mainly derived from CaCO₃.

Keynote Abstract

How transforming land use change could change our future

Debra Roberts

Durban, South Africa

This presentation will review the role of land use and land use change in driving and responding to the current climate change challenge. The information presented will draw on the findings of the Intergovernmental Panel on Climate Change's three main assessment reports from Working Group I, II and III and the three Special Reports of the Sixth Assessment Cycle i.e.: Global Warming of 1.5C; Climate Change and Land and the Ocean and Cryosphere in a changing climate. Particular attention will be focused on issues such as justice and equity.

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The Green Green Sand of Home: immersive experiences for creating soil awareness

Dr. Karen Vancampenhout¹, Dr. Bas Van Der Veken², Jan Bastiaens³, Dr. Seppe Deckers¹

¹*KU Leuven, Leuven, Belgium*, ²*Regionaal Landschap Kleine en Grote Nete, Belgium*, ³*Flanders Heritage Agency, Brussel, Belgium*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Raising soil awareness and building connectivity is paramount for creating the public and policy support needed for soil security. Nevertheless, as most people no longer experience soil in their daily lives, evoking a lasting interest in and stewardship for soil issues is not straightforward. Since 2006, we've been experimenting with soil heritage, storytelling and art to create immersive experiences for soil education and awareness raising. We have worked with the Flemish Government, academics, artists, local organisations, landscape architects, educators, musea, engineers and journalists. Together we've worked on policy projects, books, exhibitions, soil monolith collections and exhibit pieces, in-field installations, radioshow, online courses, citizen science and talks for policy makers and stakeholders in a journey to find the right narrative that holds the balance between evoking interest and emotion on one hand, and providing correct and comprehensive information on the other. In this contribution, we will highlight what we learned from working with non-experts on soil science, and successes and failures from stepping outside the academic comfort zone and open a dialog with the public.

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Agroecology and healthy soils to ensure food security and sovereignty

Professor Cristine Muggler¹, Professor Irene Maria Cardoso¹

¹*Federal University of Viçosa, Brazil, Viçosa, Brazil*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Agroecology has been long recognized as science, social movement and practice. Widely assumed as the science of the food systems, agroecology approaches the whole path between producers and consumers. Soil is one of the bases of agroecology, considering its functions, that are largely driven by soil biodiversity. Under the agroecological perspective, soil is not considered a resource, but part of nature and culture, to which humans belong. With this, soil, land or mother earth relates to the philosophy of Buen Vivir, claimed from latin indigenous people, and to food sovereignty, beyond food security. Furthermore, this philosophy brings up the need to question the present conception of soil as resource or natural capital to provide services to humans. This paper compares and discusses principles and dimensions of agroecology and soil security in the frame of socio economic and environmental issues that are at the basis of the challenges facing our common future.

Soil doctors program: a smart farmer approach for sustainable soil management and food security in Lancang-Mekong Countries

Miss Prapa Taranet¹, Ms Kreeyaporn Devahastin¹, Miss Bunjirtluk Jintaridth¹

¹*Land Development Department, Ministry of Agriculture and Cooperatives, Chatuchak, Thailand*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Sustainable soil management is one of the major challenges for agricultural systems and food security in this era of global environmental problems such as climate change and natural resource deterioration. Soil degradation is among the greatest threats in Lancang-Mekong Countries (LMC) including China, Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam where smallholding farmers play a vital role in both causing and restoring soil degradation. Recognition to this critical role, the Land Development Department (LDD) thus established soil doctors program in Thailand in 1995 by recruiting farmers, so called 'volunteer soil doctors' to work in partnership with LDD for sustainable soil and land management. There are now 77,672 soil doctors from 67,000 villages across the country acting as channels of information between LDD and other Thai farmers, and it has been highly successful in transferring knowledge and technology to local level. Recently, soil doctor program is being scaled up as Global Soil Doctors Program and engaging as part of the implementation plan for technical cooperation, awareness, and extension in support of the soil and land resource in different parts of the world including LMC. This program is supporting the capacity of LMC governmental agencies working on agricultural extension at the farm level and assists agencies to educate farmers on soil science principles for sustainable soil management. This farmer network can strengthen and support local community, with the success of the implementation strongly relies on the collaboration of different partners, including governmental agencies and soil science societies.

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Securing soil through its connectivity

Professor Damien Field¹

¹*The University of Sydney, Eveleigh, Australia*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Currently education is the primary focus of unpacking the connectivity dimension in Soil Security, which has been explored previously. We now need to consider other ways of knowing by; citizen scientists, cultural, indigenous, and advocacy groups, amateurs and those interested in gain a social license. For example, points of connection are established through people recognising the invisible qualities that come with products and services that soil provides. This measure of connectivity interacts with the capital dimension and is termed decommodification. The community's willingness to pay is another economic approach to determining the connectivity of people through the importance they place on its protection. This is illustrated by work comparing Veneto in Italy with NSW in Australia where the positive results show that in both regions people are willing to pay for carbon sequestration, earthworm density and rainfall infiltration rate independent of government action.

Looking at the circularisation of soil management to mitigate the importing of resources and manage carbon, affecting climate change, is illustrated by work in Papua New Guinea where we bring value to what was seen as waste in cocoa production and simultaneously improve farmer livelihoods. This is understood when we can explore how assessment and management are investigated using concepts of diagnosis, indicators, ecological and/or ethical frameworks.

Collectively this will deepen our understanding that is aspired to through the dimension of connectivity increasing the awareness of and opportunity for developing land use change that is framed through those who know and know of soil.

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Australia's National Soils Advocate

The Honourable Penelope Wensley¹

¹Office of the National Soils Advocate, Canberra, Australia, ²Department of the Prime Minister and Cabinet, Canberra, Australia

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Much has been done in Australia to understand, conserve and improve soil, yet soil condition and health continues to decline in many areas. Some decision makers recognise the clear connection between soil and agriculture but others continue to overlook soil as a vital natural asset that must be protected.

To address this, Australia established the role of National Soils Advocate, an independent voice advocating nationally for the need to improve soil condition and health through improved soil management. The position is a world-first in terms of elevating soil, its functions and services, to a level of national significance.

The Advocate engages closely with the scientific community, supporting assertions by validated research and experience. This evidenced-based approach translates research to action.

The position has an important international dimension, including emphasising the critical role soils play in addressing global challenges of food security, human and environmental health, biodiversity conservation and climate change. Australia has substantial experience and skills in land and water management which are also of considerable interest internationally. The Advocate supports sharing this expertise, promoting collaboration across multiple portfolios including environment and agriculture.

The Advocate takes a leadership position to inform better policy and actions that will enable change in the way soil is managed, focusing on those beyond the connected and committed 'soil community'. If those with decision-making capacity have a greater appreciation of the value of soils through well-directed messages and calls to action they are more likely to support actions that improve soil condition and functioning.

Connecting soils with people: initiatives of the Global Soil Partnership

Prof. Rosa M Poch¹, **Isabelle Verbeke**

¹*Intergovernmental Technical Panel on Soils - Global Soil Partnership (FAO)*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

As soil scientists we are aware that we can no longer work unconnected to the people: our work is directly related to highlight the soil's role in provision of ecosystem services, and thus, the soil science community should rise to the challenge of providing reliable and readily accessible information to the communities to remain relevant. Soil awareness is one of the pillars of FAO's GSP and ITPS, which works on connecting soils to people. The annual World Soil Day (December 5th) was launched in 2014. Its participation increased since then, and in 2020 alone, an estimated 800 million people worldwide participated in the event held in over one hundred countries. The event culminated in the production of a children's book titled "The magical world of soil biodiversity" through a book competition jointly organized by the FAO and IUSS in 2020. This was an exciting achievement for the book is an effective strategy to capture interest of young children in soil science in their formative stage as future decision makers. To support activities at field level promoting sustainable soil management, the Global Soil Doctors programme is available to provide farmer-to-farmer training, as in Colombia, where the FAO and the GSP worked to validate the Soil Doctors' toolkit used in the programme. Another initiative is GLOSOLAN which is a participative network in which member laboratories and experts in soil analysis share their information and experiences for the purpose of developing harmonized standards and training material, available on the GLOSOLAN webpage.

No references

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Assessing countries' commitments for soil organic carbon protection and sequestration under the three Rio Conventions

Dr Liesl Wiese-Rozanov¹

¹*Independent Consultant, Stellenbosch, South Africa*

Interdivisional 7: Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 08:00 - 10:00

Sustainable land management actions to protect and sequester soil organic carbon (SOC) stocks are increasingly advocated for their benefits to address climate change mitigation and adaptation, tackle food security, and maintain biodiversity. In the climate change context, countries' agricultural commitments related to SOC, wetlands and peatlands in Nationally Determined Contributions (NDCs) submitted under the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC) have been well assessed to date.

Under the United Nations Convention to Combat Desertification (UNCCD), 128 countries have committed to set Land Degradation Neutrality (LDN) targets. With SOC, land cover change, and net primary productivity as the principal metrics to assess LDN, numerous countries have set LDN commitments related to SOC stocks, wetlands, and peatlands.

The Convention on Biological Diversity (CBD) set 20 global Aichi Biodiversity Targets to be met by 2020 to protect and conserve biodiversity. The Aichi Targets included the enhanced contribution of biodiversity to carbon stocks (in biomass and soil) through conservation and restoration (Target 15), as well as the protection and restoration of high-biodiversity value habitats and critical ecosystems such as wetlands and peatlands (Targets 5, 11 and 14).

To understand the nature of national agricultural commitments related to SOC protection and sequestration under the three Rio Conventions, we assessed countries' NDC, LDN and Aichi Target commitments related to SOC, wetlands and peatlands. We identified overlaps and differences in the SOC-related commitments, highlighted the need for coherent national processes for SOC-related commitments, and identified opportunities to improve national process coherence.

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The potential of innovative soil management practices to address soil challenges across Europe - Outcomes of the i-SOMPE Project

MSc Olivier Heller¹, Dr Ir Frédéric Vanwindekens, Dr Ir Bruno Huyghebaert, Dr. Claudia Di Bene, Dr. Pasquale Nino, Dr. Peter Weiskopf

¹*Agroscope, Zürich, Switzerland*

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Sustainable soil management practices (SMP) and agricultural systems are promoted to enhance ecosystem services in order to minimise soil threats and sustain agriculture in a climate change context. However, a comprehensive stocktake of SMPs across Europe and their ability to successfully address multiple soil challenges (e.g. increasing soil organic carbon, avoiding soil erosion, avoiding salinization or optimal soil structure), is missing.

The i-SOMPE project is part of the European Joint Programm (EJP) SOIL and lasted from February 21 to March 2022. We assessed the potential of SMPs to address current and future soil challenges across Europe. We did so by a) reviewing the existing European literature, and b) multiple surveys among partners from 24 countries. We identified 58 well-documented SMPs and found more than 50 innovative SMPs. We assessed the bio-physical (i.e. climatic, petrologic, topographic and land use related) barriers that limit the dissemination of the documented SMPs and compared it with the actual dissemination, where possible. Furthermore, we made in-depth case studies of the socio-economic barriers (i.e. farming system related, technical, cultural and economic) to the dissemination of some documented SMPs.

Our study identified promising SMPs to address region-specific soil challenges in Europe. Besides, we provided a framework that allows the assessment of the bio-physical and socio-economic barriers to the dissemination of SMPs. The framework is based pan-european data such as climatic data from Agri4Cast, soil data from the European Soil Database, topographic information from the EU-DEM and the Corinne land cover).

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Soil and environmental issues in sandy soils

Dr. Jingyi Huang¹, **Dr. Alfred Hartemink**¹

¹*Department of Soil Science, University of Wisconsin-Madison, Madison, United States*

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Sandy soils are widely distributed across the world. Due to the growing global population and urbanization, these soils are increasingly used to provide food, feed, fiber, energy, and other services to our society. We summarize some recent studies on sandy soils and review the main soil and environmental issues related to understanding, use, and management. We classify the soil issues into three categories: 1) physical and hydrological, 2) chemical and agronomical, and 3) biological and ecological issues. Recent advances include developing models and methods characterizing soil water repellency, preferential flows, transport of nutrients, agrochemicals and industrial contaminants, and groundwater contamination, soil compaction, erosion, and evapotranspiration, improving soil fertility, structure, and biodiversity, monitoring, mapping, and managing salinity, sodicity, carbon sequestration, nutrient cycling, greenhouse gas emission, and heavy metal contamination. The main challenges are to understand changes in sandy soil conditions (e.g. soil water repellency, soil compaction, crust, erosion, salinization, structure, fertility, inorganic and organic contamination) and processes (e.g. evapotranspiration, carbon sequestration, nutrients leaching and cycling, greenhouse gas emission) under intensive agricultural activities and climate change and evaluate the impacts of soil texture on soil properties and processes. A conceptual framework is proposed for holistic understanding and management of sandy soils under changing climate conditions and agricultural activities.

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Climate-smart AND sustainable management of agricultural soils: identifying synergies and addressing trade-offs

Pr Dr Claire Chenu¹, Dr Saskia Keesstra², Dr Johanna Leppala³, Dr Ulrike Ziegler⁴, Dr Maria Fantappie⁵, Pr Sophie Zechmeister⁶, Dr David Wall⁷, Mrs Line Carlenius⁸, Mrs Raisa Gerasina¹, Dr Saskia Visser²

¹Inrae, Grignon, France, ²Wageningen Research, Wageningen, Netherlands, ³LUKE, Helsinki, Finland, ⁴Jülich Forschungszentrum, Jülich, Germany, ⁵CREA, Firenze, Italy, ⁶Boku, Vienna, Austria, ⁷Teagasc, Dublin, Ireland, ⁸Arhus University, Ahrus, Denmark

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Soils are at the crossroad of local as well as global challenges and are increasingly expected to help address challenges such as food security, combatting land degradation, adapting to and attenuating climate change. It is in particular the case for agricultural soils, for which a framework and guidelines for their sustainable management have been established under the auspices of the Global Soil Partnership. Are these guidelines compatible with the ambition of soils to be climate-smart? The European Joint Programme SOIL addresses these issues. Synergies are identified between these objectives, in particular regarding practices that increase soil organic matter contents and stocks. Trade-offs concern in particular increasing soil organic carbon sequestration versus emission of non-CO₂ GHG, or versus losses of N and P affecting water quality. Other trade-offs concern food production versus other ecosystem services provision, e.g. when rewetting peatlands or irrigating drylands. Synergies and trade-offs will be discussed in the light of the EJP SOIL results and activities.

New land use arrangement that harmonize various ecosystem services of agricultural landscape

Prof.Dr. Sonoko Bellingrath-Kimura¹, Nahleen Lemke¹, Dr. Cheng Chen¹, Prof. Dr. Ralf Bloch², Dr. Ioanna Mouratiadou¹

¹Leibniz Centre for Agricultural Landscape Research (zalf), Müncheberg, DE, ²University of Applied Sciences for Sustainable Development Eberswalde (HNE Eberswalde), Eberswalde, DE

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Agricultural landscape faces severe challenges to provide sufficient food, feed as well as resources for bioeconomy while maintaining soil fertility under climate change. Loss of biodiversity is an additional issue, where agricultural land use is an important factor. There are more ecosystem services (ESS) that have to be optimized in agricultural landscapes, which sometime contradict each other. Fulfilling all ESS at the same site is not possible, hence ESS have to be harmonized at landscape scale by diversified site specific land uses and agricultural management practices. Soil plays an essential role in finding site specific land use and management practices.

The Objective of the Project DAKIS (Digital Agricultural Knowledge and Information Systems; <https://adz-dakis.com/>) is to create a decision support system that enables site specific management targeting various ecosystem services. We chose crop yield, erosion control and biodiversity as target ESS to be harmonized in an agricultural landscape. At the first step, scenarios are developed regarding farmers land use and management options to meet ESS potentials, striving for remuneration of biodiversity and ESS, possible cooperation among actors and policy framework conditions for German agriculture. In a following step, defined scenario options will be analysed by spatially explicit agro-ecological and agro-economic system modelling. Outcomes will be enhanced knowledge on ESS, decision support options for farmers as well as indicators for sustainability impact assessment. The first use case was conducted at field scale to identify site specific management options to reduce erosion while maintaining productivity. Further use cases are planned to enhance biodiversity.

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Long-term monitoring of carbon dioxide and methane fluxes from different types of tropical peat swamp forests

Ms Nur Azima Busman^{1,2}, Dr Lulie Melling², Mr Yazid Imran², Prof. Dr Ryusuke Hatano³, Prof. Dr Akira Watanabe¹

¹Graduate School of Bioagriculture, Nagoya University, Chikusa, Nagoya 464-8601, Japan, ²Sarawak Tropical Peat Research Institute, Kota Samarahan 94300, Malaysia, ³Research Faculty of Agriculture, Hokkaido University, Sapporo 060-8589, Japan

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Carbon dioxide (CO₂) and methane (CH₄) fluxes from tropical peat swamp forest (TPSF) are essential as a reference dataset in quantification and estimation of land use change effect on carbon (C) emission. To evaluate temporal and spatial variations in soil CO₂ and CH₄ fluxes from TPSF in Malaysia, those from three major forest types, Mixed Peat Swamp (MPS), Alan Batu (ABt) and Alan Bunga (ABg), were monitored for 8 years using closed chamber method. Variations in environmental and soil physicochemical properties were also measured. In MPS, CO₂ flux was higher in dry season than wet season (159 vs 129 mg C/m²/hr), while CH₄ flux showed an opposite trend. No marked seasonality in ABt and ABg was thought to be linked to smaller variations in groundwater level (GWL). Although annual CO₂ fluxes, 859–1450 g C/m²/yr, did not vary significantly among forest types, there was a significant interaction between year and sites. Controlling factors of annual CO₂ fluxes differed among three sites: humification degree of peat for MPS, GWL, soil temperature, and relative humidity for ABt, and GWL and soil temperature for ABg. Annual CH₄ flux was higher in the order ABg > ABt > MPS. Annual CH₄ fluxes were positively correlated with humification degree and magnesium, iron, and sulphate contents in soil in MPS, with rainfall and GWL in ABt, and with soil temperature in ABg. Thus, our results suggest that both microclimates and soil physicochemical properties contribute to the variations in soil C emission from TPSF.

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1703

Soil Mission Support: Participatory identification of research & innovation gaps for a sustainable soil and land use practice

Dr. Michael Löbmann¹, Prof. Katharina Helming¹, MSc Linda Maring², MSc Jos Brils², MSc Gerald Jan Ellen², MSc Eloïse Mason³, Dr. Antonio Bispo³, Dr. Mireille Matt³, MSc Sophie Ittner⁴, Dipl. Sandra Naumann⁴

¹Leibniz Centre for Agricultural Landscape Research, Müncheberg, Germany, ²DELTAIRES, Delft, The Netherlands, ³INRAE, Paris, France, ⁴ECOLOGIC, Berlin, Germany

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Soil health is vital for many ecosystem services. The Horizon Europe Mission “A Soil Deal for Europe” aims to accelerate the transition to sustainable soil and land management and healthy soils through an ambitious transdisciplinary R&I programme, largely based on stakeholder engagement, Living Labs and Lighthouses. The H2020 Soil Mission Support (SMS) project supports the implementation of the Soil Mission and aims to improve the coordination of R&I on sustainable soil and land management. Through a co-creation process together with actors and stakeholder, SMS collates available knowledge, stakeholder R&I needs and identifies R&I gaps that need to be addressed for successful transition towards sustainable soil and land management.

The available knowledge stock was identified through a keyword based search for scientific literature in Scopus. 15,700 articles were identified and analyzed with the digital platform CorText. Stakeholder R&I needs were identified and prioritized through an online survey that was sent to 550 soil professionals, yielding 93 replies, and supplemented in two online workshops. R&I gaps were identified by comparing the knowledge stock with the stakeholder R&I needs. If a need was formulated, but knowledge is available, knowledge sharing needs to be improved. If available knowledge is insufficient, the R&I gap needs to be addressed. Major R&I gaps were identified in the policy, legislation and societal sector with a focus on policy support, awareness raising and communication. Further, social and economic impacts, interactions, opportunities and innovations are particular R&I gaps.

Löbmann M., Mason E., Bispo A., Matt M., Helming K., Maring L. (2022). Set of reports on soil and land management needs and gaps – Deliverable 2.4 Soil Mission Support.

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Impacts of soil redistribution by tillage on crop production

Prof John Quinton¹, Prof Peter Fiener²

¹Lancaster University, Lancaster, UK, ²University of Augsburg, Augsburg, Germany

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Soils used for crop production cover 15.5 million km² and almost all have been tilled at some point in their history, yet the role of tillage in reducing soil depth remains an under-recognised threat to plant production. While it has been demonstrated that tillage erosion moves significant amounts of soil down-slope, often exceeding that attributed to water and wind erosion, we know little about how the changes in soil depth and soil properties associated with tillage affect crop yields. In this talk we illustrate the impacts of tillage erosion upon yields, focusing on results from a parsimonious modelling approach coupling well established tillage erosion with crop growth models. We illustrate that landscape-scale tillage erosion/yield effect gradually increase with duration and intensity of tillage, even in areas not prone to water erosion and illustrate that yield increases in depositional areas partly compensate for yield losses in thinning. We explore the prospects for the next fifty to 100 years demonstrating that overall yields are likely to further decline in the region as modern mechanized agriculture accelerates the process of tillage erosion compared to centuries of non-mechanized tillage.

Land uses/land cover management after cropland abandonment as a strategy for enhancing ecosystem services: soil quality and organic carbon sequestration

Ms Estela Nadal-Romero¹, Melani Cortijos-López¹, Dr. Miriam Muñoz-Rojas^{2,3}, Dr. Paloma Hueso-González⁴, Dr. Erik Cammeraat⁵, Pedro Sánchez-Navarrete¹, Prof. Teodor Lasanta¹

¹*Instituto Pirenaico de Ecología (IPE-CSIC), Zaragoza, Spain*, ²*Centre for Ecosystem Science, School of Biological, Earth & Environmental Sciences, UNSW Sydney, Sydney, Australia*, ³*Departamento de Biología Vegetal y Ecología, Facultad de Biología, Universidad de Sevilla, Sevilla, Spain*, ⁴*Departamento de Geografía, Instituto de Geomorfología y Suelos (IGSUMA), Universidad de Málaga, Málaga, Spain*, ⁵*Institute for Biodiversity and Ecosystem Dynamics (IBED), Universiteit van Amsterdam, Amsterdam, The Netherlands*

Interdivisional 8: Sustainable land use, M1, August 3, 2022, 08:00 - 10:00

Mediterranean mountain areas were affected by rapid cropland abandonment during the 20th century. Post-land abandonment management practices (LMPs) can result in significant changes in landscape, soil quality and soil organic carbon sequestration. This study deals with the urgent need to analyse the effects of LMPs on land degradation through the analysis of physical, chemical, and biological soil properties, soil organic carbon sequestration, and the evaluation of soil quality. For this purpose, 12 land use and land covers in the Leza Valley (Spain) were selected including natural agroecosystems (pastures and agricultural sites), natural revegetation sites at different temporal stages, afforested areas (with and without management), shrub clearing areas, and natural forest areas (with and without management). At each site, soil samples were collected every 10 cm, down to 40 cm depth at least at three points, with a total of 450 samples. Preliminary results showed significant differences between LMPs: (i) differences were observed between the first stages of cropland abandonment and natural forest and afforested sites, (ii) carbon storage increased significantly with land management through shrub clearing (being the time since management a key factor), (iii) differences were observed in forest sites related to forest management practices. The results obtained in this study confirms the need to be aware of the effects of LMPs on the soil and will help to promote management strategies that preserve soil quality and avoid soil degradation in Mediterranean mountain areas.

This research is part of the MANMOUNT project (PID2019-105983RB-100/AEI/10.13039/501100011033) funded by the MICINN.

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Impact of green manures on legacy soil phosphorus mobilisation and crop performance

Professor Leo Condon¹

¹*Lincoln University, Christchurch, New Zealand*

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

In many agroecosystems, significant quantities of applied phosphorus have accumulated in the soil as “legacy phosphorus” which represents a potentially valuable resource that could contribute to ongoing and future plant phosphorus requirements. The inclusion of appropriate green manure crops in arable rotations may enhance the overall utilization and bioavailability of phosphorus, including legacy soil phosphorus. In the absence of a suitable field trial, an extended controlled-environment experiment was conducted to investigate and quantify the impact of three green manures crop species (blue lupin (*Lupinus angustifolius*), pea (*Pisum sativum*), barley (*Hordeum vulgare*) on mobilisation of legacy soil phosphorus and cereal crop yield and phosphorus uptake over two rotations. Results clearly demonstrated that the inclusion of blue lupin or pea as a green manure significantly increased cereal crop yield and phosphorus uptake by 27 - 35% and 15 - 29%, respectively, compared with fallow. This was due to a combination of enhanced mobilisation and acquisition of moderately labile forms of legacy soil phosphorus, together with increased biological cycling of phosphorus in soil. On the other hand, inclusion of a non-legume green manure significantly decreased cereal crop yield and phosphorus uptake compared with fallow, which was mainly attributed to enhanced net immobilisation of phosphorus during plant matter decomposition. The findings of this study clearly demonstrated that legume green manures have the potential to increase mobilisation of soil legacy phosphorus and thus improve phosphorus use efficiency in temperate crop systems, which in turn can reduce phosphorus inputs required to maintain production.

Solution for the phosphorus crisis: environmental friendly hybrid LDH serves as slow release phosphate fertilizer

Miss Wen-hui Li¹, Miss Han-Yu Chen¹, Dr. Liang-Ching Hsu³, Dr. Yu-Ting Liu^{1,2}

¹*Department of Soil and Environmental Sciences, National Chung Hsing University, Taichung City, Taiwan (R.O.C.),*

²*Innovation and Development Center of Sustainable Agriculture, National Chung Hsing University, Taichung City, Taiwan (R.O.C.),* ³*National Synchrotron Radiation Research Center (NSRRC), Hsinchu City, Taiwan (R.O.C.)*

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

The phosphorus is one of essential macronutrients for plant growth. Conventional farming usually applies excessive phosphate fertilizers; however, only about 15 percent of phosphate fertilizer is taken up by plants. The rest phosphate fertilizer usually flows into water system leading to eutrophication. Therefore, the goal of this project is to develop environmental friendly and slow release phosphate fertilizers. This study used nature polymers including chitosan (CTS) and carboxymethyl cellulose (CMC) to synthesize LDHs. From the XRD results, we confirmed that hybrid LDHs synthesis was successful. Besides, the observed maximum adsorption capacity for phosphate of hybrid LDHs were from 57.89 to 65.01 mg/g, which showed the outstanding ability to absorb phosphate. However, after the phosphate loading on the carriers, the compound of materials was changed due to the magnesium dissolution. Nevertheless, compared with other carriers, the materials could still release phosphate up to 30.19% and constant for more than 2688 h. The LCF analysis showed that phosphorus species percentage were changed not only at different desorption time but also at different polymers ratio. Especially in 0.5 ratio samples, the exchangeable and absorbed form ratio kept at an almost steady percentage during release time. It meant that exchangeable form could keep releasing and the adsorbed form would transform into exchangeable form at same time. The Fe-EXAFS results indicated the structure of the hybrid LDHs weren't same because they showed the different signal at Fe-O bond and Fe-Mg bond. That was the reason that different polymer ratio caused the distinct release mechanisms.

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Legacy soil phosphorus and biobased P fertilizers in the wheat/oleaginous-leguminous crop rotation in Mediterranean Vertisols

Dr Antonio Rafael Sánchez-Rodríguez¹, Mr Fernando Muñoz-Navarro¹, Mr José Javier Guerrero-Criado¹, Dr Ramiro Recena-Garrido², Dr Ana María García-López², Dr Antonio Delgado², Dr Mariano Fuentes-García¹, Dr José Torrent¹, Dr Vidal Barrón¹, Dr María del Carmen del Campillo¹

¹*Agronomy Department, University of Córdoba, Córdoba, Spain,* ²*Dept. Ciencias Agroforestales, University of Sevilla, Sevilla, Spain*

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

Calcareous soils are common in the Mediterranean basin. Their alkaline pH limits the availability of nutrients, such as phosphorus (P), for plants. P is a non-renewable resource, whose price challenges agriculture and food security. Sustainable fertilization strategies are required in agriculture to deal with inefficient P use and to maintain or enhance soil health since 60-70% of the soils in the EU are unhealthy for food, humans, and the environment. The main objectives of this study were to assess different P fertilization strategies (P rate and frequency of application) in the long-term (12 years) and evaluate sustainable strategies based on circular economy and recycled P sources in calcareous soils. For the first objective (two experimental sites), the application of no P produced similar yields than the application of 22 to 66 kg P / ha every two years or a single application of 132 kg P / ha every four years, in the first 8 years of the long-term experiment. In addition, microbial communities (PLFA) were influenced by P fertilization. Then (9-11 year), higher yields were obtained for the plants fertilized more often related to the plants non fertilized with P, where P availability was reduced to 15 mg P / kg. For the second objective, recycled materials such as urban solid waste (compost) and vermicompost produced similar biomass and/or yields (wheat-sunflower plants) as super phosphate. Sustainable use of legacy soil P and biobased P fertilizers could maintain or enhance soil functionality in this crop rotation in Mediterranean Vertisols.

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Addressing phosphorus legacies and efficiencies through the Science and Technologies for Phosphorus Sustainability (STEPS) Center initiative

Dr. Jehangir Bhadha¹, Xue Bai¹, Dr. Luciano Gatiboni³, Dr. Owen Duckworth²

¹University Of Florida, Belle Glade, United States, ²North Carolina State University, Raleigh, United States, ³North Carolina State University - Tide Water Research Station, Plymouth, United States

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

STEPS vision is to facilitate a 25% reduction in human dependence on mined phosphates and a 25% reduction in losses of point and non-point sources of phosphorus to soils and water resources within 25 years, leading to enhanced resilience of food systems and reduced environmental damage. Controlling transport while optimizing utilization of legacy phosphorus from soils and sediments is critical to help reach the vision of 25-in-25. In the Everglades Agricultural Area (EAA) of South Florida, farming practices have long been mindful of phosphorus management as it relates to sufficiency and efficiency of phosphorus utilization. Over two decades of phosphorus best management practices have resulted in more than 3000 metric-tons of phosphorus load reduction from the EAA to downstream ecosystems. In North Carolina, phosphorus-enriched soils are estimated to support 50-250 years of crop growth without phosphorus application, yet actual crop recoveries are highly variable. This is because only a small fraction of the total phosphorus is bioavailable for plant growth. As part of this study, soils across three edaphic regions and varying phosphorus concentrations will be characterized using combinations of tools such as P-XANES, and P-NMR that will allow for better understanding of the major forms of phosphorus in soil and sediments; and compare it to assays of bioavailability such as Mehlich phosphorus and Hedley fractionation so that chemical speciation can be better related to bioavailability. The goal is to develop management strategies that will help shift the phosphorus fertilization paradigm from “feed the soil” to “feed the plant”.

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Residual and recalcitrant phosphorus pools and isotope signatures to track legacy sources

Jessica Anton¹, Zhaohua Jiang¹, **Dr Deb Jaisi**¹

¹*Department of Plant and Soil Sciences, University of Delaware, Newark, DE USA*

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

The existing limitation of analytical methods for tracing phosphorus (P) in the environment has posed a challenge to discern specific sources such as legacy P. Here, we analyzed the recalcitrant and residual P pools from potential P sources and sinks in a sub-watershed within the larger Chesapeake Bay watershed. Harsh reagents used for the extraction of recalcitrant and residual soil P pools were tested for isotope integrity and were found not to compromise original isotope signatures. Among three reagents (10 M HNO₃, 10 M NaOH, and aqua regia) used, the aqua regia pool had the highest P content, but the matrix interference limited the isotope analysis from this pool. Phosphate oxygen isotopes ($\delta^{18}\text{O}_\text{P}$) of residual soil P revealed a generally distinct range of isotope values among different land uses, suggesting the usefulness of discriminating P sources. Interestingly, carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotopes of residual soil pools were distinct, which indicates isotope signatures are likely preserved among source sites and sink sediments. Isotope mass balance calculations show that P sources in the upstream sediment are composed of various proportions of wetlands, streambanks, and agricultural soils. Results on potential sources obtained from $\delta^{18}\text{O}_\text{P}$, $\delta^{15}\text{N}$, and $\delta^{13}\text{C}$ values of residual soil pools generally agreed with that of the Bayesian elemental fingerprinting model. In summary, isotope values of residual P pools are most likely to be isotopically intact in the field and therefore are more reliable proxies for source tracking.

none

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Too much of a good thing: the legacy of phosphorus fertilisation in restored landscapes of high biodiversity value

Professor Mark Tibbett¹, Dr Matt Daws¹, Dr Rory O'Connor¹

¹*Department of Sustainable Land Management and Soil Research Centre, School of Agriculture, Policy and Development, University of Reading, UK, Reading, United Kingdom*

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

Fertilisers supply essential nutrients perceived to be lacking in nearly all terrestrial restoration schemes. In particular, phosphorus is often applied in the restoration of highly disturbed, previously pristine landscapes. While well intentioned, we will show how the over application of phosphorus can lead to poor outcomes in terms of vegetation composition with long-term issues in ecosystem nutrition.

Native ecosystem disturbance can occur for many reasons and surface mining is an exemplar of complete ecosystem obliteration. Many mines exist in remote areas and on highly weathered, ancient, nutrient poor soils. Examples of these are the Fynbos of South Africa, the western and northern forests of Australia, the Campos Rupestres of South America and many tropical areas. Typically, restoration requirements in these areas require the return of a native vegetation community that existed prior to mining. This is particularly common for surface strip mining where large areas of land are cleared of vegetation annually. In this presentation we explain how, where and why over-fertilisation of phosphorus can occur. We demonstrate that the application of P-containing fertilisers to naturally nutrient-depleted soils can result in long-term legacy of elevated soil P, with species-specific negative impacts on plant health and growth (e.g. Tibbett et al., 2020). We show the restoration benefits that can be gained by judicious fertilisation in terms of vegetation community structure and ecosystem development. Finally, to assess where these findings may have wider applicability, we identify further global regions with nutrient-depleted soils, high plant diversity and current or prospective strip-mining operations.

Tibbett, M., Daws, M. I., George, S. J., & Ryan, M. H. (2020). The where, when and what of phosphorus fertilisation for seedling establishment in a biodiverse jarrah forest restoration after bauxite mining in Western Australia. *Ecological Engineering*, 153, 105907.

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Quantifying how much, where, and what form of legacy P across scales: the case of Illinois

Dr. Andrew Margenot¹, Dr. Amir Sadeghpour², Dr. Reid Christianson¹, Ms. Maia Rothman¹, Dr. Shengnan Zhou¹, Dr. Omid Zandvakili², Dr. Chunhao Gu⁵, Dr. Lori Abendroth³, Mr. Yuhei Nakayama¹, Dr. Giorgi Chighladze⁴, Michael Douglass¹, Dr. Chongyang Li¹

¹University Of Illinois Urbana-Champaign, Urbana, USA, ²Southern Illinois University Carbondale, Carbondale, USA, ³USDA ARS, Columbia, USA, ⁴Iowa State University, Ames, USA, ⁵University of Delaware, Newark, USA

17 Division 2: Sustainable use of legacy soil phosphorus, Gala, August 3, 2022, 08:00 - 10:00

The spatial distribution, magnitude and speciation of legacy P are challenging to quantify, complicating its management (e.g., drawdown). We demonstrate a multifaceted approach to quantify where, how much, and what type of legacy P at varying spatial scales (10 cm to 1000 km) that stands to inform legacy P utilization. We draw upon agronomic P balances, soil testing trends, long-term (145 year) field experiments, and historical soil archives in the U.S. state of Illinois, which has undergone drastic acceleration P fluxes driven by agricultural intensification in less than two centuries. Combining multiple approaches to the spatial distribution and magnitude of legacy P identifies shortcomings of single-approach methods and demonstrates their complementarity. Quantifying native soil P stocks and utilizing chronosequence approaches provides much-needed baseline measurements, which cannot be obtained by P balances, to better quantify legacy P magnitudes and speciation. Observed P speciation by XANES and sequential fractionations in soils with net P surpluses as well as deficits is consistent with hypothesized transformations of historical P inputs. Untangling the anthropogenic and edaphoclimatic interactions can help determine where and how to best utilize historically accumulated soil P.

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Stocktaking for agricultural soil quality and ecosystem services indicators and their reference values; The EJP SOIL 'SIREN' project

Dr. Jack Faber¹, Dr. Isabelle Cousin, Dr. Katharina Meurer, **Dr. Chantal Hendriks**, Dr. Loraine ten Damme, Dr. Antonio Bispo, Dr. Maria Viketoft, Dr. David Montagne, Gregory Obiang-Ndong, MSc Marjoleine Hanegraaf, MSc Ava Gillikin, Prof. Dr. Jan Bengtsson, Dr. Peter Kuikman, Dr. Astrid Taylor

¹*Wageningen Environmental Research, Wageningen, Netherlands*

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

The SIREN project has made an inventory of indicator systems for assessing soil quality and ecosystem services, as currently used by Member States associated in the EJP SOIL and beyond. The project aimed to identify and review the national frameworks and chains from soil properties via soil functions to soil ecosystem services and the indicators of soil quality state and functions, plus their evaluation criteria, across pedo-climatic conditions for the main agricultural production systems in the EU. Also, SIREN identified if these have been translated into policy options and implementation, and into directives and guidance for land management. A comprehensive conceptual framework linking soil quality to ecosystem assessment has been composed from earlier proposals in the literature, unifying various ambiguous concepts and providing consistent terminology. SIREN has taken stock of reference values and target values for indicators for SOC, soil quality, soil biodiversity and degradation risk. In particular, policy-relevant SQ indicators have been identified with potential for harmonisation in relation to national and European monitoring, and a tiered approach is proposed for implementation. Finally, knowledge gaps and development needs have been identified.

Faber et al. (in prep). Stocktaking for Agricultural Soil Quality and Ecosystem Services Indicators and their Reference Values. EJP SOIL Report .

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Assessment of the hydrological status of Marshlands in the South of Iraq using a combination of remotesensing and drought indices

Dr Ahmed Al Arazah¹, Dr Anne Verhoef², Dr Kevin White²

¹University of Baghdad, Baghdad , Iraq, ²University of Reading, Reading, United Kingdom

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

Over the past decades, these extensive Iraqi marshlands system have been heavily affected by both climate and anthropogenic factors. Desiccation was one of the most dramatic environmental disasters that occurred to the marshlands area. The marshes were artificially drained during the early 1990's for political reasons, converting approximately 90% of the marshes into deserts. These marshlands were reflooded in 2003, ending the artificial drainage as well as a three-year meteorological drought period (2000-2003). The years 2003-2005 had above-average levels of precipitation, enhancing the effect of re-flooding, thereby causing a significant and rapid rise of water levels and re-establishment of vegetation in the Iraqi marshlands. In November 2005, marshlands extent decreased somewhat due to the high evapotranspiration rates in the preceding hot summer months. Due to drought events in 2008-2009, marshland extent started to shrink further; only to recover very slightly during the winter months of 2009/2010. The recovery rate from January 2010 to January 2011 was the highest in recent years. This study analyses the effect of artificial draining systems and meteorological drought using LST and NDVI derived from remote sensing data, together with drought indices (SPI/SPEI, derived from ERA/in-situ data), for the years 2001 to 2015. ERDAS Imagine 2013 was used for image processing and its application 'Remote Sensing Indices' to extract the value of NDVI and LST. ArcGIS 10.1 software was used for the final analysis stages (including map construction).

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Functional evaluation of digital soil hydraulic property maps through comparison of simulated and remotely sensed maize canopy cover

Dr. Mulenga Kalumba¹, Dr. Stefaan Dondeyne², Dr. Eline Vanuytrecht³, Dr. Edwin Nyirenda⁴, Prof. Jos Van Orshoven³

¹The University of Zambia, Lusaka, Zambia, ²Ghent University, Gent, Belgium, ³University of Leuven, Leuven, Belgium,

⁴The University of Zambia, Lusaka, Zambia, ⁵University of Leuven, Leuven, Belgium

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

Soil maps can usefully serve in data scarce regions, for example for yield (gap) assessments using a crop simulation model. The soil property estimates' contribution to inaccuracy and uncertainty can be functionally evaluated by comparing model results using the estimates as input against independent observations. We conducted a functional evaluation of digital maps of soil hydraulic properties of the Zambezi River Basin using crop growth model AquaCrop. AquaCrop was run alimented with local meteorological data and with soil hydraulic properties derived from the digital maps on the one hand vs. estimated with the widely used Saxton & Rawls pedotransfer functions on the other hand. The two simulated time series of canopy cover (AquaCrop-CC-DSM and AquaCrop-CC-Saxton) were compared against canopy cover data derived from remotely sensed Leaf Area Index (LAI) from the MODIS archive (MODIS-CC). Pairwise comparison of the time series resulted in an RMSE of 0.07 and R2 of 0.93 for AquaCrop-CC-DSM versus MODIS-CC, and an RMSE of 0.08 and R2 of 0.88 for AquaCrop-CC-Saxton versus MODIS-CC. In dry years the AquaCrop-CC-DSM deviated less from the MODIS-CC than the AquaCrop-CC-Saxton ($P < 0.001$) while this difference was not significant in wet years. The functional evaluation showed that soil hydraulic property estimates based on digital soil mapping outperformed those based on Saxton & Rawls when used for simulating crop growth in dry years in the Zambezi River Basin. This study also shows the value of conducting a functional evaluation of estimated (static) soil hydraulic properties in terms of dynamic model output

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A cautionary tale of machine learning, land use and land suitability assessment

Dr. Anders Bjørn Møller¹, Dr. V.L. (Titia) Mulder², Professor Gerard Heuvelink², Mr. Niels Mark Jacobsen¹, Dr. Mogens Greve¹

¹Aarhus University, Tjele, Denmark, ²Wageningen University and Research, Wageningen, Netherlands

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

Farmers generally need to know if their land is suitable for the crops that they plan to grow. To address this issue, an increasing number of studies have mapped land suitability for crops with machine learning. These studies typically base their models on land use observations, assuming that farmers mainly grow crops in the most suitable locations.

This work aimed to test this crucial assumption. Firstly, we mapped land suitability for 41 specialty crops in Denmark using Maxent models based on farmers' registrations from the years 2011 – 2019 combined with environmental and socioeconomic covariates (30.4 m resolution). Secondly, we mapped land suitability for the same crops based on the ecological crops requirements (ECOCROP) database and compared the results, with a focus on table potatoes and carrots. In most cases, the correlation between the maps produced with the two methods was close to zero. Furthermore, the predictive accuracies of the MaxEnt models had no impact on their correlation with ECOCROP. Based on these findings, we argue that the two methods represent different phenomena, which we label ecological and socioeconomic suitability, respectively. As farmers operate in a socioeconomic context, prediction models based on land use observations are highly likely to reflect the socioeconomic suitability. Ambiguous terms can lead to misinterpretation and poor land use decisions. We therefore highlight the need for explicit terms to distinguish different forms of land suitability. Furthermore, researchers should consider the purpose of the land suitability assessment and ensure that their methods reflect the intended use.

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Assessing potential soil ecosystemic services in urban green areas from measurements of soil properties: insight from the URBERSOI project

Mr Gilles Colinet¹, Mrs Florine Jost¹, Mrs Daphne Handerek¹, Mr Xavier Legrain¹

¹*University Of Liège, Terra, Gembloux, Belgium*

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

Sustainable soil management includes supporting multiple ecosystem services. Holistic approaches are needed to properly evaluate the effects of practices on the multiple soil functions underlying ecosystemic services that soils can deliver.

Compared to other environments, urban soils are usually considered less for their productive capacity than supporting and regulating services. However, increasing demands for local resources creates competition between land uses for every space in urban and periurban areas.

Valuation of soil ecosystemic services often relies on expert-based matrices linking land use units to ecosystemic matrices. In limited cases, the soil functions are explicitly used as the elements to quantify as the soil contribution to ecosystemic services. These kinds of approaches either do not separate soil from its actual use (park, garden, spruce forest...), barely distinguish broad soil categories (well-drained soils versus gleysols, ...), or rely on indicators that are not directly linked to soil properties (yield, nature of vegetation...). Moreover, they usually consider actual services rather than potential.

The URBERSOI project aims at developing a methodology to assess the specific contribution of soil on potential ecosystemic services of urban green areas based on the evaluation of soil properties and the identification of indicators.

A field survey was conducted on three study areas in order to first identify the dominant soil types in urban environment and quantify soil properties. A methodological flowchart of data interpretation and indicator aggregation was then elaborated for the big categories of services depending on soil. The main lessons from the project will be presented.

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Linking soil and vegetation variables in assisted natural regeneration in the Doce river basin, Brazil

Mrs Ana Flavia Boeni^{1,3}, Mrs. Karin da Costa Ribeiro Ferraz², Mr. Gustavo Conforti Ventura Mayrink², Mrs. Débora Cristina Rother¹, Mr. Igor Rodrigues de Assis^{2,4}

¹Universidade de São Paulo, Piracicaba, Brazil, ²Universidade Federal de Viçosa, Viçosa, Brazil, ³Hungarian University of Agriculture and Life Sciences, Gödöllo, Hungary, ⁴Virginia Polytechnic Institute and State University, Blacksburg, United States of America

22 Division 3 Commission 3.1 – Soil evaluation and land use planning, Forth, August 3, 2022, 08:00 - 10:00

The next ten years will be the ecological restoration decade, and several global compromises were established to restore degraded lands. Doce river basin is one the most important of Brazil, and for decades have been degraded, and this situation worsened with the disaster of the iron tailings dam collapse. Soils play great importance in vegetation development, and many factors can influence this process. Nevertheless, these interactions are usually poorly understood in restoration projects. This work aims to identify the relationship between soil traits and forest diversity and structural metrics to manage forest restoration and improve ecosystem services provision. The study was conducted in the low and middle Doce River basin in young natural regeneration areas between three and eight years. In each site, we established five blocks with four different management (control and three intervention levels), totaling twenty plots with 400 m². After one year, we assessed some soil and vegetation variables in each plot, and Principal Component Analysis and Permanova were performed to select the most important variables and identify the relationship between the variables and treatments. The soil variables were selected in greater numbers and with greater weights. The results showed no differences between intervention management and no relation trends between vegetation metrics and soil traits because little time has passed since the abandonment and the experimental interventions. However, the sites were grouped separately with different selected variables, indicating the importance of knowing current soil conditions for each site's restoration management and monitoring.

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Utilizing Digital Soil Mapping Products for Environmental management Decisions in the United States

Ms. Jessica Philippe¹, Ms. Suzann Kienast-Brown¹, Mr. Jamin Johanson¹, Dr. Colby Brungard², Dr. Travis Nauman³

¹USDA-NRCS, United States, ²New Mexico State University, Las Cruces, United States, ³US Geological Survey, Moab, United States

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

Digital soil mapping combines field and environmental data in quantitative models to predict soil properties or types across the landscape. Soil property and type maps are critical for supporting effective land management. Digital soil mapping products and similar approaches have been used to improve mapping of ecological classifications to support land management decisions within a number of sub-disciplines in the USA. Spatial models of ecological classes provide a framework for organizing scientific knowledge about complex environmental systems in support of resource management. In the western U.S., soil property, geomorphology, and climate data have been used to quantitatively model 'ecological sites' and related groupings as a basis for understanding ecological dynamics for resource management decision-making. For instance, restoration of the keystone species big sagebrush (*Artemisia tridentata*) may be prioritized in appropriate niches based on specific quantifiable habitat constraints including specific climate, salinity, and soil depth ranges. In the northeastern U.S., custom forest management interpretations, such as site productivity and harvest operability, derived from both soil property and type inputs, provide detailed, accurate spatial representation of variables important for sustainable forestry practices. Access to this information allows for more meaningful and directed management decisions and more predictable responses to varying disturbances. As digital soil mapping products become readily available to a variety of users, they continue to grow as a fundamental component of effective resource management across all physiographic regions.

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Quantifying pedodiversity at different scales

Dr Laura Poggio¹, Dr Alessandro Gimona²

¹ISRIC - World Soil Information, Wageningen, the Netherlands, ²The James Hutton Institute, Aberdeen, Scotland (UK)

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

In this work we explore two different approaches to the quantification of pedodiversity. One based on methods used in the description of biological diversity, and therefore replacing species with soil units, and one based on spatial statistical methods applied to continuous soil properties surfaces derived from digital soil mapping (DSM).

We explore measures of local diversity, spatial turnover and regional-scale diversity based on accumulation curves, and show how to compare pedodiversity of arbitrary regions, with applications to river catchments. The results are dependent on the scale of analysis. We also show that the two approaches are complementary in the quantification of diversity. The analysis was applied to the whole of Scotland (UK).

NA

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Digital Soil Mapping and Hydrological Modelling produces solutions for severe infrastructure damage in Cosmo City, South Africa

Dr George van Zijl¹, Prof Johan van Tol², Dr Darren Bouwer³, Prof Simon Lorentz⁴, Prof Pieter le Roux³

¹Unit for Environmental Sciences and Management, North West University, Potchefstroom, South Africa, ²University of the Free State, Bloemfontein, South Africa, ³Digital Soils Africa, Port Elizabeth, South Africa, ⁴University of KwaZulu Natal, Pietermaritzburg, South Africa

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

Urbanization and hydrology have an interactive relationship, as urbanization changing the hydrology of a system and the hydrology commonly causing structural damage to the infrastructure. Hydrological modelling has been used to quantify the water causing structural impacts, and to provide solutions to the issues. However, in already-urbanized areas, creating a soil map to use as input in the modelling process is difficult, as observation positions are limited and visuals of the natural vegetation which indicate soil distribution are unnatural. This project used historical satellite images in combination with terrain parameters and digital soil mapping methods to produce an accurate (Kappa statistic = 0.81) hydrology soil map for the Cosmo City suburb in Johannesburg, South Africa. The map was used as input into the HYDRUS 2D and SWAT hydrological models to quantify the water creating road damage at Kampala Crescent, a road within Cosmo City (using HYDRUS 2D), as well as the impact of urbanization on the hydrology of the area (using SWAT). HYDRUS 2D modelling showed that a subsurface drain installed at Kampala Crescent would need a carrying capacity of 0.3 m³.h⁻¹.m⁻¹ to alleviate the road damage, while SWAT modelling shows that surface runoff in Cosmo City will commence with as little rainfall as 2 mm.month⁻¹. This project showcases the value of multidisciplinary work. The remote sensing was invaluable to the mapping, which informed the hydrological modelling and subsequently provided answers to the engineers, who could then mitigate the hydrology-related issues within Cosmo City. Van Zijl, G.M., Van Tol, J.J., Bouwer, D., Lorentz, S., Le Roux, P.A.L. 2020. Combining historical remote sensing, digital soil mapping and hydrological modelling to produce solutions for infrastructure damage in Cosmo City, South Africa. *Remote Sensing*, 12, 433; doi:10.3390/rs12030433

rassta: Raster-based Spatial Stratification Algorithms and their Application in Digital Soil Mapping

Mr. Bryan Fuentes¹, Minerva Dorantes², John Tipton²

¹*The National Institute for Conservation and Forest Development, Tegucigalpa, Honduras,* ²*University of Arkansas, Fayetteville, United States*

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

Spatial stratification of landscapes allows for the development of efficient sampling surveys, the inclusion of domain knowledge in predictive soil mapping frameworks, and the expert interpretation of interactions between landscape processes and their effect on the spatial variability of soil attributes. This work presents the rassta R package as a collection of algorithms dedicated to the spatial stratification of landscapes, the calculation of landscape correspondence metrics across geographic space, and the application of these metrics in soil sampling and digital mapping. The theoretical background of rassta is presented through references to several studies which have benefited from landscape stratification routines. Moreover, code examples are presented to demonstrate the functionality of the rassta package as a project-oriented framework for digital soil mapping.

Fuentes, B. A., Dorantes, M. J., & Tipton, J. R. (2021). Package 'rassta'. <https://CRAN.R-project.org/package=rassta>

Representative Elementary Areas to optimize field soil sampling under logistical constraints

Dr. Carla Gavilan¹, Dr. Colby Brungard¹

¹*New Mexico State University, Las Cruces, United States*

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

Information on soil properties and their spatial distribution is critical for land planning and sustainable soil management. Digital Soil Mapping (DSM) quantifies soil variation by establishing relationships between field observations and environmental covariates. Thus, the quality and accuracy of DSM predictions rely on the distribution of the observations. Several sampling approaches attempt to capture soil spatial variability. However, logistical constraints impose limitations to soil sampling in areas where soil information is essential (e.g., mountainous regions).

We propose a method to optimize soil sampling in remote areas called the Representative Elementary Area (REA) sampling. The REA strategy uses a top-down approach to stratify, subset, and identify small areas that capture the full range of landscape variability. We first stratify the study area by geomorphic environment (GE). Then, the areas are subdivided by subbasins, each of the subbasins is considered an elementary area (EA). The EAs are tested for representativeness using the Kullback-Leibler divergence and ranked based on their similarity to the larger GE. Finally, the EAs with higher similarity are selected and termed representative elementary areas (REAs). Field sampling is performed within these REAs. The method was implemented in the Mt.Hood National Forest (Oregon, USA). Comparisons were made with other sampling methods. The results demonstrate that by sampling REAs, we can capture the landscape variability while reducing logistical constraints. Also, we envision that by constraining the sampling area to REAs soil surveyors can identify soil-landscape relationships that otherwise would be difficult in sampling designs that result in more widely disbursed sample locations.

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Development of a digital soil mapping based decision framework for management of degraded organic soils for the Swiss Rhine Valley

Mr Stefan Oechslin¹, Ms Madlene Nussbaum¹, Mr Stéphane Burgos¹

¹*Berner Fachhochschule, Bern, Switzerland*

28 WG1.2 – Digital soil mapping: advances towards Digital Soil Assessment:, August 3, 2022

The Rhine Valley encompasses 4000 hectares with a fine grain pattern of organic and mineral soils formed by fluvial and lacustrine processes as well as waterlogged conditions. Soils were artificially drained and thereby made arable, resulting in ongoing land surface subsidence and emission of greenhouse gases. Local authorities are in urgent need of a decision framework to take action to stop soil degeneration and maintain soil fertility in future. As a base detailed spatial soil information and functional soil assessment is crucial.

We sampled full profile descriptions at 2'560 locations mostly down to a depth of 2 m and computed spatial predictions for 25 soil properties. To independently validate these maps additional 200 location were sampled by a stratified random design. Prediction accuracy was satisfactory with R2 between 0.61 and 0.89. Considering the complex soil layering in the area we developed an interpretation system and defined 40 classes relevant for soil management. The 25 soil property maps allowed spatial representation of these management classes at a spatial resolution of 25 m.

For each management class a set of suitable measures was evaluated regarding their cost efficiency and problem-solving contribution. The developed decision framework allows local authorities to efficiently plan sand overlays, re-wetting for nature reserves or subsidies for farming practices as well as to balance interest between farming and climate gas reduction. As a byproduct the large number of soil profile descriptions and the generated soil property maps are available to other stakeholders and for future map updates.

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Forensic 'Fingerprinting' (Provenance Determination) in the Predictive Geolocation of the Global Trade in Illicit Minerals and Metals

Dr Laurance Donnelly¹, Prof Duncan Pirrie

¹*UGS Initiative on Forensic Geology, United Kingdom*

45 WG4.1 - The application of Soil Science in the Criminal Justice System:, Alsh 2, August 3, 2022, 08:00 - 10:00

The illegal trafficking, theft and trade in minerals and metals is a major global problem. Illicit minerals and metals may become 'legitimised' via money laundering schemes and enter the supply chain after they have been refined, usually at a different geographical location to their origin. The beneficiaries are often well-organised syndicates, criminal gangs, cartels or terrorist organisation. This activity involves precious minerals and metals, platinum group minerals and conflict minerals (tin, tungsten and tantalum). Minerals and metals have inherent variability in terms of their physical, chemical (e.g. isotope ratios), morphological (surface), textural and mineralogical characteristics. This variability can be attributed to a number of factors including for example; their geological origin, post mining mineral processing, beneficiation or the blending of different streams. An objective of provenance determination (predictive geolocation) is to determine the geographical location from where a mineral or metal sample was derived or refined, to verify whether or not it originated from a conflict source or from a mine or processing plant aligned with criminal activities. Traceability refers to the physical tracing and tracking of precious minerals and metals as they move through the supply chain from the mine to the refiner and market. Traceability includes; chain of custody, sample security, bagging, tagging and certificate of origin, due diligence audits, registry of minerals producers and traders, the use of microtaggant identification particles, a geoforensic passport, elemental profiling and mineralogical profiling. An overview of these method will be provided with some operational case examples.

Donnelly, L.J. 2017. (ed.) Episodes Journal of International Geoscience. Special Issue on Forensic Geology, International Union of Geological Sciences, June 2017, 40.

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1715

Trace evidence comparison between soil on footwear and reference site locations: application to a murder investigation

Professor Lorna Dawson¹, **Mrs Linda Ainscough**², Mr Alastair Vannan², Mr Dominic Monaghan², Mrs Lisa Johnston², Dr Julie Roberts³, Dr Mark Spencer⁴, Prof Mark Brewer⁵

¹James Hutton Institute, Aberdeen, United Kingdom, ²Cellmark Forensic Services, England, ³Liverpool John Moores University, England, ⁴Consultant Forensic Botanist, , England , ⁵BioSS, , Scotland

45 WG4.1 - The application of Soil Science in the Criminal Justice System:, Alsh 2, August 3, 2022, 08:00 - 10:00

In September 2017 police saw a male walking in a residential area. When they came across him a second time he was not wearing shoes. He informed officers his wife, had not returned home. He said he was not wearing shoes as his feet were sore. Police were called to where a female body was found in a lake. The police suspected this was the missing female and her husband was arrested. Trainers were recovered from a bin near to where the suspect had been last seen. Mrs McKie's car was discovered a mile away, and was forensically examined.

A murder investigation ensued. Given issues of legitimate contact, suspect and victim living together, and limited bleeding, there were challenges to provide evidence to assist reconstruction. Blood was found on the trainers and DNA profile from the blood matched the wife's profile. A further DNA profile from the trainer showed the suspect as a significant contributor/wearer of the shoe. A murder investigation ensued.

Recovery of soil from the footwear was carried out to ensure single source samples and individual trace samples were analysed using an organic approach (Dawson and Mayes, 2014). The scenes were carefully examined and a sampling strategy was designed to ensure all potential areas of contact were represented. Consideration was given to alternative source propositions. A trial was held in Cheshire Crown Court, September 2018, with DNA and soil evidence presented. The suspect, the victim's husband, admitted killing his wife, and was found guilty of her murder.

Dawson, LA and Mayes, RW (2014) Criminal and Environmental Soil Forensics, In: B Murphy & R Morrison (eds), Introduction to Environmental Forensics, 3rd Edition. Academic Press.

Mayes, RW, Macdonald, LM, Ross, J, Dawson, LA (2009) Discrimination of domestic garden soils using plant wax compounds as markers., In: Ritz, K., Dawson, L.A. & Miller, D.R. (eds.). Criminal and Environmental Soil Forensics. Springer, Chapter 29, 463-476.

1748

The Search for Moira

Professor Lorna Dawson¹, Dr Alastair Ruffell², **Mr Patrick Campbell³**

¹James Hutton Institute, United Kingdom, ²Queens university, , United Kingdom, ³Police Scotland , , Scotland

45 WG4.1 - The application of Soil Science in the Criminal Justice System:, Alsh 2, August 3, 2022, 08:00 - 10:00

A search for missing schoolgirl Moira Anderson is ongoing. She was 11 when she left her grandmother's house in Coatbridge on February 23 1957 to buy butter and a birthday card for her mother's birthday. Moira was last seen by witnesses boarding a local Baxter's bus when the local Co-op store was closed due to bad weather. The bus driver was convicted child rapist Alexander Gartshore who was the last person to see Moira alive.

In 2013, graves were exhumed at Old Monkland Cemetery in an attempt to locate the remains of Moira but search proved unsuccessful. Witnesses came forward after this and a witness stated that she had seen a man dragging a young girl by the arms near the Carnbroe bus terminus in the late afternoon. The witness said the girl looked like Moira Anderson, later identifying the man as Gartshore. A Geographic Information System (GIS) was built to house all the relevant physical and witness information to help prioritise areas for the ongoing search.

A search in March 2017 at a nearby Canal (on the 60th anniversary of Moira's disappearance) followed a sequential methodology comprising: desktop study of the available data; (hydrological information such as bathymetry, sediment cover, water chemistry); acoustic sub-bottom imaging (water-penetrating radar, sonar); geolocation and probing of sub-bottom anomalies; deployment of suitable scent dogs. All data was compiled and stored in a Geographic Information System. This procedure creates a hierarchy of targets for examination by dive teams and thence recovery.

Alastair Ruffell and Neil Powell. Search Strategy for Buried Objects in Water: Geophysics, Probes and Dogs. 2021. Forensic. Sci. 2021, 1.

Soil material evidence in 2 crime investigations involving both primary and secondary transferences of soil materials

Professor Robert Fitzpatrick¹, Mr Mark Raven², Dr Peter Self³

¹The University Of Adelaide & CSIRO, Adelaide, Australia, ²CSIRO Mineral Resources, Adelaide, Australia, ³CSIRO Mineral Resources, Adelaide, Australia

45 WG4.1 - The application of Soil Science in the Criminal Justice System:, Alsh 2, August 3, 2022, 08:00 - 10:00

Forensic soil science progresses not only through publication of fundamental research, but also through publication of real live case studies with conclusions admissible in court. Through two diverse cases involving a sexual assault and murder investigation we demonstrate how pedological, mineralogical and chemical investigations have been critical in developing reliable soil information, from landscape to microscopic scales, to help law enforcement officers solve complex criminal investigations. Both cases involved primary and secondary transfer of soil materials. Once a trace soil material has transferred, any subsequent movements of that material, are referred to as secondary transfers. The sexual assault case illustrates that reddish-brown questioned soil was: (i) originally transferred to the victim's vehicle (primary transference) from driving on muddy forest service roads 3 days prior to the break-in of the vehicle and (ii) subsequently transferred to the suspect's jacket (secondary transference) when he brushed-up against the dried mud on the victim's vehicle during vehicle break-in. As such, the conclusive comparison between the reddish-brown soil on the victim's car and the suspect's jacket provided information linking the suspect to the crime scenes (break-in to the victim's vehicle and home). The murder case illustrates that the questioned soil materials recovered from the head/face/clothing of the deceased is a mixture of soil and lime materials, comprising: (i) natural red soil originating from the grave site, (ii) lime originating from commercial lime powder and (iii) natural dark brown soil originating from a nearby soil type from where the deceased's body was originally buried (secondary transference). Fitzpatrick RW, and Donnelly LJ (2021). Introduction to forensic soil science and forensic geology: A synthesis. In R.W. Fitzpatrick and L.J. Donnelly (Eds.), *Forensic Soil Science and Geology*. Geological Society of London, Special Publications, 492 1-32. <https://doi.org/10.1144/SP492-2021-81>; Fitzpatrick RW and Raven MD (2019). The forensic comparison of trace amounts of soil on a pyjama top with hypersulfidic subaqueous soil from a river as evidence in a homicide cold case. In R.W. Fitzpatrick and L.J. Donnelly (Eds.), *Forensic Soil Science and Geology*. Geological Society, London, Special Publications, 492,197-218. First published online 28 August, 2019. <https://doi.org/10.1144/SP492-2019-59> Raven MD, Fitzpatrick RW, and Self P (2019). Trace evidence examination using laboratory and synchrotron X-ray diffraction techniques. In R.W. Fitzpatrick and L. Donnelly (Eds.), *Forensic Soil Science and Geology*. Geological Society, London, Special Publications, 492, 165-179. First published online 28 August, 2019, <https://doi.org/10.1144/SP492-2019-36> Fitzpatrick RW, Raven MD. Self PG (2017). The role of pedology and mineralogy in providing evidence for 5 crime investigations involving a wide range of earth materials. *Episodes Journal of International Geoscience*. 40 (2) 148-156. <http://dx.doi.org/10.18814/epiiugs/2017/v40i2/017017>

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Forensic Geology and Civil Protection: when foreseeable hydrogeological disasters cause victims

Dr Rosa Maria Di Maggio¹

¹*Geoscienze Forensi Italia* ®, Rome, Italy

45 WG4.1 - The application of Soil Science in the Criminal Justice System:, Alsh 2, August 3, 2022, 08:00 - 10:00

The Civil Protection Department in Italy is governed by the Italian Presidency of the Council of Ministers and has the fundamental role of gathering and coordinating the national resources for ensuring assistance to the population in case of emergency. Thanks to the principle of subsidiarity, the national Civil Protection Department delegates local administrators as Civil Protection Authorities. This official role is carried out by the Mayors with the competence of Civil Protection within their municipal territory. Regarding foreseeable calamitous events, the Mayor must address the following Civil Protection plans: foreseeability, prevention and risk mitigation, emergency management, and overcoming the emergency.

One of the most fatal calamitous event in Italy is the hydrogeological instability, such as landslides, debris flows, floods. Recently, forensic geologists are increasingly called upon by the criminal Courts to assess whether local Authorities have adequately carried out the foreseeability, the preventing risk, and warning systems actions. Failure to follow these procedures can lead to dramatic consequences. The duty of a forensic geologist involved in such scenarios is not only to have a strong expertise of hydrogeological vulnerabilities at micro-scale level of the region of interest, but also a deep knowledge of the Civil Protection legislation.

A case of debris flow that caused the death of a person will be presented with the aim to identify the main operational steps that a geologist can take in account to evaluate the actions of foreseeability and prevention carried out by local Authorities to protect the population from hydrogeological disasters.

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Soil organic carbon to clay ratio: effective for monitoring management activities to achieve improved carbon status and condition of soils.

Mr Jonah Prout¹, Dr Keith Shepherd³, Professor Steve McGrath¹, Professor Guy Kirk², Dr Stephan Haefele¹

¹Rothamsted Research, Harpenden, United Kingdom, ²Cranfield University, Bedford, United Kingdom, ³World Agroforestry (ICRAF), Nairobi, Kenya

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Soil organic carbon (SOC) is vital for soil functions such as food production, biological diversity, carbon storage, and flood regulation. To better assess soils and improve SOC management, quantitative SOC guidelines are required. We tested the use of an index for SOC, based on three thresholds of SOC/clay, to assess soils of England and Wales (Prout et al., 2020). Clay concentration is related to a capacity for SOC protection through adsorption of SOC to mineral surfaces and occlusion within aggregates. The interactions between SOC and clay particles also influence soil physical properties and the SOC/clay ratio can indicate soil structural conditions. The index threshold ranges of SOC/clay (with indicated soil assessment) are: $\geq 1/8$ (Very Good), $< 1/8$ – $1/10$ (Good), $< 1/10$ – $1/13$ (Moderate), and $< 1/13$ (Degraded). Applying the index to the National Soil Inventory (NSI) of England and Wales, 38% of soils under arable management were degraded compared with $< 6.6\%$ of soils under grassland or woodland management. At smaller scales, the index was sensitive to management in long-term experiments. The index can also indicate carbon storage potential. Achievable SOC/clay ratios for arable, rotational grass, and permanent grass soils are $1/13$, $1/10$, and $1/8$ respectively. The index provides a simple framework with readily measured variables to identify soils in need of protection or improvement, and to monitor soils for SOC management. The range of soils within the NSI, and previous studies on other European soils, suggest that the findings of this work could apply across soils in temperate regions.

Prout, J.M., Shepherd, K.D., McGrath, S.P., Kirk, G.J.D. & Haefele, S.M. (2020) 'What is a good level of soil organic matter? An index based on organic carbon to clay ratio', *European Journal of Soil Science*, pp. 1–11. <https://doi.org/10.1111/ejss.13012>

Global modelling of soil functions to support soil security

Dr Laura Poggio¹, Dr Niels H. Batjes¹, Dr Luis de Sousa¹, Prof Dr Gerard B.M. Heuvelink¹, Bas Kempen¹, Andre Kooiman¹, Johan G.B. Leenaars¹, Stephan Mantel¹, David G. Rossiter¹, Rik van den Bosch¹

¹ISRIC - World Soil Information, Wageningen, The Netherlands

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Soils are a key natural resource to realise several UN Sustainable Development Goals. Consistent global soil information is required to underpin a large range of assessments, such as soil and land degradation, climate change mitigation and adaptation, food security, sustainable land management, and environmental conservation. With the development of digital soil mapping, the use of quantitative information on soil properties became more relevant. Nowadays there are regional, national and global maps of most basic soil properties. Yet most applications of soil data require information on soil functions. We developed a framework addressing the mapping of soil functions at global scale, using erodibility and soil carbon sequestration potential as examples. The soil information was provided by SoilGrids, global soil property maps at six standard depths and 250 m resolution. We used simplified models to derive soil functions from basic soil properties applicable in different pedo-climatic regions. We provide an indication of areas of low/high risk of soil degradation to support sustainable land management. The prediction intervals of the input soil property maps were used to provide a preliminary assessment of the uncertainty of the derived maps. The modelling framework offers great flexibility and may be applied to a diverse set of models to generate soil information products tailored to specific applications to support soil security. We highlight some of the challenges of assessing soil functions at global scale. Finally, we discuss the pros and cons of using diagnostic properties and horizons in assessments of ecosystem services together with quantitative soil properties.

NA

Securing Soil to Secure Human Health

Dr Eric Brevik¹, Dr. Margaret A. Oliver²

¹*Southern Illinois University, Carbondale, USA*, ²*University of Reading, Reading, UK*

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Soil can provide food of adequate quantity and quality and other resources, exposes humans to chemicals found in soil, leads to human contact with soil organisms, and can filter wastes. It influences human health both directly and indirectly through these mechanisms. The dimensions of soil security are important in the way soil influences human health. Dimension 1 (capability) influences soil's ability to produce food, other resources, and filter waste products to provide a clean environment, particularly clean water supplies. Dimension 2 (condition) helps determine the nutritional quality of agricultural products. Dimension 3 (capital) recognizes that there is value to the services soil provides in promoting human health, costs when soil constituents are detrimental to human health, and significant value in products such as medications that come from soil. Dimension 4 (connectivity) recognizes that societal interactions with and perspectives of soil influence the value we place on soil and the management strategies we use; this in turn influences human health through dimension 2. Dimension 4 also recognizes that loss of land as a public good may negatively influence human health. Dimension 5 (codification) focuses on issues such as conservation policies that have led to improvements in water quality and increased soil health, leading to the production of higher quality agricultural products in those soils and benefits to human health. There are significant opportunities to advance studies of soils and human health and our understanding of these relationships under the soil security concept through links such as those indicated above.

N/A

The Global Agricultural Domestication of Soil over Time

Ms. Anna Abramova¹, Dr. Ronald Amundson¹

¹*University of California at Berkeley, Berkeley, United States of America*

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Cultivated agriculture is likely the greatest human environmental perturbation of the Earth, and is an activity that continues to drive soil chemical, physical, and biological imbalances that have global implications. Presently, there is no global assessment of the footprint of agriculture on soil types. Here, we use the WRB system as a representation of the current global soil diversity and then overlay the Global Cropland Area Database to extract the fraction of cultivated vs uncultivated areas for each soil group. We also compile listings of soils that are heavily impacted (>50% of area in cultivation), endangered (>80%), and essentially extinct (>95%).

Recognizing that the human impact has varied geographically over time, we then use the KK10/HYDE3.2 Anthropogenic Land Cover Change databases to examine the temporally shifting human use of soils over the past 8000 years and how this may have impacted soil groups differentially. This analysis reveals temporal trends in (1) soil group utilization over time, (2) soil groups that had a significant agricultural impact before reversion back to non-agricultural states, and (3) soil groups that have essentially evolved over time in concert with millennia of human management.

These later soils – domesticated through much of their history – offer novel ways of re-envisioning soil geography and the factors that control it. Additionally, it identifies landscapes transiently changing from past intensive usage. This linkage of soil databases with emerging analyses of human activity during the Holocene magnify the mark of humans as a state factor on the world's soil resources.

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Impact of soil erosion on soil security under global climate change: insights from simulation of soil water dynamics and drought

Professor Tom Vanwalleghem¹, Dr. María del Pilar Jiménez-Donaire¹

¹*Universidad De Córdoba, Spain*

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Agricultural crop production in many areas of the world is limited by soil water availability. This critical reservoir can be severely affected by soil erosion. This problem is expected to increase in the next decades due to climate change affecting rainfall patterns.

In this study, the effect of soil erosion on plant water availability under different climate scenarios was evaluated. For 5 different locations, with different rainfall distribution and soil types, the soil water dynamics and derived plant stress indicators, namely static and dynamic stress, were calculated with a simple bucket-type model. Two contrasting scenarios were evaluated, RCP4.5 and 8.5, over the period 2006-2100. Finally, over this period, erosion rates between 10 and 100 t ha⁻¹ yr⁻¹ were applied, resulting in gradually increasing truncation of soil profiles.

Values of static and dynamic drought indices increase over time, with more frequent occurrences of maximum index values equal to 1, implying severe drought, especially towards the end of the century (2071-2100). The results show that soil erosion increases the agricultural drought incidence significantly, resulting in more frequent failure of crops, although the response is complex and depends highly on the rainfall distribution within any given year. This framework will contribute to identify the central role of soils in securing food production and drought monitoring and management.

Developing and implementing a diagnostic soil security assessment framework for Australia and beyond

Prof Alex McBratney¹, Prof Damien Field¹, Dr Mercedes Roman Dobarco¹, Dr Jose Padarian¹, Dr Alexandre Wadoux¹, Ms Sandra Evangelista¹, Prof Budiman Minasny¹

¹*The University of Sydney, Sydney, Australia*

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Soil security is a new concept: it does not yet have a framework for its assessment and for that to be successful it needs to be quantitative, representative and locally explicit. We aim to devise a quantitative framework for each of the five dimensions of soil security for a number of identified soil functions at any given location in the world. We have done preliminary work in the Hunter Valley, NSW and for the whole of Tasmania, Australia. The Tasmanian work suggests that a lack of policy and regulation for sub-prime agricultural land is a key driver of soil insecurity in that state. A secondary objective is to facilitate adoption of this diagnostic framework in a range of Australian jurisdictions and internationally. This work will be multidisciplinary -soil science, agronomy, environmental and ecological economics, agricultural and rural sociology) but will centre around soil science.

We are investigating and creating a quantitative diagnostic framework for assessing soil security locally and over time, with a view to improving the soil security incrementally and to understanding the drivers, whether they are biophysical, economic, sociological or policy-based.

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1378

Digital pedogenon mapping for assessing changes in soil condition from local to continental scale

Dr. Mercedes Roman Dobarco¹, Ho Jun Jang¹, Professor Alex McBratney¹, Professor Budiman Minasny¹, Dr. Brendan Malone²

¹The University of Sydney, Eveleigh, Australia, ²CSIRO Agriculture and Food, Black Mountain, Australia

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

Digital pedogenon mapping was conceptualized for assessing changes in soil condition caused by anthropogenic activities. The underlying hypothesis is that homogeneous groups of environmental covariates representing the soil forming factors for a reference time, would define unique soil entities, i.e., pedogenons. In the context of Australia, the time chosen as reference was the European settlement, since 1788 onwards the change in land management practices has intensified changes in soil condition. Information of contemporary drivers of soil change is then incorporated to divide pedogenons into subclasses with different degree and type of anthropogenic pressure. We present some examples of pedogenon mapping, from local (Edgeroi region, New South Wales) to continental scale (Australia). A space for time substitution allows to assess changes in indicators of soil condition, e.g., pH and soil organic carbon (SOC). Some of the potential applications of pedogenon mapping is to set targets for carbon sequestration, according to the capability of each pedogenon class, and to monitor changes in SOC over large areas like managed rangelands in Australia.

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Application of organic materials on land - Regulatory challenges in implementing circular economy principles in Scotland

Dr Claudia Erber¹, Dr Alan Cundill

¹*Scottish Environment Protection Agency, Stirling,*

Interdivisional 7 - Soil securing humanity | Humanity securing soil, Lomond Auditorium, August 3, 2022, 10:30 - 12:30

The world faces major challenges with climate change and mass extinction being regarded as the main ones. The circular economy is seen as a way to help tackle these problems by eliminating waste and pollution, keeping products and materials in use and regenerating natural systems.

The recycling of waste materials to land is a well-established way of implementing circular economy principles. However, there is a risk that this approach puts further pressure on our soils. What sounds convincing in theory is not that easy to implement, given the multiple challenges which need to be considered when regulating waste application to land.

We must understand the risk of each material so that the right level of regulation can be established. This must include the avoidance of unintended pollution swapping.

There is a need for a strong link to planning, to ensure that waste outputs have adequate storage capacity and sufficient local landbank. In Scotland nearly 50% of the population live in less than 10% of the total land area. Biodegradable municipal waste will be banned from landfill from 1 January 2025. After treatment this material is likely applied to land as compost or digestate. High transport cost will determine the distance the material can be applied from the source.

To prevent illegal waste application to land, data, audits and site investigations are required. However, these are often dismissed in times of limited budgets and resources. Collaboration with other authorities is required to tackle serious waste crime.

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Land use decisions under climate change: Reconciling food production and tree planting

Dr Jacqueline Hannam^{1,3}, Mrs Caroline Keay¹, Dr Katie Medcalf², Dr Gemma Bell², Mr Ian Rugg³, Mr Arwel Williams³, Mr James Cooke³

¹Cranfield University, Cranfield, United Kingdom, ²Environment Systems, Aberystwyth, United Kingdom, ³Welsh Government, , United Kingdom

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Key current policy decisions include how to reconcile competing demands for land use and how these will shift under climate change projections. A co-produced modelling exercise in Wales developed several spatial outputs of land capability for agriculture, suitability for crops and suitability for tree species under future climate scenarios. There was an improvement in land capability for agricultural production in the near future but a decline by 2080 due to increased drought stress. Several current crop types such as potato showed a decrease in the most suitable areas by 2080. The model also highlighted the potential for the expansion of novel or emerging crops, such as tea, that are not currently grown in Wales due to biophysical limitations. Ambitious tree planting targets have been announced to meet net zero targets in Wales, yet the amount of land predicted to remain most suitable for sessile oak and Sitka spruce will decline significantly by 2080. Thus, planting on land with limitations may need to be achieved to meet the targets but this will impact on the optimal tree growth at maturity. The outputs demonstrated how spatial modelling can be used to assist policy decisions to take into account the soil, climate and biophysical conditions for several land use types under future climate scenarios.

Keay C. A., Hannam J.A. 2020. The effect of Climate Change on Agricultural Land Classification (ALC) in Wales. Capability, Suitability and Climate Programme, Welsh Government Report 95pp

1757

Protect Black Soils to Achieve Food and Environmental Security: Report of the Global Status of Black Soils

Ph.d. Lúcia Helena Anjos¹, Ph.D. Yuxin Tong², Ph.D. Ivan Vasenev³, Ph.D. Marcos Esteban Angelini⁴, Ph.D. Pavel Krasilnikov⁵, MSc William May⁶, Ph.D. Xiaoyuan Geng⁷, Ph.D. Luca Montanarella⁸, **Prof. Rosa M Poch**, Ph.D. Alexei Sorokin⁹

¹UFRRJ, Seropedica, Brasil, ²GSP, FAO, , Italy, ³Russian Timiryazev State Agrarian University, , Russian Federation, ⁴Instituto Nacional de Tecnología Agropecuaria; GSP/FAO, , Argentina, ⁵Lomonosov Moscow State University, , Russian Federation, ⁶Agriculture & Agri-Food Canada, , Canada, ⁷Agriculture & Agri-Food Canada, , Canada, ⁸Joint Research Centre, European Commission, , Italy, ⁹Lomonosov Moscow State University, , Russian Federation

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Black soils are among most threatened soil resources of the world. Depleting these soils have consequences for food security, climate change and biodiversity loss. They are very fertile and thus considered “the world crop basket” or “giant pandas in cultivated farmlands”, receiving increasing pressures for usage. They are intensively farmed all over the world, and increasingly cultivated for cereal, pasture, range and forage systems. Their significant soil organic carbon (SOC) content makes them very sensitive as sinks and sources of greenhouse gases. The recognition of central role of black soil resources for food security, agricultural sustainability and productivity, and increased awareness that they play a significant role in climate change adaptation and mitigation triggered numerous projects, initiatives and actions globally (SDG 13). Considering the great importance of black soils and risks of severe degradation, because of recommendation of FAO’s Global Soil Partnership (GSP) on the UN’s SDGs, the International Network of Black Soil (INBS) was launched in Rome, March 2017. 31 Countries and one Union joined the Network, 82 experts from 26 INBS member countries contributed to develop the Report of Global Status of Black Soils and Global Black Soil Distribution Map. The report structure includes definition of black soils, global distribution and regional features, their essential role for ensuring global food security and to mitigate global climate change, the drivers and processes of degradation, the sustainable management and best available practices to mitigate degradation, and potential environmental and food production response and, the principle land-use and farming policy recommendations. International Network of Black Soil (INBS), <https://www.fao.org/global-soil-partnership/inbs/en/>

The “Groundwater Benefit Zone” in Saline Agriculture, Proposals, Contributions, and New Scientific Issues

Professor Ying Zhao¹

¹*Ludong University, Yantai, China*

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

The groundwater has great potential for water resource utilization, accounting for about a quarter of vegetation transpiration globally and contributing up to 84% in shallow groundwater areas. However, in irrigated agricultural regions or coastal areas with shallow groundwater levels, due to the high groundwater salinity, the contribution of groundwater to transpiration is small and even harmful. This paper proposes a new conception of groundwater benefit zone in the groundwater-soil-plant-atmosphere continuum (GSPAC) system. Firstly, it analyzes the mutual feedback processes of the underground hydrological process and aboveground farmland ecosystem. Secondly, it elaborates on the regional water and salt movement model proposed vital technologies based on the optimal regulation of the groundwater benefit zone and is committed to building a synergy that considers soil salt control and groundwater yield subsidies. Finally, based on the GSPAC system water-salt coupling transport mechanism, quantitative model of groundwater benefit zone, and technical parameters of regional water-salt regulation and control, the scientific problems and development opportunities related to the conception of groundwater benefit zone have been prospected.

Groundwater benefit zone; soil water and salt movement; model simulation; mechanisms; modification technology

Improving soil ecosystem services in Houston, Texas through large-scale tree planting frameworks providing sustainable land use and air pollution reductions

Dr. Deborah January-Bevers¹

¹*Houston Wilderness, Houston, USA*

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

For the storm-prone Greater Houston region, there is a critical need to better connect the soil ecosystem services (ES) provided by the diverse assemblages of forests, prairies, wetlands, riparian waterways and estuaries to long-term sustainability and disaster. Adding to these challenges are the region's clay-rich soil composition, made up largely of vertisols and alfisols which greatly influence watershed infiltration and runoff, especially during heavy rain events. These same soils affect environmental enhancement and recovery efforts in the region's rivers, bayous, bays and estuaries, where the dynamics of various commercial industries intersect with riverine systems, fisheries, coastal wetlands and marine life. Houston Wilderness' Ecosystem Services Primer, 2nd Edition discusses ways for determining ecosystem services (ES) benefits and values using different established study/valuation methods depending on targeted infrastructure/project goals. The HW ES Primer brings together land, water, air, soil and biodiversity, recognizing that their linkages provide a wide variety of services and benefits that are not specific to any one part. Case examples are discussed, where practical nature-based solutions were implemented. One example is a multidisciplinary framework, implemented in Houston, Texas, beginning in 2019, that consists of three parts: 1) identification of optimal native tree species for sustainable land use and air pollution mitigation; 2) selection of large-scale native tree planting locations where populations are already disproportionately experiencing flooding, increased heat and air pollution related health effects that are further exacerbated from climate change; and 3) engagement of multi-sectoral leadership broadened beyond those traditionally working on climate change resilience.

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Using soil health testing to design crop rotations that are fit for the future by balancing productivity with sustainability

Ms Catriona Willoughby^{1,2,3}, Professor Paul Hallett², Dr Alex Hilton¹, Dr Elizabeth Stockdale³, Dr Kairsty Topp⁴, Dr Robin Walker¹, Professor Christine Watson¹

¹Scotland's Rural College, Aberdeen, United Kingdom, ²University of Aberdeen, Aberdeen, United Kingdom, ³National Institute of Agricultural Botany, Cambridge, United Kingdom, ⁴Scotland's Rural College, Edinburgh, United Kingdom

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Well-designed crop rotations can improve yields and soil health, but not all rotations are equally beneficial. We assessed food production and soil health of contrasting rotational systems at two UK sites. Rotations at the conventionally managed site received fertiliser and either green waste compost (GWC), turkey manure (TM) or paper crumble (PC) amendments. The organically managed site had rotations with and without livestock and manure amendments. Both the conventional and organic sites had been under the same management for at least eight years. We expected farming systems with healthier soils to have higher yields than those with poorer soil health. Soil health indicators including macro and micronutrient content, bulk density, water retention, saturated hydraulic conductivity and soil organic matter (SOM). These were assessed alongside structural evaluations and earthworm counts, all field tests commonly recommended to farmers. A challenge was identifying soil health indicators independent of site characteristics. Soil structural field assessments and earthworm counts correlated with bulk density, macroporosity and SOM at both sites. Soil micronutrient contents were highly site specific and not driven by management. SOM drove variance in yield in organic rotations, while higher soil macronutrient content led to higher yields in rotations which received fertiliser ($p < 0.05$). PC additions led to significant increases to soil health overall ($p < 0.05$). Yields increased with amendment additions regardless of fertiliser use, amendment type and site ($p < 0.001$). In all other rotations, management significantly drove yields but did not effect soil health.

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Co-benefits and tradeoffs of conservation agriculture management on multiple ecosystem services: a synthesis of meta-analyses

Dr. Zach Simpson¹, Dr. Marshall McDaniel¹, Dr. Lisa Schulte Moore¹, Dr. Fernando Miguez¹, Dr. Jarad Niemi¹

¹*Iowa State University, Ames, United States of America*

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Conservation agricultural management practices (CAMPs) can either support or hinder ecosystem services (ESs)^{1 2}. Ideally, we want to manage agroecosystems to have the greatest positive effects for both targeted and untargeted ESs (i.e., co-benefits), while mitigating any negative effects for other ESs (tradeoffs). The evidence for when, where, and why CAMPs cause ES co-benefits or tradeoffs is scant, but increasingly needed as ESs are being valued in private and/or public markets (e.g., soil carbon sequestration and water quality benefits)^{3 4}. One established method to broaden and deepen our understanding of the effect of a single CAMP on one ES is through meta-analysis. But this approach has been too narrow to further our knowledge on the co-benefits or tradeoffs in ESs with a change in agroecosystem management. We conducted a second-order meta-analysis by synthesizing published meta-analyses and their datasets, supplemented with some primary studies, to form one cohesive database for assessing co-benefits and tradeoffs of several CAMPs (reduced tillage, cover crops, crop diversity, residue management, fertilizer management, and land conversion/retirement) on multiple ESs (soil carbon, fertility, greenhouse gas emissions, and microbial and physical properties; crop yield; and water quality). Our central questions are, (1) how do conservation agricultural practices in temperate cropping systems affect these multiple ecosystem services? and (2) What contextual details (e.g., moderating variables) are these ecosystem service outcomes conditional on? We present preliminary findings; identify gaps in the literature; and provide guidance for new meta-analyses in order to increase their utility in second-order meta-analyses or decision making.

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Soil Health is the Guide: Three lessons from assessing grazing management practices in the western United States

Ms. Kristi Mingus¹, Dr. Megan Nasto², Dr. Kris Hulvey², Austen Lambert¹, Dean Stacy¹, Miles Coker¹, Lucille Rollins¹

¹*Natural Resources Conservation Service, Price, USA*, ²*Working Lands Conservation, Logan, USA*

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Grazing management practices have been inextricable from rangeland soil health in the western United States for nearly two hundred years, yet tools to assess soil health remain elusive to ranchers attempting to improve stewardship of the land. Soils in riparian areas and the extensive Kearl and Solak soil series were evaluated across four different grazing practices—continuous, early season, mid-season, and watershed-based—on a landscape scale in Rich County, Utah to tease apart impact of management on soil health. Three key discussions have arisen from baseline analysis: 1) Infiltration rates and physical soil properties that inform these rates, such as soil structure and bulk density that change with compaction, can provide an easy ‘first look’ into soil health. 2) As the availability of mid-infrared spectroscopy equipment becomes more widely available, a cheap, rapid assessment of soil characteristics on a landscape-based level may prove a useful tool for ranchers assessing both soil health parameters and feasibility of entering carbon markets. 3) Ranchers on public lands can feel boxed into less sustainable grazing management practices, but the ranchers in Rich County that recently participated in the largest grazing allotment consolidation project in the western United States (Payne, 2018) are proving that—with collaboration and persistence—watershed-based grazing management plans have the possibility to succeed, creating grazing management plans where soil health is the guide.

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Trade-offs needed in delivering environmental services through extensification of improved UK upland pasture soils

Dr John Scullion¹, Dr Caroline G Freeman¹, Dr Andrew Detheridge¹, Prof Gareth Griffith¹, Dr Dylan Gwynn-Jones¹

¹*Aberystwyth University, Aberystwyth, UK*

Interdivisional 8 - Sustainable land use, M1, August 3, 2022, 10:30 - 12:30

Soils are now expected to deliver a range of environmental services, in addition to their traditional role in food and fibre production. This has led to intense debate in relation to land use and management particularly in upland pastures. Undisturbed, these semi-natural grasslands are global biodiversity hotspots for macrofungi (waxcaps), but they also have an important influence on catchment hydrology given their location, with typically high rainfall and sloping topography. In the UK, much of this upland acid grassland was limed, fertilised and reseeded to improve agricultural production in the last century. In such pasture-based agriculture, extensification, involving reductions in inputs and grazing intensity, is proposed as a means of enhancing delivery of broader soil environmental services. However, it is unclear whether there are any conflicts between delivery of different services with such extensification. On a long-term field experiment established on improved pasture in mid-Wales UK, inputs of lime and/or fertiliser were maintained or withdrawn to investigate potential impacts on production, water regulation (infiltration), carbon (stocks and fluxes) and biodiversity (plant and fungal). Different treatments were better able to deliver on particular environmental services. For example, maintenance liming and fertilisation benefitted infiltration but reduced plant diversity compared with extensification treatments; eDNA studies indicated that plant diversity responses were decoupled from those of soil fungal communities. Findings will be discussed in relation to the complexity of applying management drivers of environmental services, trade-offs in their delivery and the need for a more nuanced debate on upland land management.

Simulating the capacity of legacy soil phosphorus to maintain long-term crop productivity under reduced phosphorus fertiliser inputs

Miss Jennifer Davies¹, Dr Victoria Janes-Bassett¹, Dr Martin Blackwell², Mr Andrew Burgess³, Professor Jessica Davies¹, Professor Philip Haygarth¹

¹Lancaster University, Lancaster, United Kingdom, ²Department of Sustainable Agriculture Sciences, Rothamsted Research, North Wyke, United Kingdom, ³Burgess Farms, Produce World Group Ltd, Peterborough, United Kingdom

17 Division 2: Sustainable use of legacy soil phosphorus:, Gala, August 3, 2022, 10:30 - 12:30

To ensure plant-optimum phosphorus (P) concentrations in soil solution to maintain crop yields, agricultural strategies have historically focused on applying phosphate fertilisers in excess of crop requirement. Over time excess P has accumulated in the soil and has contributed to the eutrophication of surface waters via leaching and loss by erosion. However, this legacy P could also represent a reserve that has the potential to offset fertiliser P inputs. To exploit the legacy P in the soil without compromising productivity, it is important to understand the length of time that crop yields can be sustained using this reserve, and the main factors controlling this.

Using the biogeochemical model N14CP we have investigated the long-term capacity of legacy P to provide agronomically sufficient P to a grassland and cereal cropping system in response to reduced and eliminated P fertiliser inputs under various historical fertiliser regimes. Observational data were utilised from two long-term agricultural experimental sites (permanent grassland and wheat plots) to test how the model performs in managing legacy P for crop production in the short-term. Preliminary results indicate that for the wheat crop, yield has the potential to be maintained at current levels for between 5–134 years with no annual applications of P fertiliser depending on the historical fertiliser use on the plot. This is increased to 42–283 years on the permanent grassland site. We hope that by using long-term model simulations that we can continue to challenge the mindset that crops need annual inputs of P to maintain yield.

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Phosphorus fractions and availabilities in different soil depths after 20 years of continuous soil P management.

Yue Hu^{1,2}, **Dr Klaus Jarosch**^{3,4}, Dr Mareike Kavka¹, Prof Bettina Eichler-Löbermann¹

¹University of Rostock, Rostock, Germany, ²Leibniz Institute of Plant Genetics and Crop Plant Research, Malchow/Poel, Germany, ³Agroscope, Zurich, Switzerland, ⁴University of Bern, Bern, Switzerland

17 Division 2: Sustainable use of legacy soil phosphorus:, Gala, August 3, 2022, 10:30 - 12:30

Soil phosphorus (P) management is mostly guided by soil P tests of topsoil samples, yet, the influence of P fertilization on soil P processes in deeper soil compartments are still not well understood. We report on latest findings of a P fertilization trial which was established in 1998 on a moderately acidic Cambisol in northern Germany and consists of four P-fertilization treatments with an inherent P-fertilization gradient. Soil samples were obtained after 20 years from each treatment in three depths (0-30, 30-60, 60-90 cm) and analysed for basic soil parameters, Hedley-P-fractions and isotopically exchangeable P.

The labile Hedley-P fractions (sum of Resin-P and NaHCO₃-P) very much followed the expectations, i.e. an increase with P-fertilization level and a decrease with soil depth. However, more recalcitrant Hedley-P fractions (sum of H₂SO₄-P and Residual-P) did not follow this pattern, resulting in similar P concentrations between treatments and soil depths in most cases. P availability derived from isotopic exchange kinetics showed a similar pattern. In detail, P fractions that are exchangeable within a short period of time (E1min) showed a more distinct pattern between treatments and depths than exchangeable P fractions exchangeable over longer time periods (E>3months).

Despite substantial differences in total soil P and effective P budget between the treatments our results suggest that the applied management mostly affected the more labile and short-term exchangeable P fractions and had little effect on the more recalcitrant and more slowly exchangeable P fractions in each analysed soil depth.

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What controls the availability of organic and inorganic P sources in top- and subsoils ? A ³³P isotopic labelling study

Ms Juanjuan Ai^{1,2}, Dr. Callum Banfield^{1,2}, Dr. Guodong Shao¹, Dr. Kazem Zamanian³, Mr Tobias Stützerbecher², Dr. Michaela Dippold^{1,2}

¹*Geo-Biosphere Interactions Department of Geosciences, University of Tübingen, Tübingen, Germany*, ²*Biogeochemistry of Agroecosystems, Department of Crop Sciences, University of Göttingen, Göttingen, Germany*, ³*Department of Soil Science of Temperate Ecosystems, University of Göttingen, Göttingen, Germany*

17 Division 2: Sustainable use of legacy soil phosphorus:, Gala, August 3, 2022, 10:30 - 12:30

Besides nitrogen, phosphorus (P) is a major limiting nutrient for plant growth with restricted global resources. Increasing subsoil P availability could help to mitigate the approaching limitation in P-fertilizer resources. Root exudates can provide easily available carbon and energy source for microorganisms to mobilize soil nutrients but details on distinct processes how root exudates interact with specific P forms alter their mobilization are scarce, especially in subsoils. This study aimed to identify the controlling factors and microbial processes regulating organic and inorganic P availability in top- and subsoils by ³³P isotopic labelling. Based on a novel root exudate collection method, key rhizosphere strategies for P mobilization could be disentangled. We found that microbial top- and subsoil communities use high and low available mineral P to a similar extend, but subsoil communities were much more efficient in mobilizing and incorporating complex litter-derived P than topsoil communities, and this capability is enhanced when root-exudates are present. We observed a clear increase in microbial activity and nutrient-mobilizing mechanisms (e.g. P-related enzymes) by root exudate addition, which was in many cases higher in sub- than in topsoils. We conclude that subsoil communities are well capable of using litter-derived P, especially if root exudates accelerate overall activity and element cycling. Our study indicates that high root exudation is of key relevance for those crops, depending on subsoil nutrients and litter-derived P. In consequence, detritusphere P in subsoil root channels re-used by roots is likely to be plant-available as consequence of the microbial P (re-)cycling processes.

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Adsorption and desorption dynamics of organic phosphorus forms from Fe/Al oxyhydroxides and clay minerals.

Phd ISSIFOU AMADOU¹

¹Unilasalle-aghyale (sfr Condorcet Fr Cnrs 3417), Beauvais, France, BEAUVAIS, France

17 Division 2: Sustainable use of legacy soil phosphorus:, Gala, August 3, 2022, 10:30 - 12:30

Recycling phosphorus(P) from organic inputs is becoming a necessity for sustainable P management in agroecosystems. However, the P contained in organic inputs is in various inorganic and organic forms that differ in their availability to plants. Most research has focused on the inorganic P form (Pi) showing it most adsorbed to the soil surface. In contrast, the fate of organic P (Po) forms has been understudied to date, and there is still a lack of knowledge about the contribution of these forms to plant nutrition. We investigate the sorption and desorption dynamics of the three major forms of Po present in organic input and soil: myo-inositol hexakisphosphate (myo-IHP), glycerophosphate (GLY) and glucose-6-phosphate(G6P) and one form of Pi on Fe/Al oxides (goethite, gibbsite) and clay minerals (kaolinite, montmorillonite). The results of this study highlight several processes that are important for understanding P sorption and release in the soil system. The myo-IHP form is found to be the more strongly adsorbed form of P and GLY the weaker adsorbed form. The different soil mineral may also affect Po availability. The minerals tested can be classified according to their affinity for Po forms as follows: Fe/Al oxides >> clay minerals. Gibbsite is the mineral with the highest sorption and lowest desorption of Po forms. Furthermore, Po forms show a slower desorption rate per day than Pi forms. This implies that when Po forms are used as fertilizer, they will be able to desorb slowly at the rate of plant uptake, even in the long term.

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Associations of inositol phosphates and complex phosphomonoesters with soil organic matter

Dr Jolanda Reusser^{1,2}, Prof Dr Alessandro Piccolo³, Dr Giovanni Vinci³, Claudia Savarese³, Prof Dr Riccardo Spaccini³, Dr Vincenza Cozzolino³, Silvana Cangemi³, Dr Rene Verel⁴, Prof Dr Emmanuel Frossard², Dr Timothy McLaren⁵

¹Swiss Soil Monitoring Network NABO, Agroscope, Zurich, Switzerland, ²Department of Environmental Systems Science, ETH Zurich, Lindau, Switzerland, ³Interdepartmental Research Center on Nuclear Magnetic Resonance for the Environment, Agro-Food and New Materials (CERMANU), University of Napoli Federico II, Portici, Italy, ⁴Department of Chemistry and Applied Biosciences, ETH Zurich, Zurich, Switzerland, ⁵School of Agriculture and Food Sciences, University of Queensland, St Lucia, Australia

17 Division 2: Sustainable use of legacy soil phosphorus; Gala, August 3, 2022, 10:30 - 12:30

Phosphorus (P) is an essential element for organisms and an integral component of cellular structures. In terrestrial ecosystems, the main source of P for plant nutrition originates from the soil environment. However, the chemical nature of more than half of organic P (P_{org}) in soil remains unresolved. Previous studies indicate that this pool is of apparent large molecular size, complex in structure, resistant to enzymatic hydrolysis, and closely associated with the soil organic matter (SOM). The aim of this study was to investigate the association of P in SOM by combining the Humeomics sequential chemical fractionation method (SCF), which separates SOM components according to bonding type, and characterization of P_{org} using nuclear magnetic resonance (NMR) spectroscopy.

In summary, 38 % of the extractable P_{org} from a Gleysol soil sample was present in the form of the unresolved pool of phosphomonoesters in solution ³¹P NMR spectra. The Humeomics SCF indicated that 47 % of this pool was associated with the SOM through ester and ether bonds, whereas another 30 % was associated with the mineral phase.

Furthermore, the extractability of inositol phosphates (IP) was increased by a factor of 1.7 using the Humeomics SCF procedure compared to a single-step NaOH-EDTA extraction. The observed concurrent removal of IP with the fractionation of the SOM suprastructure could explain the presence of these compounds in apparently large molecular associations.

We demonstrate that major pools of P_{org} in soil are associated with the SOM through multiple bonding types, comprising a diverse array of P species.

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Arbuscular mycorrhizal fungi are more important than root hairs of maize for utilizing legacy P in soils

Dr Jiachao Zhou¹, Prof Lin Zhang¹, Prof Gu Feng¹, Ms Lawrie Brown¹, **Dr Tim George¹**

¹China Agriculture University, Beijing, China, ²The James Hutton Institute, Dundee, United Kingdom

17 Division 2: Sustainable use of legacy soil phosphorus:, Gala, August 3, 2022, 10:30 - 12:30

Root hairs, arbuscular mycorrhizal (AM) fungi and the rhizosphere microbiome all play important roles in utilization of legacy P in mycorrhizal plants. However, how the plant-AM fungi-rhizosphere microbiome continuum interacts efficiently to promote the use of soil P is still unclear. Here, we present results from controlled environment experiments on maize with three factors, two root hairs genotypes, two AM fungal inoculation treatments and two soil P levels to reveal the effects of root hairs, AM fungi and their interaction on rhizosphere microbial mediated organic P (Po) cycles. Compared to root hairs, AM fungi contributed more to active microbial community assembly, functional gene recruitment and Po mineralization. The rhizosphere microbial Po mineralizing process driven by AM fungi contributed more than half of plant P assimilation in the P limited condition. The application of inorganic P (Pi) reduced the function of AM fungi and root hairs, and even reduced the effect of root hairs and AM fungi on rhizosphere microbial community assembly and Po mineralizing ability. Our findings demonstrate the importance of AM fungi for maize, not only in its role in nutrient absorption and stress resistance, but also as a driving force for rhizosphere microbiome recruitment.

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Understanding GHGs dynamics of alternative management practices under shallow water table conditions

Dr. Matteo Longo¹, Dr. Gemini Delle Vedove², Prof. Nicola Dal Ferro¹, Dr. Riccardo Polese¹, Mrs. Barbara Lazzaro³, Prof. Francesco Morari¹

¹DAFNAE Dept., University of Padova, Padova, Italy, ²Dipartimento di Scienze Agrarie ed Ambientali, Università di Udine, Udine, Italy, ³Regione Del Veneto, Direzione Agroambiente, Caccia e Pesca, U.O. Agroambiente, Mestre, Italy

21 Division 3, Commission 3.2 - Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 10:30 - 12:30

Alternative management practices are promoted to reduce nutrient pollution and mitigate greenhouse gas (GHG) emissions. However, the effect of water table (WT) on GHG emissions from mineral soils under different cropping systems have not yet been fully examined. In a three-year experiment, we quantified GHGs (N₂O, CH₄ and CO₂) emissions in a highly equipped lysimeter experiment, comparing contrasting cropping systems (conventional -CV-, conservation -CA- and conventional agriculture with cover crops -CC-) as managed according to different WT levels (free drainage -FD-, 60 and 120 cm depth). Gas fluxes were continuously measured using dynamic chambers connected to a FTIR analyzer, resulting in a massive number of recorded fluxes (over 16800). During the cropping season, heterotrophic was distinguished from total respiration using an in-situ calibrated model. The soil water content and temperature were also monitored in the whole soil profile.

Under CC and CA, both N₂O and CH₄ were influenced by the presence of the water table, with lower values associated with FD (e.g., 3.0 vs 1.2 kg N-N₂O ha⁻¹ for WT and FD, respectively). Heterotrophic respiration was similar among management practices (1441.5 kg C-CO₂ ha⁻¹), but higher under FD. In terms of total GHG emissions, CC outranked CV and CA, averaging 2459.9, 2186.0 and 1875.6 kg C-CO₂e ha⁻¹, respectively. This study showed contrasting results and did not fully confirm the mitigation effect of alternative management practices, especially when associated with shallow water table conditions.

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Nitrous oxide emissions in poorly drained soils in a corn and soybean cropping system: Effect of drainage and N applications

Dr. Karina Fabrizzi¹, Dr. Fabian Fernandez¹, Dr. Rodney Venterea^{1,2}, Dr. Seth Naeve³

¹Department of Soil, Water, and Climate, University of Minnesota, St Paul, United States, ²USDA-ARS, Soil and Water Management Unit, St Paul, USA, ³Department of Agronomy and Plant Genetics, University of Minnesota, St Paul, United States

21 Division 3, Commission 3.2 - Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 10:30 - 12:30

In the USA Midwest subsurface tile-drains remove excess water and increase crop productivity, but many fields or portions of fields still have poor drainage that result in anaerobic conditions and N loss by denitrification, especially under wet springs due to climate change. The objective was to evaluate in-season N₂O emissions in a corn and soybean cropping system under tile-drainage and natural (no tile) conditions with different N fertilization management. The study was set up with drainage as whole plot (drained and undrained) and N treatment [zero-N control, and 135 kg N/ha as single pre-plant and split N application (pre-plant plus at V6 with urease inhibitor)] as split plot in a randomized complete-block design with four replications. Drained compared to undrained soils increased corn grain yield. In corn, undrained soils produced 1.8 times more cumulative N₂O emissions than drained soils. Similarly, undrained relative to drained soils increased N₂O emissions in one of the three soybean years. Season-long cumulative area-scale N₂O emissions (2014-2016) combined across corn and soybean showed a trend for greater N₂O emissions under undrained (3.2 kg N/ha) than drained soils (2.1 kg N/ha) with substantially greater emissions during the corn phase. Nitrogen fertilizer in corn increased emissions by 2.1 times for the single- and 1.6 times for the split-application relative to the zero-N control. However, compared to the single N application, the split-N application reduced N₂O emission without negatively affecting corn yield. In soybean, residual N fertilization from the corn phase did not increase N₂O emissions regardless of drainage. Fernández, F.G., Venterea, R.T., & Fabrizzi, K.P. (2016). Corn nitrogen management influences nitrous oxide emissions in drained and undrained soils. *Journal of Environmental Quality*, 45 (6),1847-1855. doi: 10.2134/jeq2016.06.0237

Effects of biodegradable plastics on soil properties and greenhouse gas productions

Professor Emeritus Kazuyuki Inubushi¹

¹*Chiba University, Matsudo, Japan*

21 Division 3, Commission 3.2 - Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 10:30 - 12:30

Microplastics may cause environmental problems such as oceanic and soil pollution. Biodegradable plastics become popular aiming to avoid such problems. However decomposition of plastics in soil may induce impact on soil health. We investigated effects of biodegradable plastics on soil physicochemical properties, gas production and plant growth. Three kinds of biodegradable plastics 1) nonwoven fabric sheet made of poly-lactic acid (PLA) and polybutylene-succinate (PBS), 2) laminate sheet made of polybutylene adipate terephthalate (PBAT) and pulp, and 3) drinking cup made of PLA, were cut into small pieces and added to soil, then incubated aerobically in the dark. Soil pH, mineral nitrogen contents, and gases production were measured. These plastics were also tested in pot experiment with Komatsuna (*Brassica napa*) for seed germination, plant growth and fresh weight at the harvest.

Soil pH in fabric plastics dropped during initial 2 weeks of incubation, then recovered to similar pH as control (without plastic). Nitrate contents in soil with laminate plastics kept lower than control, while CO₂ production in soil with laminate plastics was higher than the control and the other plastics during incubation period, and even higher than added plastic-C. N₂O was produced rapidly within 1 week of incubation in soil with the laminate plastics, and cumulative N₂O production in incubation was also more than the control. The seed germination and plant growth tended to be suppressed with fabric and laminate plastics. These results indicate marked influences of biodegradable plastics on soil properties, greenhouse gas production and plant growth.

Inubushi et al. 1999. Effect of salts and moisture content on N₂O emission and nitrogen dynamics in Yellow soil and Andosol in model experiments, *Biology and Fertility of Soils*, 29: 401-407

Boots et al. 2019. Effects of Microplastics in Soil Ecosystems: Above and Below Ground, *Environ. Sci. Technol.* 53: 11496–11506

Nitrate, nitrous oxide, and ammonia loss mitigation with optimum rate of enhanced efficiency nitrogen fertilizer and application timing in corn

Dr. Fabian Fernandez¹, Sonia Menegaz²

¹*Department of Soil, Water, and Climate, University of Minnesota, St Paul, United States,* ²*Proterra Investment Partners, Minneapolis, USA*

21 Division 3, Commission 3.2 - Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 10:30 - 12:30

Enhancing crop productivity while mitigating the negative environmental impact of agriculture with advanced nitrogen (N) management practices is of paramount importance. Nitrate (NO₃) leaching to water resources and atmospheric losses of nitrous oxide (N₂O) and ammonia (NH₃) can increase with N applications. The objectives of this 7-year study (2014-2020) in Minnesota, USA were to compare traditional to advanced N management practices on corn yield and profitability, N losses (NO₃, N₂O, and NH₃), and cropping system (plant and soil) N balance when N applications are near the economic optimum rate for crop production. Traditional management was pre-plant urea and advanced management was pre-plant controlled-release polymer-coated urea (ESN) and split applications with one-third of the total rate as urea or ESN pre-plant and two-thirds urea with a urease inhibitor at V6 corn development stage. Pre-plant ESN and split applications enhanced grain yield relative to pre-plant urea. However, split applications had no environmental benefit relative to pre-plant urea, whereas pre-plant ESN reduced NO₃ loading and NH₃ emissions and N₂O emissions especially in wet years. Nitrogen balance as an approach to calculate N efficiency or environmental quality impact had limited utility because plant N uptake overshadowed treatment effects on N loss measurements. While split N applications had greater net economic returns than pre-plant urea, they had limited environmental benefits, but pre-plant ESN showed important agronomic, economic, and environmental advantages. This advanced management practice deserves further attention if we are to meet sustainable crop production goals in the face of climate change.

Menegaz, S.T. (2021). Mitigation of nitrate, nitrous oxide, and ammonia loss with time and source of nitrogen application in corn. [Master thesis]. University of Minnesota.

Trade-offs or co-benefits of carbon input strategies on greenhouse gas emissions in low organic matter soils of the Southeast U.S.

Dr. Alex Woodley¹, Dr. Wayne Robarge¹, Dr. Henrique Da Ros Carvalho¹

¹*North Carolina State University, Raleigh, United States*

21 Division 3, Commission 3.2 - Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 10:30 - 12:30

The sub-tropical coastal plain soils of the Southeast U.S. are generally low in soil organic carbon (<1%) due to hot humid conditions, coarse textured soils and intensive agriculture. This often results in low soil health scores [1] and concern over system resilience. A series of studies have been established to evaluate various carbon input strategies in organic and conventional farming systems on soil carbon stocks and the interaction these inputs have on nitrous oxide (N₂O) emissions and soil health. The expected modest carbon gains are at risk of being negated if these strategies induce relatively higher N₂O emissions. The carbon inputs range on a spectrum of carbon decomposability, including biochar, compost and cover crops. We will present data from three field sites with corn and sorghum grown in the summer of 2021. One site has 12 automated chambers continuously measuring N₂O and carbon dioxide (CO₂), as well as static chamber measurements for an assessment of emission trade-offs and method comparison. The remaining sites have been sampled for soil carbon and soil health parameters. Lastly, a study located within a long-term experiment (20yr) at the Center for Environmental Farming Systems will be presented. This single-year campaign focused on the impact of divergent land management (organic vs. conventional, no-till vs till, forage vs row crop) has on N₂O emission, when all system rotations aligned with corn grown in 2019. Preliminary data showed the transition from three years of forage to corn induced 230% increase in N₂O compared to continuous row crop.

[1] Roper, W.R., Osmond, D.L., Heitman, J.L., Wagger, M.G. and Reberg-Horton, S.C. (2017), Soil Health Indicators Do Not Differentiate among Agronomic Management Systems in North Carolina Soils. *Soil Science Society of America Journal*, 81: 828-843.

<https://doi.org/10.2136/sssaj2016.12.0400>

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Effects of pre-processed organic fertilizers on soil organic matter and nutrient stocks in agricultural soils

Dr Julien Guigue¹, Anke Neumeier¹, Dr Yaser Ostovari¹, Dr Andreas Muskolus², Henk Martens³, Emina Mešinović², Prof Ingrid Kögel-Knabner^{1,4}, Prof Jan Willem van Groeningen³, Dr Alix Vidal^{1,3}
¹Chair of Soil Science, Technical University of Munich, Freising, Germany, ²Institute of Agricultural and Urban Ecological Projects at HUB (IASP), Berlin, Germany, ³Soil Biology Group, Wageningen University, the Netherlands, ⁴Institute for Advanced Study, Technical University of Munich, Garching, Germany

29 WG1.3 – Progress in Digital Soil Morphometrics - deeper and more precise soil observations, Alsh 2, August 3, 2022, 10:30 - 12:30

Sustainable agriculture implies the maintaining of soil organic matter (SOM) stocks that are a central component of soil fertility. The use of organic amendments is one of the levers to achieve these goals, and is an alternative to the use of synthetic mineral fertilizers. Here, we aimed at investigating how the pre-treatment of organic fertilizers (i.e., the separation of liquid and solid fractions of biogas digestate) affect SOM stocks, nutrients and soil structure in agricultural soil down to a depth of one metre, and after seven years of application.

We collected soil from a field experiment in North-East Germany and quantified the soil organic carbon and nitrogen stocks, and nutrient contents. Samples were further analysed for aggregate size distribution, as well as organic carbon and nitrogen contents within these aggregates. We also applied hyperspectral imaging to scan undisturbed core-samples in the Vis-NIR range in order to reveal hotspots of organic matter along the soil profile. Soil carbon distribution was predicted as a function of spectral response using a machine learning ensemble. Organic C stocks were low (53 t ha⁻¹), and the application of organic fertilizers resulted in C accumulation in the first 10cm (+26%) and from 20-40cm (+30%), as compared to mineral fertilization. Soils fertilized with mineral only or with liquid digestate have relatively more microaggregates (+19-40%) in the soil down to 80cm. The pre-treatment of organic fertilizers could help to increase nutrient recycling and SOC stocks in agricultural soils and is relevant for the promotion of circular agriculture.

Nielsen, K., Roß, C.-L., Hoffmann, M., Muskolus, A., Ellmer, F. & Kautz, T. 2020. The Chemical Composition of Biogas Digestates Determines Their Effect on Soil Microbial Activity. *Agriculture*, 10, 244

Characterization of podzolic soils using digital soil morphometrics in subtropical subalpine forests

Student Yin-Chung Huang¹, Professor Cho-Ying Huang², Professor Zeng-Yei Hseu¹

¹*Department of Agricultural Chemistry, National Taiwan University, Taipei, Taiwan,* ²*Department of Geography, National Taiwan University, Taipei, Taiwan*

29 WG1.3 – Progress in Digital Soil Morphometrics - deeper and more precise soil observations, Alsh 2, August 3, 2022, 10:30 - 12:30

Digital soil morphometrics is a potential and quantifying approach to classify soils by using proximal sensors. The prediction ability of soil attributes with the combination of proximal sensors and machine learning is widely accepted. However, the relationship between soil morphological characteristics and sensor signals is difficult to elucidate with such an approach. Hence, this study aimed to investigate the linkages between soil morphological characteristics and proximal sensing including portable X-ray fluorescence spectrometry (pXRF) and visible and near infrared spectrometer (Vis-NIR). The criteria of Spodosols, i.e., Munsell color and optical density of oxalate extractant (ODOE) were chosen as target features. The colors of diagnostic horizons in podzolic soils are indications of spodic material, and the accumulation of organic matter and Fe and Al sesquioxides were hypothesized to be correlated with proximal sensor signals. Ten soil profiles with podzolization in the subalpine forest in Taiwan were described and sampled. Munsell colors were transformed to the color index proposed by Mokma (1993) and all horizons were subjected to pXRF, Vis-NIR, and principle component analysis (PCA). The elemental composition by pXRF revealed that the color index was significantly correlated with pXRF measured Al ($r = 0.52$, $p < 0.001$) and Fe ($r = 0.40$, $p < 0.01$), while ODOE only correlated with Fe ($r = 0.46$, $p < 0.001$). Additionally, a significant correlation between Vis-NIR reflectance and color index was observed. PCA further validated the difference among horizons with 90% of variance explained in the first principle component.

Mokma, D.L. (1993). Color and Amorphous Materials in Spodosols from Michigan. *Soil Science Society of America Journal*, 57(1), 125-118.

<https://doi.org/10.2136/sssaj1993.03615995005700010024x>

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Value added pedology, a micromorphologic rewrite of a Natrudoll (Solonetz) case study in North Dakota, USA

Dr. David Hopkins¹, Mr. Meyer Bohn

¹*North Dakota State University, Fargo, United States*

29 WG1.3 – Progress in Digital Soil Morphometrics - deeper and more precise soil observations, Alsh 2, August 3, 2022, 10:30 - 12:30

Graduate students have added responsibilities in the soil genesis course at North Dakota State University, USA, and field case studies have been emphasized for a decade. Case studies permit additional training in pedology and enable better soil interpretations. A 2016 case study investigated the recorrelation of a natric soil, the Exline series. This series has limited extent, but served as the modal Intrazonal solonetz soil in “Soils of the North Central Region of the United States” published in 1960. The soil was used in a Collegiate Soil Judging contest in 1970. In 2016, graduate students examined a soil trench in the same soil map unit on the same farm to assess the recorrelation. Students mapped the 4 m trench face and sampled for laboratory analyses. Due to the short-range nature of morphologic variation in sodic soils, students identified nine unique genetic horizons; horizon boundaries were commonly broken or irregular. Additionally, USDA taxonomic criteria were met for mollic, albic, glossic, natric, and calcic horizons. After students’ efforts, the instructor resampled the soil trench to perform micromorphologic analysis. Graduate students observations of soil structure, clay coatings, and secondary minerals such as gypsum are highlighted in thin section images providing compelling evidence for pedogenic processes. EDX and XPS techniques are being evaluated to quantify elemental domains of secondary mineral concentrations reflective of genetic pathways. Thin section evidence coupled with earlier morphologic and soil chemical analyses offer a much more comprehensive rendering of how the Exline landscape ‘conforms’ to the traditional solonetzic genetic pathway.

Soils of the North Central region of the United States. 1960. North Central Regional Publication No. 76. Agricultural Experiment Station, University of Wisconsin. Madison

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Elaboration of a national soil spectrum library - preliminary results of predictivity tests

Ms Zsófia Adrienn Kovács^{1,2}, Dr Janos Meszaros¹, Dr Gábor Szatmári¹, Dr Péter László¹, Nóra Szűcs-Vásárhelyi¹, Dr László Pásztor¹

¹Institute for Soil Sciences, Centre for Agricultural Research, Budapest, Hungary, ²ELTE Doctoral School of Environmental Sciences, Budapest, Hungary

29 WG1.3 – Progress in Digital Soil Morphometrics - deeper and more precise soil observations, Alsh 2, August 3, 2022, 10:30 - 12:30

Soil observations of the Hungarian Soil Degradation Information System were carried out between 2010 and 2012 on 2000 parcels of 285 farms representing the whole territory of Hungary. 6600 soil samples were collected and measured in laboratory for chemical parameters (pH, SOM, CaCO₃, NO₃, P₂O₅, K₂O, Na, Mg, SO₄, Mn, Zn, Cu). The soil samples were retained and they represent a countrywide soil data bank. Very recently we initiated the spectral characterization of the stored samples. The main objective is to establish relationships between traditionally measured soil properties and spectral features to support mapping activities, which tend to rely on hyperspectral remote sensing.

The soil samples are measured with a portable spectral device, namely ASD Field Spec Pro spectroradiometer. By finalizing the spectral measurements, a nationally representative spectral library will be set up, which will contain data on (i) the above listed soil chemical parameters and (ii) reflectance values in 2151 spectral bands. This dataset provides a unique opportunity for testing the predictivity of soil chemical parameters by spectral variables.

First predictivity tests have been carried out to estimate soil organic carbon, available phosphorus and potassium by reflectance spectra. Partial Least Square Regression, Support Vector Machine, Random Forest and Artificial Neural Network were used due to their well-known performance in similar situations using 10 fold cross-validation for the validation of the developed models.

Our paper presents the elaboration of the soil spectrum library and the first results of the predictivity tests carried out between its elements.

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Forecasting soil water content with soil models and weather information

Dr. Michael Young

¹*University of Texas, Austin, USA*

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Soil water content influences many Earth surface processes, from flooding to ET to groundwater recharge. Assimilating pedotransfer functions, digital soil models, and high-resolution weather forecasts, we can forecast soil water content and storage, and then use these forecasts to solve practical problems like flood risk potential and irrigation needs. Especially where human wellbeing is concerned, errors in soil water state estimates need to be minimized. What is our current skill in forecasting soil water content and storage, and how can we apply that knowledge to address societal needs? In this talk, we focus on flood risk. Soil water content and environmental data from the Texas Soil Observation Network (TxSON), and weather forecasts from the National Blend of Models (US National Weather Service) are assimilated at hourly time intervals for 11 days, into HYDRUS-1D, a well-known physics-based simulation package. After calibration, we forecast soil water content over a seven-month period. For any given hour, the ensemble of model outputs using these forecasts are compared against actual soil water content as forecast lead time is reduced. As an example, results show significant correlation ($R^2 > 0.80$; $RMSE = 0.03 \text{ m}^3/\text{m}^3$) at lead times of 24 hours for loam-textured soils, and remaining above $R^2 = 0.50$ ($RMSE = 0.07 \text{ m}^3/\text{m}^3$) at ~ 50 hours lead time. Depending on the time sensitivity of decisions, this lead time could be used to issue flood warnings, schedule irrigation, etc. Improved weather forecasts should improve these outcomes.

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Modelling the impact of land-management based natural flood management measures using combined soil hydrological and surface-groundwater models

Professor Anne Verhoef¹, Dr Sarah Collins², Dr Maleki Badjana¹, Dr Charlotte-Anne Chivers³, Dr Chris Short³, Dr Barbara Percy⁴, Dr John Hammond¹, Dr David Macdonald², Dr Majdi Mansour², Dr Samantha Broadmeadow⁵, Prof Tom Nisbet⁵, Ryan Jennings⁶, Dr Steve Rose⁶, Dr Barry Hankin⁶, Dr Richard Gantlett⁷, Dr Amanda Ingham⁸, Adrian Hares⁹, Professor Hannah Cloke¹, Professor Joanna Clark¹

¹The University of Reading, Reading, United Kingdom, ²British Geological Survey, Keyworth, United Kingdom, ³University of Gloucestershire, Cheltenham, United Kingdom, ⁴Institute for Environmental Analytics, Reading, United Kingdom, ⁵Forest Research, Farnham, United Kingdom, ⁶JBA Consulting, Skipton, United Kingdom, ⁷Yatesbury House Farm, Yatesbury, United Kingdom, ⁸Hampshire & Isle of Wight Wildlife Trust, Curdridge, United Kingdom, ⁹A. Hares Farming, Highworth, United Kingdom

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Natural Flood Management (NFM) has the potential to reduce the risk of downstream flooding. As part of the NERC-funded LANDWISE research project, we explored the effect of NFM measures on the soil water balance, and related surface- and sub-surface runoff generation, for agricultural land in the Upper Thames Catchment in southern England. We present the results from applying a soil hydrological model (SWAP) using a range of soil-land use configurations and crop files. Soil parameter values were derived from the NATMAP data base and informed by field surveys, while vegetation parameters were obtained from a mix of stakeholder workshops, farm surveys and interviews. These were adjusted for the effects of land management measures such as conventional tillage versus zero-till using expert judgement. SWAP was driven by long-term daily weather input data and used to simulate changes in field-scale water fluxes and stores during key flood events, such as those that occurred in July 2007 and the winter of 2013-2014.

SWAP model outputs were fed into an existing semi-distributed surface water-groundwater model developed by the British Geological Survey (BGS) for the River Coln catchment (a tributary of the Upper Thames Catchment). River flow simulations for the two flood events compared favourably with measured flows. The results are used to assess the effectiveness of a range of NFM and land use change scenarios on reduction of flood generation within the Upper Thames.

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Linking Static and Dynamic Properties To Define Soil Heterogeneity At The Meter-Scale

Dr. Daniel Gimenez¹, Dr. Attila Nemes², Dr. Matthew Patterson¹, Dr. Esther Bloem², Dr. Annette Dathe³, Dr. Ruth Kerry⁴

¹Rutgers University, New Brunswick, USA, ²Norwegian Institute for Bioeconomy Research, As, Norway, ³Cornell University, Ithaca, USA, ⁴Brigham Young University, Provo, USA

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Evaluation of transport processes in soil requires the quantification of transport coefficients. These coefficients, and the proxy properties used to predict them, vary in space and in some cases time. The characterization of these variations across scales can be achieved by resolving the spatial structure of the properties of interest and by continuous in-situ monitoring. In this study we seek to: (1) quantify the spatial variation in measurements taken at close spacing, and (2) investigate if such variation has a temporal component. Two 2-m³ soil volumes were sequentially instrumented with 20 TDR-tensiometer pairs to monitor water content and pressure potential during 2 non-overlapping time intervals that together spanned approximately 1 year. Sensors were installed in regions with contrasting electrical resistivity, detected with electrodes arranged in 2D and 3D patterns. A total of 121 geo-referenced cores were sampled after the monitoring periods from the two soil volumes. Laboratory measurements on these cores included: water retention (using a combination of techniques), hydraulic conductivity, bulk density, organic carbon content and a quasi-continuous particle-size distribution curve. In addition, 38 of the aforementioned cores, sampled from the proximity of the sensors, were used to derive X-ray tomography-based pore network characteristics. In this presentation, we will (1) quantify and discern the type (random vs. systematic) of spatial heterogeneity found in water retention data, (2) investigate correlations between pore networks and the properties of TDR-tensiometer time series, and (3) search for evidence of temporal variation in the properties of those time series.

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Qin, M, D. Giménez, and R. Miskewitz (2018) Temporal dynamics of subsurface soil water content estimated from surface measurement using wavelet transform. *J. Hydrol.* 563: 834-850.

Machine learning to investigate model representation of SOC storage and dynamics

Dr Umakant Mishra^{1,2}, Dr Sagar Gautam^{1,2}

¹*Sandia National Laboratories, Livermore, United States*, ²*Joint Bioenergy Institute, Emeryville, United States*

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Response of soil carbon to future climate remains a major uncertainty in the global carbon cycle. Recently, use of machine learning approaches has increased in investigations of soil organic carbon (SOC) storage and dynamics. We used machine learning approaches with soil organic carbon field observations (n=6,213), data of environmental factors (n=31), and three earth system model projections to (1) develop functional relationships between environmental factors and SOC stocks, (2) benchmark land surface model representations of environmental controllers of SOC stocks, and (3) predict decadal changes in continental United States (U.S.) surface SOC stocks under future emission scenarios. The functional relationships between environmental controllers and SOC stocks that we derived, produced similar prediction accuracy as obtained from the random forest machine learning approach. Environmental control representation of SOC stocks in current coupled model intercomparison project phase six (CMIP6) Earth system models are not consistent with field observations. The results of decadal and total SOC changes in continental U.S. surface soils, obtained from ensemble machine learning approach is not in agreement with CMIP6 simulations. We identified land cover types and land areas in continental U.S. where both machine learning and Earth system models agree and disagree in the direction of SOC change under future climate. In summary, computational approaches can help in quantifying climatic impacts on SOC and reducing the uncertainty that exists in model projections of future carbon climate feedbacks.

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Model selection from incubation data for representing soil carbon dynamics

Mrs Mina Azizi-Rad^{1,2}, Dr Carlos Sierra^{1,3}

¹Max-Planck-institute For Biogeochemistry, Jena, Germany, ²Leibniz Universität Hannover, Hannover, Germany,

³Department of Ecology, Swedish University of Agricultural Sciences, Uppsala, Sweden

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Soil incubation studies provide important information about the rates at which organic matter decomposes under controlled environmental conditions. These experiments offer important opportunities to parameterize soil carbon models, however, there is uncertainty about the most appropriate model structure that can be obtained from incubation experiments. Here, we used time-series data from 158 incubations from different soils to test different model structures and determine the appropriate balance between model complexity and parsimony. We used information theory metrics to select models that can better predict the data without making additional assumptions on the model structure. In other words, we determine what model structure can be identified from the data alone without making extra assumptions of possible processes occurring during decomposition. Our results showed that soil incubation data do not provide enough information to identify rates of stabilization or destabilization usually encoded in transfer coefficients in dynamic models. The data also did not provide evidence for the existence of one single homogeneous pool that decomposes at one single rate. Instead, the analysis provided strong support for the existence of two distinct pools that decompose at identifiable rates, but without exchange of carbon among them. Our analysis also suggests that information on the time carbon stays in soils (its transit time), usually encoded in isotopic studies, can greatly improve our ability to identify appropriate dynamic models from incubation data.

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Experimental, theoretical, and modeling approaches to characterize hydraulic properties of stony soils

Mr. Mahyar Naseri¹, Dr. Sascha C. Iden¹, Prof. Dr. Wolfgang Durner¹

¹*Technical University of Braunschweig, Braunschweig, Germany*

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Stony watersheds are widespread around the world. Despite the importance of rock fragments in vadose zone hydrology, the common approach in land surface and hydrological models is to ignore them. The research on characterizing hydraulic properties of stony soils, i.e. their water retention and hydraulic conductivity curves is deficient.

We revisit the seventy-year-old classic literature/research, progress, and limitations/failures in research on characterizing hydraulic properties of stony soils. The state of the art research and the future research needs at different spatial scales are reviewed from theoretical development, experimental investigation, and modeling perspectives.

The review will be followed/supported by recent advancements in laboratory measurements and inverse modeling of hydraulic properties of stony soils, numerical simulations of different configurations of stony soils in three spatial dimensions, and the development of a physical model based on the effective medium theory in the framework of the research by Naseri, Iden and Durner (2019, 2020, and 2021).

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Including manure-amendments to croplands in Canadian modelled estimates of soil organic carbon sequestration and greenhouse gas emissions

Mr. Francis Durnin-Vermette¹, Dr. Chang Liang^{2,3}, Dr. Doug MacDonald³, Dr. Bao-Luo Ma², Dr. Tiequan Zhang⁴, Dr. Paul Voroney¹, Dr. Adam Gillespie¹

¹University Of Guelph, Guelph, Canada, ²Ottawa Research and Development Centre, Agriculture and Agri-Food Canada, Ottawa, Canada, ³Pollutant Inventories and Reporting Division, Environment and Climate Change Canada, Gatineau, Canada, ⁴Harrow Research and Development Centre, Agriculture and Agri-Food Canada, Harrow, Canada

37 WG2.2 – Modelling soil processes from ped to global scale:, Alsh 1, August 3, 2022, 10:30 - 12:30

Canada reports estimates of its national greenhouse gas (GHG) emissions and carbon sequestration as a commitment under the United Nations Framework Convention on Climate Change (UNFCCC). Canada uses a modelling approach for these estimates; however, while carbon (C) from crop residues is included, C from manure applications is not. This is a critical gap given that manure contributes as much as 35% of agricultural soil C.

To address this gap, we seek to develop an approach to include manure in these modelled estimates. To this end, we have reviewed lab- and field-based manure incubation studies focusing on the effects of animal type, storage length, composting practices, and chemical composition on manure C mineralization rates. This review informed the parameterization of manure amendments using a differential evolution optimization algorithm. These manure parameterizations were added to a version of the Century soil carbon model which is recommended by the Intergovernmental Panel on Climate Change (IPCC).

We assessed the performance of this modified model using data from Canadian long-term manure-amendment experiments. Our modelled estimates were compared with those from similar soil carbon models (RothC, ICBM), and evaluated using the coefficient of determination (R²), root mean square error (RMSE), and the Nash-Sutcliffe efficiency statistic (NSE).

These improved estimates will advance our understanding of the potential of long-term manure additions to croplands to store carbon, and will help guide decisions made by policymakers as well as farmers. Our estimates improve methods used in Canada's national GHG inventory, and can inform development of other national inventories.

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The Impact of Leys and Sheep Grazing on Soil Structure and Hydrological Functioning

Miss Emily Howes¹, Dr Ian Pattison¹, Professor Jonathan R. Leake², Dr Lydia M. J. Smith³, Dr Patrick McKenna³, Professor Sami Ullah^{4,5}, Professor David L. Jones⁶, Professor Adrian L. Collins⁷, Dr Lisa Norton⁸

¹*School of Energy, Geoscience, Infrastructure and Society, Heriot Watt University, Edinburgh, United Kingdom,*

²*Department of Animal and Plant Sciences, University of Sheffield, Sheffield, United Kingdom,* ³*NIAB, Huntingdon Road, Cambridge, United Kingdom,* ⁴*School of Geography, Earth and Environmental Sciences, University of Birmingham,*

Edgbaston, Birmingham, United Kingdom, ⁵*Birmingham Institute of Forest Research, University of Birmingham, Birmingham, United Kingdom,* ⁶*School of Environment, Natural Resources and Geography, University of Bangor,*

Bangor, United Kingdom, ⁷*Sustainable Agriculture Sciences Department, Rothamsted Research, North Wyke, Okehampton, United Kingdom,* ⁸*UK Centre of Ecology and Hydrology, Lancaster Environment Centre, Bailrigg, Lancaster, United Kingdom*

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

The increasing intensification of agriculture in the latter half of the 20th Century has led to widespread decline in the physical quality of arable soils, including compaction, loss of organic matter and reduced hydrological functioning. If left untreated, this could threaten the sustainability of food production systems and ecosystem health. A variety of regenerative agricultural methods have been proposed to mitigate this damage involving novel combinations of ley-arable rotations, integrated grazing and tillage management. Growing practitioner and policy interest has established a need for greater evidence of individual and combined effects of these practices on soil structure to establish clear guidance for the farming sector to facilitate more sustainable agricultural systems.

We employ field and laboratory methods to examine changes in soil structure, including bulk density and compaction, and functioning such as hydraulic conductivity, following introduction of grass-clover and herbal leys, integration of sheep grazing into ley-arable rotations and no-tillage cultivation across trial areas in eastern England. By exploring interactions between these properties, we aim to build a holistic understanding of how these regenerative agriculture approaches affect soil physical quality. Preliminary findings from a research site in Duxford, Cambridgeshire, indicate that soil pores were more homogeneously distributed in leys than conventional arable agriculture. Penetration resistance was significantly higher at 16-20cm under mowing than grazing in the herbal ley, whereas grazing and mowing did not result in any significant differences in penetration resistance in the grass-clover ley. Herbal leys had a significantly higher percentage soil moisture content than grass-clover leys.

Evaluating Soil Health Practices at Field Scale

Associate Professor Abbey Wick¹, Dr. Caley Gasch¹, Dr. Aaron Daigh¹, Dr. Marisol Berti¹

¹*North Dakota State University, Fargo, United States*

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

The Soil Health and Agriculture Research Extension (SHARE) Farm in southeastern North Dakota, USA is a farmer-driven, long-term research site which focuses on soil management practices. Treatments were replicated at field-scale on 65 ha and included (1) subsurface drainage, (2) conservation tillage and (3) cover crops. The crop rotation is corn (*Zea mays*), soybean (*Glycine max*), spring wheat (*Triticum aestivum* L.). Soil moisture and temperature data were collected along with soil health measurements and crop yields for two complete rotations (6 yrs). Trends in soil moisture and temperature across tillage treatments did not cause any difference in crop populations, growth or yields; however, soybean yields were significantly higher on subsurface drainage treatments compared to non-drained. Soil health indicators did not vary amongst treatments in the first three years of the study and none of the indicators were strongly correlated with crop yield. However, across treatments, aggregate stability was the most sensitive to management with higher aggregate stability in the cover crop plus no-till treatments. As a result, we recommend (1) farmers adopt several soil health building practices simultaneously to reduce risk associated with variable climatic conditions, (2) monitor soil aggregation as an indicator of soil health and (3) continue to adjust practices as conditions and logistics change.

none

Restoring soil ecosystem health and functioning in regenerative-based grain crop production systems

Dr Gerhard Du Preez¹, Prof Driekie Fourie¹, Ms Ane Loggenberg¹

¹*Unit for Environmental Sciences and Management, North-West University, Potchefstroom,, South Africa*

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

Promoting soil ecosystem health is central to the sustainability of regenerative agricultural systems. However, most soil health assessment frameworks include only basic biological measurements resulting in limited information on the ecosystem status of soils. We therefore aimed to investigate the ecological restoration of soils in regenerative-based crop production systems using nematode-based indices of soil ecosystem health and functioning. Additional biological parameters included active carbon, soil respiration, and total organic matter, while physico-chemical parameters including pH, electrical conductivity, texture and metal and nutrient content were also measured. The study sites, which have been under regenerative agriculture for a minimum of seven years, were located in the semi-arid Eastern Free State region of South Africa. Our results showed that, compared against conventional farmlands (negative reference) and natural veld (positive reference), the regenerative farmlands presented significant ecological restoration with structured food webs and fertile soils, as well as increased ecosystem functioning. Redundancy analyses confirmed that the observed effects were mainly resulting from differences in practices between the systems (i.e., conventional vs. regenerative). Inorganic nitrogen levels, pH, as well as copper and nickel concentrations also presented a significant effect. For example, negative, linear relationships were evidenced between inorganic nitrogen and soil food web structure ($R^2=0.51$; $p<0.0001$), as well as between copper and soil respiration (microbial activity) ($R^2=0.6$; $p<0.0001$). These results clearly show that regenerative practices can restore the health and functioning of soil ecosystems and ultimately promote ecosystem service delivery. However, the use of agrochemicals should be carefully considered considering their potential harmful effect.

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1905

Soil carbon sequestration beyond global targets: soil organic matter increases in a modern arable and ley farming system

Dr Richard Gantlett^{1,2}, Dr Jake Bishop¹, Professor Martin Lukac^{1,3}

¹University of Reading, Reading, UK, ²Yatesbury House Farm, Calne, UK, ³Department of Forest Management, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences, 16521 Prague, Czech Republic

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture; Lomond Auditorium, August 3, 2022, 14:30 - 16:30

Mitigating climate change is critical to the survival of modern human society and agriculture can play its part. Carbon can be sequestered in soils as soil organic matter (SOM), a method of carbon capture. Accumulation of SOM also typically leads to the regeneration of soil functions which support food production, natural flood and drought management and soil biodiversity.

This study used a 7-year agroecological organic crop rotation in a no-plough tillage system, which included a 2-year diverse ley (23 species mix of legumes, herbs, and grasses). Four treatments were compared: removing crop residues; retaining crop residues; continuous fallow; and a 5-year continuous diverse ley.

SOM in the top 100 mm of soil increased by between 1.21 and 3.14% yr⁻¹ in the biomass input treatments, and at the 100-300 mm depth by between 0% and 1.57% yr⁻¹. Aboveground biomass retention did not impact SOM accumulation.

With strong SOM accumulation at the 0-100 mm soil depth and at least no loss of carbon at the 100-300 mm depth, these diverse ley rotation systems easily surpass the COP21 global target of 0.4% annual increase in soil organic carbon stock.

Carbon sequestration in SOM is a relatively low-cost technique of carbon capture with multiple additional benefits. Increases in SOM driven by crop rotations have been linked with increases in below-ground and above-ground biodiversity, crop productivity, and flood and drought resilience. Carbon capture in agricultural soils by productive diverse leys, as demonstrated in this study, is both a climate change mitigation and adaptation strategy.

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Scalable Targets for Soil Health Improvements in Regenerative Agriculture

Dr. Nathaniel Looker¹, Dr. Vance Almquist¹, Ms. Quanteria Randle^{1,2}, Mr. Brent Thomas^{1,3}, Mr. Robert Thomas^{1,2}, Dr. Cristine L.S. Morgan¹, Dr. C. Wayne Honeycutt¹

¹Soil Health Institute, Morrisville, United States, ²Prairie View A&M University, Prairie View, United States, ³University of Arkansas at Pine Bluff, Pine Bluff, United States

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

Predicting the soil health benefits of regenerative practices in row-crop production requires tools for quantifying soils' potential functioning across pedologic settings. Knowledge of potential soil health is essential for setting achievable field- and farm-level goals and for identifying priority areas within landscapes and regions where management changes may yield disproportionate improvements. We developed an approach to quantifying the potential soil health of broadly defined soil groups, using indicators of soil functioning under perennial vegetation to constrain the dynamic physical, chemical, and biological properties of each soil group. We present results of a pilot implementation of this approach in the cotton-producing soils of the South Central USA. We estimated potential improvements in soil organic carbon storage, 24-hour carbon mineralization, water-holding capacity, and wet aggregate stability by comparing soils under perennial vegetation to soils under row crops grown using business-as-usual practices and soil health management systems. Estimated potential improvements in organic carbon stocks (0-30 cm) were similar in magnitude across three study regions varying in climate and parent material but were approximately two times greater in fine-textured soils than medium- or coarse-textured soils. Potential aggregate stability and carbon mineralization (0-15 cm) also varied with soil texture and management, but these relationships differed by region. Our approach produces locally relevant Soil Health Targets to help farmers evaluate outcomes of regenerative agriculture in terms of progress towards their soils' intrinsic capabilities.

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A tree against hunger: Enset-based farming systems for building soil health in the tropics

Dr. Karen Vancampenhout¹, Mr. Sabura Shara², Mr. Gezahegn Garo², Dr. Fasil Teffera², Dr. Olivier Honnay¹, Dr. Roel Merckx¹, Dr. Rony Swennen¹

¹*KU Leuven, Leuven, Belgium*, ²*Arba Minch University, , Ethiopia*

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

Drought tolerant, multipurpose perennial crops are an important avenue in protecting soil health and increasing resilience against climate change in the tropics. Nevertheless, many of these are so called 'orphan crops' and have received much less attention in international literature as compared to annual or temperate crops. One such crop is Enset (*Ensete ventricosum* or 'false banana'), grown in the densely populated Ethiopian highlands. Nicknamed 'the tree against hunger' it can keep producing during drought, while maintaining a high carbon sequestration rate and canopy cover to protect the soil from erosion. Wild enset is a forest gap species, and agroforestry with enset is a promising avenue to rehabilitate landscapes and mitigate landslide hazard. The fruit of Enset is insipit, but the juice, fermented pseudostem and corm are consumed, while the leaves provide cattle fodder in the dry season and the fibers are used in household applications. It is an important food security crop for over 20 million people. Nevertheless, very little research has been done and guidelines on how to manage soil fertility, nutrient cycles and health in Enset gardens are lacking. In this contribution, we summarize ten years of research into the enset systems of the Gamo highlands, with a focus on ecological amplitude, soil-plant-nutrient interactions, soil carbon and health, rhizosphere mycorrhizae, disease susceptibility, effects of shade and reduction of post-harvest losses.

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Implementing Regenerative Agriculture and Measuring Soil Health on the Farm

Dr Tom Storr¹

¹*Dyson Farming Ltd, Nocton, United Kingdom*

Interdivisional 5: Soil science and the emerging philosophy of regenerative agriculture:, Lomond Auditorium, August 3, 2022, 14:30 - 16:30

The importance of soil health is increasingly recognised in policy and amongst farmers, especially those engaged with the philosophy of regenerative agriculture. Implementing regenerative agricultural practices to improve soil health at farm scale over different soil textures and rotations is not without its challenges. The assessment of soils whether that be to inform soil management decisions, act as a metric for reporting or in the case of soil carbon be analysed and traded is not simple either.

For the last two years soil structure and earthworms have been assessed across 8,500 ha of arable land, which has helped inform management decisions such as type of cultivation (if at all) and the use of cover crops. This is in addition to the routinely 4-year cycle of soil nutrient and organic matter testing that has allowed the targeted use of organic materials. Of increasing interest is how soil carbon may be efficiently and robustly monitored across a wide geographic area with different soil textures and land uses. In the near-future soil health assessments will not only be used to inform management decisions but to i) ensure compliance with policy and ii) provide an understanding of changes to soil carbon stock across different land uses and soil textures.

Following the implementation of regenerative agricultural practices and the measurement of soil health at scale across many soil textures and rotations I report on what has worked well, the strategy towards sampling and where further guidance and techniques from the scientific community are needed.

Not applicable

The relevant range of scales for 3D multi-scale contextual spatial modelling

Dr. Tobias Rentschler^{1,2,3,4}, Prof. Dr. Martin Bartelheim^{1,5}, Dr. Marta Díaz-Zorita Bonilla^{1,5}, Dr. Thorsten Behrens^{2,4}, Dr. Sandra Teuber^{1,4}, Prof. Dr. Thomas Scholten^{1,2,4}, Dr. Karsten Schmidt^{1,2,3,4}
¹CRC 1070 ResourceCultures, University of Tübingen, D-72074 Tübingen, Germany, ²Cluster of Excellence Machine Learning: New Perspectives for Science, University of Tübingen, D-72076 Tübingen, Germany, ³eScience-Center, University of Tübingen, D-72074 Tübingen, Germany, ⁴Department of Geosciences, Soil Science and Geomorphology, University of Tübingen, D-72070 Tübingen, Germany, ⁵Department of Pre- and Protohistory, Later European Prehistory, University of Tübingen, D-72070 Tübingen, Germany

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1, August 3, 2022, 14:30 - 16:30

Multi-scale contextual modelling is a prerequisite for spatial soil modelling. In machine learning approaches, it accounts for spatial autocorrelation and incorporates spatial context by using environmental covariates on multiple spatial scales. For spatial soil modelling, there are three relevant scales: i) the soil profile with quasi-local soil formation processes that are independent of the spatial context, ii) short-range catenary processes such as erosion, sediment transport, and reallocation, and iii) long-range processes related to climate and large-scale terrain properties like mountain ranges. Such contextual information improves the accuracy of the machine learning based soil models and unravels the biogeochemical and physical processes involved, thus, enhancing the machine learning model's predictability and interpretability. Recent studies investigated the spatial dependence of topsoil properties only. We hypothesized that soil forming processes in subsoil relate to different spatial context information than topsoil processes and properties. We sampled 130 soil profiles at up to five depth intervals in a heterogeneous agricultural landscape in Andalusia, Spain, and compared the relevance of the investigated scales at different soil depths. The results showed that small to intermediate scales do not increase model accuracy, whereas large scales increase model accuracy for topsoil models. In contrast, subsoil models benefit from all scales, small, intermediate, and large. Based on the different relevance, we conclude that covariates on different scales are necessary for modelling soil processes and properties not only in the horizontal domain but also for different soil depths, i.e. the vertical domain, and can largely improve 3D soil mapping.

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Predicting urban locations at risk of high soil Pb concentrations using a random forest model.

Mrs Sarah Donoghue¹, Professor Margaret Graham¹, Dr Benjamin Marchant², Ms Fiona Fordyce², Dr Neil Stuart¹

¹University of Edinburgh, Edinburgh, United Kingdom, ²British Geological Society

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1, August 3, 2022, 14:30 - 16:30

Lead (Pb) is a naturally occurring toxic element, which results in neurological effects even at low exposure levels, especially in children under 6¹. An important potential exposure pathway for children is through ingestion of contaminated urban soil². Locating soil with high Pb concentrations traditionally involves costly and time-consuming sampling, laboratory analysis and mapping. Predictive modelling that utilises existing data from similar urban areas offers a potentially valuable short-cut.

This project amalgamated observed soil Pb concentrations from the British Geological Survey's (BGS) Geochemical Baseline of the Environment (G-BASE) dataset³ with nine covariate datasets: organic matter percentage, land use, road distance, building age/distance, and historic industry distance/type/age/density. These were collated in ArcGIS for three British cities – Glasgow, Belfast, and Leicester. The Glasgow dataset was used to train a random forest (RF) model, which was combined with quantile regression forests (QRF), to predict areas of the city at higher risk (>30% probability) of containing high soil Pb (>200mg kg⁻¹).

A confusion matrix comparing predicted high-risk locations with observed soil Pb concentrations in Glasgow, had an overall accuracy of 75% and a 68% producer's accuracy (i.e. rate of correct classification of observed features) for high soil Pb samples. The Glasgow model was used to predict high-risk locations in Belfast and Leicester, with 76/83% overall accuracy and 50/48% producer's accuracy to known high Pb soil samples respectively. Consequently, the predictive model can help locate the areas of a city most at-risk from high soil Pb levels to target subsequent soil sampling and eventual remediation.

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Measurement error-filtered machine learning in digital soil mapping

Mr Stephan Van Der Westhuizen^{1,2}, Prof Gerard.B.M. Heuvelink^{2,3}, Dr David Hofmeyr¹, Dr Laura Poggio³

¹Stellenbosch University, South Africa, ²Wageningen University & Research, , The Netherlands, ³ISRIC - World Soil Information, , The Netherlands

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1, August 3, 2022, 14:30 - 16:30

Machine learning (ML) has gained much popularity in digital soil mapping (DSM) in the last decade, but there are still quite a few challenges (Wadoux et al., 2020). One of these challenges is to effectively account for measurement errors when mapping a soil property with ML. With kriging models this is easily accommodated with techniques such as filtered kriging (Cressie, 1993). In terms of ML, one apparent solution is to use maximum likelihood and attach weights to observations so that observations with more uncertainty (i.e., those with a higher measurement error variance) receive less weight when calibrating a ML model. However, the estimated residual variances, which include the measurement error variances, will no longer be constant. We therefore propose a two-stage maximum likelihood approach to account for measurement errors. In this talk I will give a brief overview of the methodology and present results from a synthetic simulation study as well as from a case study of clay data in Namibia. In the results, we show that by implementing measurement error-filtered ML, prediction performance of ML models can improve. We benchmark these performances against a filtered kriging model.

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Spatial cross-validation is not the right way to evaluate soil map accuracy

Dr Gerard Heuvelink¹, Dr Alexandre Wadoux, Dr Sytze de Bruin, Dr Dick Brus

¹*ISRIC - World Soil Information and Wageningen University, Wageningen, Netherlands*

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1,
August 3, 2022, 14:30 - 16:30

Most digital soil mapping studies evaluate the map accuracy through cross-validation with the data used for calibrating the underlying mapping model. Recent studies, however, have argued that standard cross-validation statistics of most mapping studies are optimistically biased, because these methods ignore spatial autocorrelation in the data. These studies argue that spatial cross-validation should be used instead, and contend that standard cross-validation methods are inherently invalid in a geospatial context because of the autocorrelation present in most spatial data. In this presentation we argue that these studies propagate a widespread misconception of statistical validation of maps. We explain that unbiased estimates of map accuracy indices can be obtained by probability sampling and design-based inference and illustrate this with a numerical experiment. In our experiment, standard cross-validation (i.e., ignoring autocorrelation) led to smaller bias than spatial cross-validation. Standard cross-validation was deficient in case of a strongly clustered dataset that had large differences in sampling density, but less so than spatial cross-validation. We concluded that spatial cross-validation methods have no theoretical underpinning and should not be used for assessing map accuracy, while standard cross-validation is deficient in case of clustered data. In case of the latter, sensible alternatives are density-weighted and model-based cross-validation. Both alternatives were tested and compared with standard cross-validation and spatial cross-validation using a soil organic carbon stock map for western Europe. Results confirmed that both alternative methods had smaller bias than standard and spatial cross-validation.

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What is the accepted level of erroneous decision for the Swiss arable land inventory? Uncertainty perception of digital soil maps.

Dr. Madlene Nussbaum¹, Simon Tanner¹, Prof. Dr. Stéphane Burgos¹

¹*Bern University of Applied Sciences, Zollikofen, Switzerland*

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1, August 3, 2022, 14:30 - 16:30

Detailed soil maps are crucial to balance interests of urban planning and soil protection. In Switzerland, high-quality arable land is protected by an inventory and surfaces inside the inventory can only exceptionally be developed. Recently, legal frameworks were modified to require detailed soil maps to change the inventory. So far, conventional soil maps at scale of 1:5'000 – directly linked to a prescribed sampling density – are acknowledged to be sufficiently accurate. As conventional mapping is very time-consuming digital soil mapping is currently considered by regional governments to accelerate data collection.

To test digital soil mapping to generate such detailed maps we selected a typical area on the Swiss Plateau of 800 hectares. We sampled 1'120 locations by feature space coverage design. Spatial predictions were computed for soil properties and soil suitability classes were derived. Additional independent validation data was sampled by a stratified random design at 120 locations and used to evaluate overall prediction accuracy. Model uncertainty was propagated into the end product by a non-parametric bootstrap. Different levels of quality were obtained by repeating the mapping using subsets of 30, 60 and 100 % of calibration data.

Various representations of overall accuracy and spatial uncertainty were prepared. Following one of the recently formulated ten Pedometrics challenges, we evaluated (mis)understanding thereof by in-depth guided expert interviews with six inventory decision makers. Level of acceptable uncertainty for the inventory and whether end users rather trusted certain sampling densities as opposed to statistical accuracy measures was further discussed in the interviews.

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Pedo-Econometric Assessment of the Efficiencies of Soil Functions

Dr. Katsutoshi Mizuta, **Professor Sabine Grunwald**¹

¹*University Of Florida, Gainesville, United States*

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1,
August 3, 2022, 14:30 - 16:30

Integral soil security is a multi-perspectival framework that emphasizes relations between soil, soil-ecosystems, people, community, and cultures. The concept was formalized to secure soil resources and to avoid or minimize adverse environmental and anthropogenic impacts as well as undesirable consequences for people. However, it remains unclear whether and how soil security can be quantitatively assessed at different geographic scales; and to discern the security levels of soils linked to ecosystem functionality addressing multiple functions such as habitat integrity, water regulation, carbon sequestration, and nutrient regulation. We have discovered how management-oriented pedo-econometric methods are poised to assess soil-ecosystem functions and levels of soil security. Our case study demonstrates the pedo-econometric soil security approach applied to optimize the functions nutrient regulation in form of the total nutrient efficiency (TNE) in soils model for various land use/cover types in Florida, USA. The Data Envelopment Analysis (DEA) was used to compute TNE scores in soils based on site-specific soil-environmental conditions. Efficiency scores guide land use management and nutrient regulations to optimize TNE with lowest scores found in citrus tree groves, improved pasture, and urban land uses. The TNE was juxtaposed to the soil carbon efficiency function. The DEA soil security approach has great potential to be transferred to other regions and to model other soil-ecosystem functions; and the approach is scalable to local, regional, national, continental, and global scales.

Mizuta, K., Grunwald, S., Phillips, M. A., Bacon, A. R., Cropper, W. P., & Moss, C. B. (2021). Emergence of the pedo-econometric approach. *Frontiers in Soil Science*, 1. <https://doi.org/10.3389/fsoil.2021.656591>

Mizuta, K., Grunwald, S., Phillips, M. A., Moss, C. B., Bacon, A. R., & Cropper, W. P. (2021). Sensitivity assessment of metafrontier data envelopment analysis for soil carbon sequestration efficiency. *Ecological Indicators*, 125(Article 107602). <https://doi.org/10.1016/j.ecolind.2021.107602>

Discovering Quantitative Soil-Landscape Relationships from Soil Survey Data.

Mr Hunter Winsor¹, Dr. Colby Brungard¹

¹*New Mexico State University, Las Cruces, USA*

13 Division 1 Commission 1.5: How Pedometrics can cross boundaries and change society:, M1, August 3, 2022, 14:30 - 16:30

Soil surveyors must create conceptual soil-landscape models to be consistent in their mapping efforts (Schoeneberger et al., 2012). These mental models are fundamental tools for understanding and communicating soil spatial variability but they are rarely explicitly recorded. The loss of these conceptual models represents a significant loss of expensive and difficult-to-reacquire knowledge. However, recent advances in computational methods and ready access to national-scale soil survey in the USA have opened the possibility of mining conceptual soil-landscape knowledge directly from the spatial patterns contained in existing soil survey.

We demonstrate the ability to mine conceptual soil-landscape models from existing soil survey by combining a novel method of generating soil toposequences with association rule mining. We compare these results to expert-derived conceptual soil-landscape relationships and find that expert-derived rules occur with a mean strength that is 1.25 times stronger than random chance. From the expert-derived relationships, we obtained benchmark hyper-parameters to prune the association rule mining outputs. This produced a separate set of rules with a mean strength 2.50 times stronger than random chance.

We also demonstrate how soil co-occurrence networks (Beaudette & Roudier, 2019) can identify the geographic extent to which conceptual soil-landscape relationships apply as well as methods to graphically plot these relationships. These results demonstrate that it is possible to retrieve quantitative soil-landscape models directly from soil survey.

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Schoeneberger, P. J., Wysocki, D. A., Benham, E. C., & Soil Survey Staff. (2012). Field Book for Describing and Sampling Soils (3.0). Natural Resources Conservation Service. Washington D.C.

Climate impacts on metal bioavailability in agricultural soils

Soeren Drabesch^{1,2}, Alandra M. Lopez³, Aleksandra Pienkowska², Natalia Sánchez², Dr. Carolina Vergara Cid², Tianmei Wang³, Tianyu Wang², Prof. Dr. Britta Planer-Friedrich⁴, Prof. Dr. Andreas Kappler¹, Prof. Dr. Scott Fendorf³, **Dr. Marie E. Muehe²**

¹Center for Applied Geoscience, University of Tuebingen, Tuebingen, Germany, ²Plant Biogeochemistry, UFZ, Leipzig, Germany, ³Earth System Science, Stanford University, Stanford, USA, ⁴Environmental Chemistry, University of Bayreuth, Bayreuth, Germany

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Global food demand of a growing and developing population is postulated to increase to more than three billion tons of cereals by year 2050, requiring more than 70% increase in overall food production¹. 90% of that increase is expected to be met by higher yields and cropping intensity, thereby depleting agricultural soils of nutrients and increasing the probability of enhanced soil contamination. The remaining 10% of food production would be achieved by expanding to more arable land, currently about 51 million km² or 50% of habitable land², albeit in soils that are inferior in quality in terms of contaminant content and suitability for high demand crops. Besides total contaminant loadings in soils, their availability to biota is crucial for ecosystem health, food quality, and ultimately human health. The partitioning of contaminants between soil solids and solution depend strongly on prevailing environmental conditions. We currently have a scarce understanding of how soil metal/loid bioavailability is affected by climate change, namely increases in atmospheric CO₂, temperature and precipitation shifts. We postulate that climate change will increase metal/loid mobility and availability in soils. We investigated what impact climate change has on metal/loid mobility in a variety of experimental settings and agricultural soils of different origin, management strategy, texture, pH, natural and spiked contamination extents. In sum for our soils with a pH below 7, imposed future climatic conditions shifted metal/loid partitioning from solids to solution rendering these non-degradable contaminants more bioavailable. Underlying biogeochemical processes responsible for shifts in metal mobility will be discussed.

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²UN Food and Agriculture Organization. Our World in Data.

Climate change-induced alterations in freeze-thaw patterns in Sweden – implications for pore space characteristics and hydraulic properties of agricultural soils

Tobias Klöffel¹, Mats Larsbo¹, Nicholas Jarvis¹, Jennie Barron¹

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

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Freeze-thaw (F/T) cycles have frequently been stated to be an important factor affecting the evolution of pore space characteristics and hydraulic properties of agricultural soils (Carter, 1988; Bodner et al., 2013). Climate change is expected to lead to alterations in these cycles in the coming decades in Northern Europe, including Sweden. Specifically, long and intense freezing periods are likely to be superseded by more frequent fluctuations in temperatures above and below zero (Strandberg et al., 2015). Research is needed to assess the implications of these shifts for the pore space and hydraulic properties of agricultural soils and thus potential consequences for their physical quality and water functions.

The results of a laboratory experiment will be presented, in which undisturbed samples from a compacted soil layer were subjected to four different F/T scenarios: two scenarios representative for current climatic conditions in central Sweden and two likely future climate scenarios. The impact on various pore space characteristics was investigated using X-ray computed tomography at a resolution of 55 μm , while soil water retention curves were measured to estimate changes in pore-size distribution below X-ray resolution. Infiltration capacity was also measured at two supply tensions in the near-saturated range. The results are discussed in relation to the role of freeze-thaw cycles for the physical quality and water functions of agricultural soils and potential implications for soil management in a future climate.

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Carter, M. R. (1988). Temporal variability of soil macroporosity in a fine sandy loam under mouldboard ploughing and direct drilling. *Soil Tillage and Research*, 12:37-51.

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Escherichia coli and Rhodococcus erythropolis transport and fate: straining or attachment?

Dr Nasrollah Sepehrnia¹

¹University of Aberdeen, United Kingdom, ²Universitat Rovira i Virgili, Spain, ³Isfahan University of Technology, , Iran, ⁴Hamburg University of Technology Institute of Geo-Hydroinformatics, , Germany, ⁵University of Kentucky, Department of Plant and Soil Sciences, , United States

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Pathogenic and nonpathogenic bacterial transport and retention mechanisms depend on attachment and flow pathways in soils, which are affected by hydrophobicity. To this end, an experiment set-up was designed to predict *Escherichia coli* and (PTCC1767) *Rhodococcus erythropolis* transport through air-dried (-15000 cm) and respective wetted states (0 cm) of a wettable and water repellent sand media. A pulse of bacteria and bromide (i.e., 1×10^8 CFU ml⁻¹ and 10 mmol l⁻¹, respectively) was poured onto the surface of initially air-dried wettable and water repellent sand columns. Saturated flow using a tension infiltrometer was imposed on the top of the columns, rewetting the soils. Leaching continued for four pore volumes. Then, a subsequent pulse was poured on the column surfaces and leaching was extended to a further six pore volumes using bacteria-free water. Simulation was performed for either pulse, separately. The results illustrated that the dominant retention process into the wettable sand was attachment and detachment of both bacteria for dry infiltration. In wet infiltration, however, straining dominated the retention process. The mechanisms were discriminately different for the repellent media and bacteria strains. The specific behaviors of wettable and water repellent systems in transport and retention of bacteria were investigated.

Bradford, S.A., Simunek, J., Bettahar, M., van Genuchten, M.T., Yates, S.R., 2003. Modeling colloid attachment, straining, and exclusion in saturated porous media. *Environ. Sci. Technol.* 37, 2242–2250.

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Soupir, M.L., Mostaghimi, S., 2011. *Escherichia coli* and Enterococci attachment to particles in runoff from highly and sparsely vegetated grassland. *Water, Air, Soil Pollut.* 216, 167–178.

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Impact of Soil Properties and Land Management on Water Quality

Dr. Samira Daroub^{1,2}, Dr. Andres Rodriguez¹, Dr. Mohsen Tootonchi¹, Ms. Maryory Orton¹

¹University of Florida, Everglades REC, Belle Glade, United States, ²University of Florida, Soil and Water Sciences Dept., Gainesville, United States

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Growers in the Everglades Agricultural Area (EAA) in South Florida, USA implement mandatory best management practices (BMPs) to reduce off farm phosphorus (P) discharges. These BMPs include soil testing and application of fertilizers, water management, and soil erosion/ sediment transport management. The BMP program has been very successful since its start in 1995 with greater than 50% average P load reduction from the EAA basin watershed, compared to a baseline period. Although all farms in the EAA implement BMPs in a similar manner, there are wide differences in P discharges in drainage water from individual farms. The objective of this research is to evaluate soil properties that may impact phosphorus sorption and desorption in the highly organic soils of the EAA. These soils are becoming shallower due to oxidation of organic matter due to artificial drainage. Six farms were selected consisting of three pairs with similar management practices and current land use, but with differences in P concentrations and/or loads in the discharge water. Phosphorus sorption isotherms, P soil saturation ratio, and the relationship of available P to metals are being studied and correlated to land management and soil depth. Discharge water quality and volume from all farms are being monitored through auto samplers, dataloggers, and pump flow sensors. This study will aid in the improvement of the effectiveness of current BMPs and the incorporation of new practices to improve P retention and availability to crops while minimizing leaching and runoff of P in discharge water.

Daroub, S.H., Van Horn, S., Lang, T.A., and Diaz, O.A. 2011. Best management practices and long-term water quality trends in the Everglades Agricultural Area. *Critical Reviews in Environmental Science and Technology* 41 (6):608-632.

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Hidden dangers of converting UK conifer forests to broadleaf woodlands

Miss Caitlin Lewis¹, Professor Martin Lukac¹, Dr Elena Vanguelova², Dr Matthew Ascott³

¹University Of Reading, Reading, United Kingdom, ²Forest Research, Farnham, United Kingdom, ³British Geological Survey, Wallingford, United Kingdom

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Non-native coniferous plantations, primarily planted for timber in the early part of the 20th century, have long been associated with potentially negative impacts on surface water and groundwater quality due to high levels of nitrogen accumulation in their soils. Recent changes in forestry policy and in attitudes towards biodiversity triggered a shift towards restocking conifer forests with broadleaved species. The need to design climate resilient forests favours the establishment of mixed broadleaf forests over coniferous monocultures. Little is known, however, about the potential consequences of this change in forest management for nitrate leaching fluxes and groundwater quality. Although mature broadleaved forests have been shown to enhance water quality (Nisbet et al., 2011), the conversion of coniferous woodland typically stimulates breakdown of organic matter, leading to a pulse release of nutrients which cannot be taken up by the nascent broadleaved forest.

We conducted a study at Thetford Forest, Norfolk, to measure throughfall and soil solution chemistry, soil C/N ratios and net nitrification in a chronosequence of forest stands at varying stages in the conversion process. Results show an accumulation of nitrogen in the deep mineral soils ten years after the change from conifers to broadleaves. Observed changes in soil C/N ratios also indicate the potential for elevated nitrate leaching fluxes within the first decade post conversion. Our observations clearly show that there is a need to consider the impact on water quality when creating climate resilient forests.

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<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.701.4543&rep=rep1&type=pdf>
(accessed 20/01/2021)

Mitigating flooding-induced phosphorus losses from soils using inorganic soil amendments

Dr Darshani Kumaragamage¹, Dr Doug Goltz¹, Dr Srimathie Indraratne¹

¹*University Of Winnipeg, Winnipeg, Country*

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Significant reductions in phosphorus (P) runoff and leaching losses have been reported with soil amendments, however their effectiveness in reducing flooding-induced P release is less known. Flooding during rainfall events and spring snowmelt in cold regions could enhance P release from soils to overlying water. A series of laboratory incubation studies with intact soil cores flooded either under simulated snowmelt or summer flooding conditions evaluated the effectiveness of surface amendment of gypsum, alum, magnesium sulfate, ferric chloride, calcium carbonate, manganese oxide and zeolite, in reducing P release to overlying floodwater. Soils used were collected from flood-prone agricultural fields in the Red River Valley region in Manitoba, Canada. Unamended and amended intact soil columns were flooded for 8 weeks at 4°C (simulating snowmelt conditions) or at 22°C (simulating summer flooding). Surface amendment of gypsum, magnesium sulphate, alum, ferric chloride, and manganese oxide were significantly reduced the dissolved reactive P concentrations in pore water and floodwater whereas calcium carbonate and zeolite were not effective. The percent reduction in floodwater DRP concentration in amended treatments compared to unamended treatment varied depending on the soil, type of amendment, rate of amendment used, and the time of flooding. The results show promise of amendment applications prior to a flooding event in reducing flooding-induced P losses; thus, fall application of amendments could be practised in mitigating P losses from P enriched agricultural fields during spring snowmelt runoff. More research is needed to evaluate the effectiveness of amendments under natural field conditions.

Vitharana, U. W., Kumaragamage, D., Balasooriya, B. L. W. K., Indraratne, S. P., & Goltz, D. (2021). Phosphorus mobilization in unamended and magnesium sulfate-amended soil monoliths under simulated snowmelt flooding. *Environmental Pollution*, 287, 117619

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Hold it there – Utilising soil hydrology and temporary storage areas to attenuate surface runoff.

Mr Martyn Roberts^{1,2}, Dr Josie Geris¹, Professor Paul Hallett³, Dr Mark Wilkinson²

¹*School of Geosciences, University of Aberdeen, Aberdeen, United Kingdom*, ²*The James Hutton Institute, Aberdeen, United Kingdom*, ³*School of Biological Sciences, University of Aberdeen, Aberdeen, United Kingdom*

21 Division 3, Commission 3.2 – Soil water, pollutant and gas movement in the context of a changing climate, Forth, August 3, 2022, 14:30 - 16:30

Temporary storage areas (TSAs) mitigate flood risk and harvest rainwater by attenuating surface runoff and providing additional storage during large rainfall events, that then drain shortly after. They vary from the micro-scale ($\sim 0.05\text{m}^3$) to large retention ponds ($\sim 10,000\text{m}^3$), but all utilise soil water storage and infiltration to mitigate flood and drought risk. Soil hydrology and therefore TSA functioning depends on soil structure, which changes over time periods as short as major weather events or tillage activities, and over multiple years through agricultural and biological activity. Here we explore how spatial and temporal changes in soil hydraulic properties within the wetted footprint and contributing area affect TSA functioning. We used field observations from TSA sites in Scotland with different land uses (winter wheat and spring barley) but similar soil types (Brown soils). Soil properties were collected for 3 zones: (1) TSA active zone ($\sim 10\%$ full) – inundated for the longest time; (2) TSA full zone ($\sim 50\text{-}100\%$ full) – active during large storms; and (3) Field zone – field control points outside the wetted footprint. Preliminary results found that saturated hydraulic conductivity, bulk density, and porosity did not vary spatially between zones. For the structurally stable soils explored, this suggests that soils within the footprint did not degrade since TSA installation, maintaining effectiveness for infiltration and holding water. Understanding the spatial patterns and temporal variations of soil hydrological properties and associated TSA functioning, will help to design effective TSAs for flood risk reduction under a range of (changing) climate conditions.

NA

Combination between Vis-NIR spectroscopy and Sentinel-2 to assess the variability of soil carbon pools in organic farming of southern Italy

Dr Luana Circelli^{1,2}, Dr. Erika Di Iorio², Prof. Claudio Colombo²

¹Research Centre for Agricultural Policies and Bioeconomy, Council For Agricultural Research And Agricultural Economy Analysis, Rome, Italy, ²Department of Agricultural, Environmental and Food Sciences, University of Molise, Campobasso, Italy

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Monitoring soil carbon pools becomes essential to understand the factors that affect the spatial variability and the carbon storage at small scale. In situ Vis-NIR spectroscopy measurements are fast, less expensive and effortless compared to classic dry and wet chemical analytical methods. The aim of this research was to analyze and predict the content of both organic and inorganic carbon fractions in an organic farm in South of Italy, combining the Vis-NIR spectroscopy as proximal sensing and the Sentinel-2 spectral data. First, the application of different physico-chemical analytical methods allowed to obtain detecting of more stable and recalcitrant forms of organic carbon compare to labile ones. From the combination between different spectral preprocessing and regression models, first and second derivative transformations and partial least squares (PLS) regression have achieved excellent results in the prediction of soil organic and inorganic C fractions. The evaluation gap of soil C pools from field to farm scale was improved by the satellite Sentinel-2 spectral data in Vis-NIR predictive models. The obtained accurate results proved that Vis-NIR spectroscopy is an important tool to recognizing the spatial variability of the soil C pools.

Navarro-Pedreño, J., Almendro-Candel, M.B., & Zorpas, A.A. (2021). The Increase of Soil Organic Matter Reduces Global Warming, Myth or Reality? *Science*, 3(1):18.

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Convolution neural network for simultaneous prediction of soil properties in New Zealand

Dr Yuxin Ma¹

¹*Landcare Research, Palmerston North, New Zealand*

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Multi-task learning (MTL) algorithms can be advantageous in building a spatial prediction model that simultaneously predicts different soil properties instead of creating multiple models for multiple soil properties. MTL is able to improve the model performance by sharing information contained in the training data considering the underlying cross-relatedness between different soil attributes in comparison to the single-task setting, particularly when the target variables are correlated. Recently deep learning becomes popular due to its capacity to learn nonlinear features and deep models have been used as basic models in MTL.

This study aims to develop capability that implements constraints to soil attribute predictions in New Zealand using an emerging deep learning method, the convolutional neural network (CNN). In this study, 11421 Vis-NIR spectra datasets with regards to soil texture (sand, silt and clay) from the topsoil and water content values (Field Capacity (FC), Total Pore Volume (TPV) and Permanent Wilting Point (PWP)) in New Zealand were used to train models. The spectroscopy data were pre-processed by spectral trimming, baseline correction, smoothing, and normalization.

The dataset was randomly split into 70% training and the remaining as a test set. The performance of three prediction models was compared: partial least squares regression (PLSR), Cubist tree models and CNN in terms of R² and RMSE. We also compared different ways to feed spectral data into the CNN model: one-dimensional (1D) data (as a spectrum) or as two-dimensional (2D) data (as a spectrogram) and the spectroscopy data with and without pre-processing.

Ng, W., Minasny, B., Montazerolghaem, M., Padarian, J., Ferguson, R., Bailey, S., McBratney, A.B., 2019. Convolutional neural network for simultaneous prediction of several soil properties using visible/near-infrared, mid-infrared, and their combined spectra. *Geoderma* 352, 251–267.

Evaluation of Mn and Fe Oxide Reduction Dynamics using a Rhizosphere Camera and Image Analysis

Dr Thorsten Knappenberger¹, Olivia LeFevre¹, Dr Joey Shaw¹, Dr. Yaniv Olshansky¹

¹*Auburn University, Auburn, USA*

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Redox potentials are measured in the field by determining voltage differences between Pt probes and a reference electrode. An alternative for evaluating reduced soil conditions is the Indicator of Reduction in Soils (IRIS). IRIS tubes or films are used with coatings of iron or manganese oxide to observe depth or occurrence of reducing conditions with coating removal, often assessed weekly. We evaluated the use of a rhizosphere camera to capture manganese and iron reduction (coating removal). A rhizosphere tube was coated with manganese and iron oxide and inserted into a saturated column filled with a surface horizon from a wetland soil (Gleysol). Images were taken hourly over 28 days and compared with Eh/pH data. Manganese images were converted to the HSV color space, and reduced conditions were found when the saturation channel of the image was below 20%. The iron reduction was detected by converting images to the CIE L*a*b* color space. Images were inspected to determine where iron reduction had occurred. Euclidian distances of each pixel oxidized and reduced colors were calculated, and a pixel was considered to represent coating removal when the Euclidian distance was shorter to the reduced color than to the oxidized color. Reducing conditions were observed for manganese and iron after one and four days, respectively. This approach allows the observation of reduction dynamics up to a temporal resolution of five minutes. Spatial patterns of manganese and iron reduction can be observed and analyzed for spatial processes affecting the micro-variability of manganese and iron reduction. LeFevre, O. V., Knappenberger, T., Shaw, J. N., & Olshansky, Y. (2021). Camera illustration of Indicator of Reduction in Soils (IRIS) reduction dynamics. *Agricultural & Environmental Letters*, 6(3), e20051.

Analyse-to-go on the field: prototypes4soil2data

Dr. Stefan Hinck¹, Andreas Möller², Matthias Terhaag³, Daniel Mentrup⁴, Hendrik Kerksen⁴, Elena Najdenko⁵, Dr. Frank Lorenz⁵, Heinrich Tesch⁶, Dr. Tino Mosler⁶, Walter Nietfeld⁷, Walter Peters⁸, Vadim Riedel¹, Prof. Arno Ruckelshausen¹

¹University of Applied Sciences Osnabrück, Osnabrück, Germany, ²ADVES GmbH & Co. KG, Goldenstedt-Lutten, Germany, ³ANEDO GmbH, Eydelstedt, Germany, ⁴iotec GmbH, Osnabrück, Germany, ⁵LUFA Nord-West, Oldenburg, Germany, ⁶MMM tech support GmbH & Co. KG, Berlin, Germany, ⁷Bodenprobetechnik Nietfeld GmbH, Badbergen, Germany, ⁸Bodenprobetechnik Peters GmbH, Badbergen, Germany

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Knowledge of the small-scale nutrient status of a field is an important basis for decision-making when it comes to optimising the use of fertilisers in crop production. At present, the traditional method involves soil sampling in the field and soil sample analysis in the laboratory. In the "prototypes4soil2data" project, the soil2data results are being further developed into a product. In the preceding research project "soil2data", a mobile field laboratory for carrier vehicles was developed. A mixed sample is collected during the drive over. A wet-chemical preparation and analysis of the soil sample is done. The overall process "soil sampling and analysis" is divided into process sub-steps: soil sample planning, soil sample collection, soil preparation, soil analysis and data management. The setup of the mobile field laboratory is modularly designed. Furthermore, the process sub-steps are modified for the mobile field laboratory and the time sequence of process sub-steps is parallel. The soil extraction methodology is based on the VDLUFA method to ensure the interoperability of the analysis results with the VDLUFA fertiliser recommendation. An innovative key component here is the NUTRISTAT analysis module (lab-on-chip). The pH value and the nutrients "NO₃-", "H₂PO₄-", "K+" and the electrical conductivity can be measured. In addition to the advantages of fast data availability and no need to transport soil material to the laboratory, it forms a future basis for new application options, e.g. high sampling density or dynamic adjustment of soil sampling while working in the field.

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A Global Soil Spectral Calibration Library and Estimation Service

Dr Keith Shepherd¹, Dr Rich Ferguson², Dr Dave Hoover², Dr Fenny van Egmond³, Dr Jonathan Sanderman⁴, Dr Yufeng Ge⁵

¹*Innovative Solutions For Decision Agriculture (iSDA), Harpenden, UK*, ²*USDA-NRCS-NSSC-KSSL, Lincoln, USA*, ³*ISRIC World Soil Information, Wageningen, Netherlands*, ⁴*Woodwell Climate Research Center, Falmouth, USA*, ⁵*University of Nebraska-Lincoln, Lincoln, USA*

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

There is increasing interest in infrared reflectance spectroscopy as a tool for rapid inexpensive soil analysis, particularly to aid digital soil mapping at various scales, for monitoring soil health, and for scaling soil testing services in lower income countries. However, deployment of the technology is being held up by the large variation in soil analytical methods and operating procedures used in different laboratories, poor reproducibility of analyses within and among laboratories, and a lack of soil physical archives. An additional barrier is the expense and complexity of building soil spectral libraries and calibration models. The Global Soil Spectral Calibration Library and Estimation Service is an initiative designed to help overcome these constraints. It will provide a freely available, online service to which users can upload infrared spectra and obtain estimates of a range of soil properties, with stated uncertainty, for anywhere in the world. The service is based on the open, high quality and diverse spectral calibration library and the extensive soil archives of the Kellogg Soil Survey Laboratory (KSSL) of the Natural Resources Conservation Service of the United States Department of Agriculture. Countries are encouraged to submit diverse soil samples to KSSL, both to tune the calibration library for local use and grow it for the benefit of all. The initiative is supported by the Soil Spectroscopy for Global Good network and the Global Soil Laboratory Network of the Global Soil Partnership. This global public good stands to benefit soil assessments globally and enormously increase efficiencies.

Shepherd, K.D., Ferguson, R., Hoover, D., van Egmond, F., Sanderman, J., & Ge, Y. (2022). A Global Soil Spectral Calibration Library and Estimation Service, *Soil Security* (submitted).

ESTIMATING SOIL ORGANIC MATTER FROM CELL PHONE IMAGES

Dr. Asim Biswas¹

¹*University of Guelph, Guelph, Canada*

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Soil organic matter (SOM) is considered as the backbone of soil health and soil quality. Thus, its' estimation is critical to support the development of management decision including precision agriculture. To overcome challenges of laborious, expensive, and time-consuming laboratory measurements, recent advances in image acquisition systems provided a new dimension of image-based SOM prediction. Soil moisture can significantly influence soil color and thus confounds the relationship between SOM and soil color. This study quantifies the effects of soil moisture on the relationship between SOM and color parameters derived from cell phone images and establishes suitable SOM prediction models under varying conditions of soil moisture contents (SMCs). Images were captured with a cellular phone over time representing various SMCs. Images were preprocessed and five color space models were used to quantify soil color parameters. SMC exerted a considerable influence on SOM prediction accuracy when its value reached >10% and was considered as the critical SMC. For the soil samples at below the critical SMC, the color parameter R based model produced satisfactory prediction accuracy for SOM with R²_{cv}, RMSE_{cv}, and RPD_{cv} values of 0.936, 4.44% and 3.926, respectively. For the soil samples at above the critical SMC, the SOM predictive model including SMC as a predictor variable showed better accuracy (R²_{cv}=0.819, RMSE_{cv}=7.747%, RPD_{cv}=2.328) than that without including SMC (R²_{cv}=0.741, RMSE_{cv}=9.382%, RPD_{cv}=1.922). This study showed potential of cellular phone to be used as a proximal soil sensor fast, accurate and non-destructive estimation of SOM both in the laboratory and field conditions.

NA

Soil structure revealed from covariation in thermal and electrical properties

Dr. Josh Heitman¹, Dr. Yongwei Fu, Dr. Robert Horton

¹*Nc State University*

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Both soil thermal and electrical properties provide insight about the solid-pore structural arrangement that dictates soil hydraulic properties. But when each is considered separately, the picture remains incomplete. Soil thermal conductivity varies widely according to soil density and composition at low relative saturation, but is less sensitive to pore connectivity as saturation increases. Alternately, soil electrical conductivity varies widely according to pore connectivity over a range of saturation, but is less sensitive to density, which in turn defines total porosity and the total cross-section of soil that is available for water flow. To-date, very few studies have thoroughly examined electrical, thermal, and hydraulic properties together on the same soil. Because electrical and thermal properties each provide unique insights on fluid and solid phase arrangement, we hypothesize that thermal and electrical properties characterized together may offer new opportunity to dynamically predict soil hydraulic properties of structured soils from in situ measurements. Here we present preliminary work comparing electrical and thermal properties of intact soil samples with their natural structural arrangement to the properties of repacked, disturbed soil samples. Co-located thermal and electrical property measurements were obtained with thermo-time domain reflectometry over a moisture range from saturation to dry.

N/A

1894

Evaluation of an in-situ electrochemical sensor towards the quantification of Soil Organic Carbon

Mr Vikram Narayanan Dhamu¹, Dr Anil Somenahally³, Dr Sriram Muthukumar², Prof Shalini Prasad¹

¹The University of Texas At Dallas, Richardson, United States, ²EnLiSense LLC, Allen, United States, ³Texas A&M University, Overton, United States

31 WG1.5: Sensing soil chemical, physical and biological properties - advances and emerging techniques, Alsh 1, August 3, 2022, 14:30 - 16:30

Soil organic carbon (SOC) is an important soil health metric, and needs to be continuously monitored for accurately assessing land use management impacts on soil quality and functions. Current SOC monitoring is either based on extensive soil sampling for analyzing in the laboratory or using proximal sensing methods, which are less accurate. Thus, implementation of soil sensors for accurate in-situ measurements could fundamentally improve SOC assessment. Electrochemistry as a sensor transduction mode is highly viable in different environments. Hence, a sensor based 'bottom-up' approach powered by electrochemical principles was evaluated in this study to quantify SOC in different soil types representing wide range of SOC concentrations. The sensor testing activity was performed on soil as a solid electrolyte under probing similar to a standard electrochemical cell where a composite layer of ionic liquid and Biochar coated as a film on top of the metallized electrodes were utilized. The conjoint interface herein formed between the electrode and electrolyte was perturbed and polarized by applying a conjunctive pulsed DC bias to the electrode system and thereby studying the effect of the polar current as a function of the SOC concentrations yielded the desired sensor response with linearity $R^2 > 0.95$. The proposed sensor platform results were then compared against the standard laboratory method based on dry-combustion. Results with a mean variance of <5% across a 10 soil sample study against the reference method showed the merits of the proposed electrochemical sensing platform as a potential in-situ, on-demand platform to quantify SOC levels.

Bisutti I., Hilke I., Raessler M. (2004) Determination of total organic carbon – an overview of current methods. *TrAC Trends in Analytical Chemistry* 23:716-726.

Lehmann J., Bossio D.A., Kögel-Knabner I., Rillig M.C. (2020) The concept and future prospects of soil health. *Nature Reviews Earth & Environment*:1-10.

Vikram Narayanan Dhamu et al 2021 *J. Electrochem. Soc.* 168 037505

Meersmans J., Van Wesemael B., Van Molle M. (2009) Determining soil organic carbon for agricultural soils: a comparison between the Walkley & Black and the dry combustion methods (north Belgium). *Soil Use and Management* 25:346-353.

Degrees that train students for careers in soil science: Perspectives from diverse countries

Dr Eric Brevik¹, Damien Field², Jacqueline Hannam³, Maja Krzic⁴, Rainer Horn⁵, Cristine Muggler⁶, Jude Odhiambo⁷, Yoshitaka Uchida⁸, **Danny Itkin**⁹, Hong-sheng Wu¹⁰, Liana Pozza², Laura Bertha Reyes-Sánchez¹¹, Thomas Scholten¹²

¹College of Agricultural, Life, and Physical Sciences, Southern Illinois University Carbondale, Carbondale, United States of America, ²Sydney Institute of Agriculture, School of Life and Environmental Sciences, University of Sydney, Sydney, Australia, ³School of Water, Energy and Environment, Cranfield University, Cranfield, United Kingdom, ⁴Faculty of Forestry / Faculty of Land and Food Systems, University of British Columbia, Vancouver, Canada, ⁵Institute for Plant Nutrition and Soil Science, Kiel University, Kiel, Germany, ⁶Earth Sciences Museum Alexis Dorofeef, Department of Soils, Federal University of Viçosa, Minas Gerais, Brazil, ⁷Department of Soil Science, School of Agriculture, University of Venda, Thohoyandou, South Africa, ⁸Faculty of Agriculture, Hokkaido University, Sapporo, Japan, ⁹Department of Geography and Environmental Studies, University of Haifa, Haifa, Israel, ¹⁰Department of Agricultural Resources and Environment, Nanjing University of Information Science and Technology, Nanjing, China, ¹¹Department of Agricultural Engineering, Higher Studies Faculty of Cuautitlán, National Autonomous University of Mexico, Mexico City, Mexico, ¹²Department of Geosciences, University of Tübingen, Tübingen, Germany

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

Soil science is an extremely interdisciplinary field, which means it does not necessarily have an obvious academic home and multiple academic departments have been documented offering soil science coursework and curricula. This study investigated how different academic cultures in 11 countries around the world (Australia, Brazil, Canada, China, Germany, Israel, Japan, Mexico, South Africa, United Kingdom, and United States of America) view soils based on the placement of soils within their undergraduate academic degree programs. Soil science training was scattered among a wide range of academic subject areas, with agronomic, environmental, or geosciences being the most common. Several countries had some academic programs that offered soil science as a stand-alone program, but except for China, stand-alone soil science programs were not the most common way to offer undergraduate soil science degrees in any of the countries investigated. Many of the countries investigated reported a shift in the academic placement of soil science training away from the agronomic sciences toward an environmental or geosciences focus in recent decades. The study concluded that each country's unique culture plays a part in determining where academic soil training is found.

Brevik, E.C., Field, D., Hannam, J., Krzic, M., et al. Degrees pursued by students in different countries to train for careers in soil science. In: Patzel, N., Grunwald, G., Brevik, E.C., Feller, C. (Eds), Cultural Understanding of Soil. Springer, Cham. in press.

How Mindfulness Meditation Practices Impact How People Relate to Soils and Nature: Traditional Buddhist and Contemporary North American Perspectives

Professor Sabine Grunwald¹

¹*University of Florida, Gainesville, United States*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

Secularized mindfulness meditation has gained widespread popularity in North American culture specifically to reduce stress and anxiety and enhance well-being and health. Mindfulness meditation practice originated in Oriental Buddhism as part of nondual liberative traditions. The psycho-spiritual dimensions of mindfulness meditation (Sati, awareness) and perfections practices (paramitas, e.g. loving-kindness) are an essential part of multiple Buddhist traditions. These kinds of psycho-spiritual practices contribute to shape how practitioners relate to other people, nature, the environment including soils but with contrasting outcomes which will be critically discussed in this presentation. In Theravāda Buddhism, deep meditative absorption (samadhi) seeks individual liberation (emptiness of self) but tends to distance and detach from nature (spiritual escapism). In Mahāyāna Buddhism Yogācāra (Mind-Only) school the psycho-spiritual subjective phenomenological experience in meditation is emphasized to realize emptiness of self and phenomena through becoming and being one with nature. These compassion and meditative practices stress belonging through visceral emotive connections with nature, things, and people that evoke care and proactive environmental engagement. In Mahāyāna Buddhism Mādhyamaka (Middle Way) school the absence of intrinsic nature of self and phenomena is asserted through deconstructive ontology in meditation (doctrine of dependent origination of causality). This school stresses the constructs of interdependence and interbeing implying that soil and everything else in the environment are interrelated. Although meditation seems outwardly the same practice the inner psycho-spiritual dimensions and nonduality constructs differ distinctly among Buddhist traditions/schools. Hybridizing Buddhist mindfulness meditation practices into North American culture co-creates new relations how people relate to soil and nature.

Grunwald, S. (2022). Ecosattvas and ecodharma: Modern Buddhist perspectives of soil and the environment. In N. Patzel, S. Grunwald, E. C. Brevik, & C. Feller (Eds.), *Cultural understanding of soils*. Springer.

1850

Soil Voices

Dr Jude Allen¹, Ms Isla Robertson

¹*Soil Voices, Totnes/Morven, UK*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

The poster will give an outline of the Soil Voices project. Soil Voices is collecting stories and memories about soil to build a global map of your soil stories. We want to remind people how crucial soil is to human survival and well-being, so that we can all remember to value it and care for it together. We raise awareness of the importance of soil, particularly amongst people who are not normally interested in it, by bringing soil back into the heart of human storytelling culture. We gather stories that reconnect us to the soil, reintroducing lost experiences and knowledge of how much all of us depend on the stuff that is beneath our feet. We want to get people excited about soil, and bring it back into our conversations, building connections between writers, soil practitioners, food producers and consumers. We want you to love soil in the way that it should be loved! We will present a selection of stories on the poster and also plan to interview attendees and invite them to submit their own soil story for inclusion on our website, <https://soilvoices.org/>
n/a

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'Decolonizing narratives of conservation': Blood and Soil politics and the Long Histories of Colonial Violence*

Dr Jim Scown¹

¹*Cardiff University*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

The environmental politics of Trump's America and the European far-right centre on what Joe Turner and Dan Bailey call 'ecobordering' – a process of 'stoking fears that immigration will deplete national ecological resources (land, water, food, etc.)' [1]. There are similarities here with the Blood and Soil ideology of Nazism, which joined the soil of a bounded nation to the blood of a racially defined population. Throughout the twentieth century, soils have been co-opted as spaces for building identity, and in the process remade as places of exclusion, legitimising terrible violence, often on the grounds of perceived resource scarcity.

But to be fully understood, this worrying emergence of 'eco-fascist ideas, ... rooted in an earlier age of blood-and-soil nationalism,' must also be placed in a longer history [2]. Hannah Holleman notes 'the broader context of the rapid expansion of colonialism and imperialism from which the international problem of soil erosion emerged', environmental degradation that feeds nationalist fears over food shortages or scarcity [3]. Alongside contemporary eco-fascist ideas, this paper examines histories of imperial violence suffered by soils and peoples across the world from 1600-1900. Seen in this *longue durée*, eco-fascism both responds to and extends the violent legacies of extractive colonialism. Taking up Salazar et al.'s call to 'decoloniz[e] narratives of conservation', approaching 'soils as critical zones for intervention and reparation in the Anthropocene', this paper draws out the long histories of violence and exploitation in which Western society is implicated, and that ethno- and eco-nationalist environmental sentiments perpetuate [4].

[*] I have chosen to apply to the 'Culture and Soil' theme of the conference as this paper is not specifically focussed on soil science, though if the organisers feel this work better sits within the 'History, philosophy and sociology of Soil Science' theme, I would be happy to present there instead.

[1] Joe Turner & Dan Bailey, "'Ecobordering': casting immigration control as environmental protection', *Environmental Politics* (2021). DOI: 10.1080/09644016.2021.1916197

[2] Oliver Milman, 'Climate denial is waning on the right. What's replacing it might be just as scary', *Guardian*, 21 Nov. 2021. www.theguardian.com/environment/2021/nov/21/climate-denial-far-right-immigration

[3] Hannah Holleman, 'De-naturalizing Ecological Disaster: Colonialism, Racism and the Global Dust Bowl of the 1930s', *Journal of Peasant Studies*, 44.1, pp. 234-60.

[4] Juan Francisco Salazar et al., eds, *Thinking with Soils: Material Politics and Social Theory* (London: Bloomsbury, 2020).

1090

European Cultural Roots of Relating to Soil

Dr Nikola Patzel¹

¹*Iuss&dbg, Überlingen, Germany*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

European cultural patterns of relation to soil trace back to religions and science of this manifold cultural area and sub-continent. Polytheistic and monotheistic religions moulded relations to nature in Europe. These are Balto-Slavic and Celtic, Germanic and Greco-Roman religions, as well as the mid-east and Judaeo-Christian zone of religious origins. All these religions also have led to more or less 'secularized' reverberations in European societies till today.

Looking at science in contrast, the main scientific bunches of roots for soil understanding come from the physicochemical realm at one side, and from the bio-ecological realm at the other. The scientific paradigm of globalized science itself emerged in Europe in several waves of cultural change.

Both rooting zones of European relations to soil have become integral part of cultural identities in European societies. And both have been effective in this cultural area's large multi-layer expansion of power and paradigm that has effectuated almost global influences and vibes.

Chapters by the auhor in the IUSS book on "Cultural Understanding of Soils." Springer Publisher, 2022.

1829

Understanding farmers' cultural relations with soil: a cross-country comparison in the Mediterranean

Ms Emmeline Topp¹, Dr Cristina Quintas-Soriano², Professor Tobias Plieninger¹

¹*Social-ecological Interactions in Agricultural Systems, University of Kassel, Witzenhausen, Germany*, ²*Andalusian Center for the Assessment and Monitoring of Global Change (CAESCG), Department of Biology and Geology, University of Almeria, Almeria, Spain*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

Dryland farmers across the Mediterranean increasingly seek solutions to the challenges of soil and water conservation. Farming practices such as minimum tillage have limited uptake in Mediterranean countries, despite their promise for meeting these challenges. Soil is not only a material resource but also a cultural resource, and understanding more about Mediterranean farmers' cultural relations to soil could help support appropriate conservation measures. In the ConServeTerra project, we designed a farmer survey to reveal these cultural relations and compare across three Mediterranean countries: Spain, Morocco and Tunisia. First, we investigate the concepts that farmers associate with soil through a freelist technique. Second, we investigate farmers' perceptions of good soil management and of the relationship between tillage and water through open-ended questions. Third, farmers' attitudes to cultural and traditional aspects of farming are revealed through responses to statements on a Likert scale. Preliminary results suggest that farmers associate elements of life with soil that go beyond farming practices to human existence. Some of these concepts are shared among countries, such as heritage and food, whereas some, such as biodiversity and fertility, are more frequently identified in Spain than in Morocco. Attitudes towards the tradition of tilling in the agricultural season, gender roles in farming and following the example of ancestors differ between respondents in Spain and Morocco, whereas attitudes towards the need for change and innovation are more similar. These results illustrate the difference in cultural context for soil conservation across the Mediterranean and identify avenues for further research.

NA

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Cultural understanding of soils. Results from an inter-cultural project.

Dr Nikola Patzel¹, Dr Sabine Grunwald, Dr Eric Brevik, Dr Christian Feller

¹*Iuss&dbg, Überlingen, Germany*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

The speakers are the editorial team of the IUSS book on Cultural Understanding of Soils, a project of the working group on cultural patterns of soil understanding of Division 4 of the IUSS. We reflect on this project of representing inter- and intra-cultural diversity of cultural understanding of soils. It describes opportunities for the international community of soil scientists to communicate with different realities in their societies, for developing more intercultural literacy, and maybe to broaden curricula of soil education.

IUSS book on Cultural Understanding of Soils, edited by Nikola Patzel, Sabine Grunwald, Eric Brevik and Christian Feller (Springer Publisher, 2022)

Native American origin myths and potential links to modern culture

Dr Eric Brevik¹, Dr Jeffrey Homburg², Dr Sabine Grunwald³

¹*Southern Illinois University, Carbondale, USA*, ²*Catena Affiliates and University of Arizona, Tucson, USA*, ³*University of Florida, Gainesville, USA*

46 WG4.2: Culture and Soil. Outlook and insights from around the world, Alsh 2, August 3, 2022, 14:30 - 16:30

Some Native American creation myths reference soil, clay, or earth as key formative elements. In some cases, the creator breathed life into the soil or simply shaped the soil into people. Emergence myths involve humans emerging from a hole in the Earth. In these myths, human origins are intimately linked to the Earth or soil. Myths commonly reflect cultural issues and beliefs. For example, the Akimel O'odham creation myth include black and white people, with blacks and whites regarded as mistakes that the creator corrected when the Akimel O'odham were created. The Yuma creation myth depicts white people as pouty, selfish, and greedy, a cultural view held by many Native Americans towards Europeans who encroached on their land in the Americas. Traditional Native American cultures are intimately connected to the natural world, something that is reflected in their creation myths. Parallels and connections exist between Native American views of their relationship with nature and the environmental movements in North America today. However, lack of understanding of Native American views by many in the environmental movement has also been noted, and a deeper understanding of these views is desirable. Animistic underpinnings of Native American creation myths have been criticized and marginalized by Western rationalistic, materialistic, and pluralistic views in contemporary American culture and religion that justify dominating the environment for short-sighted purposes over long-term sustainability goals. These Western views are directly responsible for soil degradation, and they result in serious hurdles in maintaining and restoring soil and environmental health. Homburg, Jeffrey, Sabine Grunwald, and Eric C. Brevik. From Native American tradition to modern day America, Native origin legends that involve soil and Earth. In: Nikola Patzel, Sabine Grunwald, Eric C. Brevik, and Christian Feller (Eds), *Cultural Understanding of Soil*. Springer, Cham. in press.

Keynote Abstract

Rock dust: a reverse weathering mechanism for tropical soils: environmental and economic aspects

Suzi Huff Theodoro

Universidade de Brasília

Brazil is a country with an area of 5,637,360km² and is formed by a huge geodiversity which supports an even more expressive biodiversity distributed in six different biomes. Its main forms of land occupation are urban/industrial, agriculture, pastures (managed or unmanaged), forests, silviculture, field vegetation, humid areas, continental/coastal water bodies, and uncovered areas (IBGE, 2021). Over the last 10 years there has been an expansion of about 25% in the areas destined for pasture, 70% for silviculture, and 5% for agriculture. Over the last year the Amazon forest has lost around 27% more natural vegetation when compared to previous rates (INPE, 2021).

These data indicate that natural areas are under accelerated conversion, especially to support the production of agricultural, animal protein and wood commodities which supply an international market that has a large demand for semi-processed products.

But there are some limiting factors. The first one is related to the country's production base - its soils. Most of Brazil is located in tropical regions where weathering processes are intense. In general, these soils are deep and have high lixiviation rates, resulting in reduced natural fertility. Although they are considered an infinite resource and are fragile, they have been subjected to intense transformations by the agribusiness model that could accelerate erosion processes and the loss of superficial organic matter, thus weakening their productive capacity.

The other limiting factor is linked to the inputs. To ensure increased production rates, the Brazilian production model uses a huge quantity of imported soluble fertilizers (an average of 80% over the last 10 years), capital-intensive technologies, extensive areas subject to transformation, and a strong international demand for its products. These conditions, combined with the profile of Brazilian farmers, have allowed the country to become an important world player in the agribusiness sector. But this status may not be long-lived. Fertilizers have been suffering successive price increases, making it impossible for farmers with less capital to access the required amount. Besides this, the conversion of natural forests into pasture or agricultural areas has had a negative repercussion on public opinion worldwide.

Are these obstacles a defeat for commodity-producing countries like Brazil? Moreover, how to continue producing commodities and preserving their forest resources, as these activities are directly linked to climate regulation?

A great option that presents itself in Brazil is the use of soil remineralizers (ground rock), as provided by the stonemeal technology. In the last 20 years, several studies have demonstrated the effectiveness of using certain kinds of ground rock to change the fertility levels of tropical soils. This option has shown to be adequate to ensure the supply of inputs, which are locally or regionally available, at lower costs and with very consistent production results. Besides guaranteeing good levels of production, the soil remineralizers have the potential to restore degraded areas, allowing for thousands of unproductive areas to be converted into several forms of use, including CO₂ sequestration and stored capacity. These inputs, especially when associated with organic sources

(bio-inputs), have the potential to reverse the low levels of soil fertility and therefore represent a process similar to reverse weathering.

A number of positive productive results obtained in different regions, the innovative profile of Brazilian farmers coupled with the restricted access to fertilizers (high costs) have led Brazil to become the first country to establish, through laws and regulations, conditions and minimum guarantees for the use and commercialization of soil remineralizers. Adhesion to this option has grown exponentially over the last five years due to the following reasons: regional availability of several types of rocks appropriate for this use with lower acquisition costs; improvement of the productive capacity of the soil; residual effect of the supply of nutrients for longer periods, especially when associated with organic sources; increase of the nutritional content in the plants (since the rock powders are multi-nutrient); reduction of environmental impacts (soil and water contamination) by the soluble fertilizer and reduction of the need to convert new natural areas.

Keynote Abstract

Empowering Soil Scientists with Data-Driven Techniques

Dr Ranveer Chandra

CTO Agri-Food, Microsoft, USA

Soil science relies on carefully designed measurements, sophisticated sensors, physical soil archives, and process based models. This has led to amazing discoveries over the last century on understanding the physical, chemical, and biological properties of soil. However, the lack of large scale measurements and the inability of process based models to analyse them at scale, has limited the understanding of the dynamic soil characteristics.

Recent advances in technology, such as Cloud and AI, can empower soil scientists to develop new understanding of soils and create breakthrough discoveries. Researchers can gather previously unavailable data using Internet of Things (IoT), store it in digital twins in the Cloud, and use AI to uncover new properties of soil or reason about future impact.

In this talk, I will present some of the latest advances in cloud and AI technologies, and how they might be powerful enablers for soil scientists.

I will also present some of our work on agricultural soils. Data driven techniques can boost agricultural productivity by increasing yields, reducing losses, improving soil health, and cutting down input costs. However, these techniques have seen sparse adoption owing to high costs of manual data collection and limited connectivity solutions. Our system leverages Cloud, IoT & AI innovations for farm soils that enables seamless collection and analysis of data across various sensors, cameras, drones, and satellites.

Bioavailability and colloidal characterization of heavy metals and radionuclides in waterlogged, contaminated Belgian soils via Diffusive Gradients in Thin Films

Mr. Francesc Xavier Dengra i Grau^{1,2,3}, Prof. Dr. Erik Smolders¹, Dr. Liesbeth Van Laer², Dr. Lieve Sweeck³

¹*Division of Soil and Water Management, KU Leuven, Leuven, Belgium,* ²*R&D Disposal, Belgian Nuclear Research Centre (SCK CEN), Mol, Belgium,* ³*Biosphere Impact Studies, Belgian Nuclear Research Center (SCK CEN), Mol, Belgium*

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

The “Sigmaplan” is a Belgian programme that aims to permanently flood different lands of Flanders to favour the downstream resilience against the flooding effects of climate change. Some of these areas involve the Grote Nete and the Winterbeek river basins, that show riparian contaminated soils by heavy metals and also by radionuclides, both naturally occurring (NORM) and from anthropogenic sources as a result of historical discharges from the phosphate and nuclear industries. However, the impact of this new waterlogged (anaerobic) state on the bioavailability, colloidal behavior, and fate of these elements of concern still remains unknown. This research intends to determine *ex situ* the labile pools of Cd, Zn, Ni, As, Pb, Cs, Ra and U in the Grote Nete and Winterbeek soils, both in oxic and anoxic conditions. To do so, we will deploy Diffusive Gradient in Thin Films (DGT) devices in both soils, under different simulated reducing conditions. This technique has recently seen large developments for concentration analysis of different elements in pore waters (Li et al, 2019). We will consider DGTs piston-shaped devices containing two different commercial binding gels: titanium oxide (Metsorb[®]) and styrene divinylbenzene (Chelex-100[®]), and one self-made gel (zirconium oxide). These binding gels will be further analysed through LA-ICP-MS and gamma spectrometry, with special attention to the Ra concentrations and redox sensitive elements. We will present the results and discussion arising from this study and its influence in each element’s solid-liquid distribution coefficient (KD).

Li, C., Ding, S., Yang, L., Wang, Y., Ren, M., Chen, M., Fan, X., & Lichtfouse, E. (2019). Diffusive gradients in thin films: devices, materials and applications. In *Environmental Chemistry Letters* (Vol. 17, Issue 2, pp. 801–831). Springer Science and Business Media LLC.

<https://doi.org/10.1007/s10311-018-00839-9>

Using remote sensing to monitor heavy metals in plants at the former sewage farm near Berlin

Dr. Magdalena Sut-Lohmann¹, MSc Friederike Kästner², MSc Shaghayegh Ramezany¹, MSc Mark Grimm¹, Prof. Thomas Raab¹

¹Brandenburg University of Technology Cottbus-Senftenberg, , ²Helmholtz Centre Potsdam, Research Center for Geosciences, ,

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

Sewage disposal onto agricultural land is a common practice that results in accumulation of organic matter, salts, and nutrients. However, in the past, these activities led also to enrichment of various organic contaminants and heavy metals (HM). Former sewage farms are commonly located in the suburbs of metropolitan areas and have been farmland for many decades. Thus, in many cities and industrial regions, like the Berlin-Brandenburg metropolitan area, former sewage farms pose a problem for expanding economies and urban settlements. A proper example are former sewage farms surrounding Berlin, where the discharge of untreated wastewater led to the HM accumulation of soils in significant amounts.

We present a study, conducted on a former sedimentation basin, within the frames of “Innovative drone based hyperspectral detection of HM in plants in relation to phytomining – HyPhy“ project. To evaluate the feasibility of HM accumulation monitoring in hyperaccumulators with hyperspectral sensors, site screening, greenhouse experiments and outdoor spectral data collections were conducted. HMs were determined using X-ray fluorescence (XRF), Atomic Emission Spectroscopy (MP-AES), diffuse reflectance infrared fourier transform spectroscopy (DRIFTS) and Tessier sequential extraction. To study chosen metal uptake, hyperaccumulator *Brassica juncea* was daily irrigated with zinc (Zn), copper (Cu) and nickel (Ni) solutions. Data collation was performed using hyperspectral sensors VNIR from Cubert GmbH and SWIR HySpex from the Norwegian company NEO that are supported by drones. For data validation point spectrometer PSR+ from Spectral Evolution was applied. We aim to present project conduction stages and the latest results.

Kästner, F., Sut-Lohmann, M., Ramezany, S., Raab, T., Feilhauer, H., Chabrillat, S. (2022) Estimating heavy metal concentrations in Technosols with reflectance spectroscopy, *Geoderma*, Volume 406, 115512.

Uranium and cadmium accumulation in European agricultural soils due to mineral phosphate fertiliser applications

Mr. Benoit Bergen¹, Dr. Mieke Verbeeck^{1,2}, prof Erik Smolders¹

¹*Ku Leuven, Leuven, Belgium*, ²*Rothamsted research, UK*

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

This study was set up to survey the general long-term impact of P fertilisers on concentrations of cadmium and uranium in European soils. A total of 218 soil samples was collected from 15 long-term (3-78 years, median 18 years) P trials with a pairwise comparison of topsoil composition between the fertilised and corresponding unfertilised soils.

Statistically significant differences in aqua regia soluble metals due to fertiliser application were detected more frequently for U (10 of 15 trials) than for Cd (4 of 15 trials). The concentrations of U and Cd in soil linearly increased with cumulative applied P across all soils and sites; a total addition of 1 ton P ha⁻¹ increased the mean topsoil (23 cm depth) concentrations by 0.11 mg U kg⁻¹ soil (0.09-0.12 mg U kg⁻¹, 95% CI) and 0.03 (0.02-0.04) mg Cd kg⁻¹ soil. These results correspond with mass balance predictions (1 ton P ha⁻¹; +0.15 mg U kg⁻¹ soil and +0.02 mg Cd kg⁻¹ soil) based on previously determined average trace element (TE) concentrations in EU fertilisers.

Data thus suggests that 30% of the theoretical U input from fertilisers is lost while losses of cadmium from soil are undetectable. However, large variability on observed Cd accumulation suggests that for certain trials considerable losses of Cd occurred.

This study provides data to better evaluate the modelled trace metal accumulations in soil and to evaluate the prevailing metal limits in mineral fertilisers.

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Radiocesium uptake by vegetables in different soils after nuclear accident of FDNPP

Dr. Takuro Shinano¹, Dr. Yusuke Unno², Ms Hisae Fujimoto¹, Ms Akiko Maruyama¹, Ms Saeko Yashiro³, Mr Satoshi Asaeda³, Dr Hayato Maruyama¹, Dr Toshihiro Watanabe¹, Dr Atsuhi Nakao⁴, Dr Katsushi Kubo⁵, Dr Takashi Saito³

¹Hokkaido University, Sapporo, Japan, ²Institute for Environmental Sciences, Rokkasho, Japan, ³Fukushima Agricultural Technology Centre, Minamisoma, Japan, ⁴Kyoto Prefectural University, Kyoto, Japan, ⁵National Agricultural and Food Research Organization, Fukushima, Japan

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

After TEPCO's FDNPP accident, a large area was contaminated with radionuclides including agricultural fields. The major concern was focused on radiocesium, and the major countermeasure was top soil stripping and potassium fertilizer application. Though many researches have been focused on very limited crop species (e.g. rice and soybean), the farmers in the contaminated area also produced a large number of other crop species. Among them, vegetables are occupying a major position not only for self-consuming but also for selling. Very few reports have been published on the ratio of the activity concentration of radiocesium in the harvesting organ to that in soil (e.g., IAEA TECDOC 2020). We conducted field and pot experiments to have precise information about the radiocesium uptake ability of several vegetables and found that relatively high ability of the uptake was found in several species. Furthermore, based on the analysis of using a leguminous crop species (*Lupinus albus* L.), which demonstrates very high ability of radiocesium uptake around its special root structure (cluster roots) zone. A part of the radiocesium uptake ability seems to be regulated by the ability of dissolving elements from the soil minerals.

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Assisted phytoextraction of Zn from contaminated soils using alternate submersion cycles; a novel approach

Dr. Elio Padoan¹, Dr. Annapaola Giordano¹, Prof. Franco Ajmone-Marsan¹

¹*Università degli Studi di Torino, Grugliasco (TO), Italy*

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

Phytoextraction has been one of the most studied phytoremediation technique. Most studies dealt with the main limitation of the technology: the low solubility and bioavailability of metals, which diminish the potential of this approach by reducing the extraction rate of the metals thus extending remediation times.

The most studied method to increase the extraction rate is the use of hyperaccumulator or fast-growing plants. The use of chemical or biological techniques to increase metals availability to plants have also been studied, leading to procedures that use soil amendments, chelating agents or specific bacterial consortium.

In this work, we used a novel concept of assisted phytoremediation, which takes advantage of the increased metal availability with the use of controlled flooding conditions, with aerobic-anaerobic cycles. Metal release under anaerobiosis, mainly due to the dissolution of Fe-Mn oxides, controls, in some soils, a considerable fraction of some elements, such as zinc.

To test if, during the flooding cycle, this release will increase Zn uptake rate, we used three different Zn-contaminated soils and we investigated the extraction potential of different species subjected to redox cycles.

The first results gave promising results for *Brassica juncea* as accumulator species, which was able to extract, after two flooding and drying cycles, up to three times more than the control plants. More results will be necessary to better define the possibilities of this new technique, including the use of different plant species and its upscaling to field use.

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SOIL MERCURY LEVELS IN A NATURAL PROTECTED AREA DEGRADED BY ILLEGAL ARTISANAL AND SMALL-SCALE GOLD MINING IN THE PERUVIAN AMAZON

Mr Manuel Gabriel Velásquez Ramírez^{1,2}, Mr Dennis del Castillo², Mr Erik Smolders¹, Mr Vladimir Ramirez³, Mr Joel Paitan³, Ms Adenka Muñoz², Mr Edwin Becerra², Mr Ronald Corvera²

¹Ku Leuven, Leuven, Belgium, ²Instituto de Investigaciones de la Amazonía Peruana (IIAP), Iquito, Peru, ³SERNANP, Tambopata, Peru

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

The Artisanal and small-scale gold mining (ASGM) exploitation in the Amazon has degraded tropical pristine forest and increased mercury (Hg) risk pollution. In Latin-America, Peru losses up to 10000 ha per year of forest, meanwhile illegal ASGM liberates about 181 tons per year of Hg. Because Hg movement is not comprehensive yet, here we aim to reveal Hg levels in a natural protected area (Reserva Nacional Tambopata) which was degraded by illegal ASGM for more than 15 years. We selected 500 ha, collected 103 surficial soil samples and got samples from 8 soil pits in degraded and non-degraded areas. Soils were analysed to determinate Hg and physicochemical soil characteristics. According to the Canadian Environmental Quality Standards for Agricultural Soil, there was no Hg pollution; soil Hg levels in degraded areas were 0.7; however, in specific points, we got up to 11 mg/kg; mean while, soil Hg level in non-degraded areas was 0.05 mg/kg. As stated to correlations, mercury variability was explained by clay particles (+0.50), pH (-0.47), bulk density (-0.45), soil organic matter (+0.44), sand particles (-0.41), exchangeable Al and H (0.41). Degraded soil layers in pits showed that Anthropotic Udorthents got less than 0.027mg/kg; however, in non degraded areas they got up to 1.8 mg/kg and even 8.6 mg/kg in the corresponding Typic Udifluvents and Typic Dystrudepts. In conclusion, we suggest degraded soils accumulates Hg during soil improvement with vegetation, and non degraded areas have been accumulating Hg, caused by Hg uptake from the environment and leaching process.

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Trace elements in palm oil production systems: Implications for international agriculture

Miss Hadee Thompson-Morrison¹, Professor Sally Gaw¹, Professor Brett Robinson¹, Fransisca Ariantiningih², Sugesti Muhammad Arief²

¹University of Canterbury, Christchurch, New Zealand, ²Orangutan Information Centre, Medan, Indonesia

Interdivisional 10: Land contamination and degradation, including Urban Land, Lomond Auditorium, August 4, 2022, 09:30 - 11:30

The African oil palm (*Elaeis guineensis*) is the highest yielding oil crop at 4 t/ha. Indonesia and Malaysia are the largest producers of palm oil due to their suitable climates. Production occurs on a range of plantation types and soils, with varying management practices. Oil palm production requires phosphate fertilisers and fungicides that contain Trace Element (TE) contaminants. They are often used in quantities exceeding plant requirements¹. This can lead to contamination with Cd, Cu and Zn in oil palm plantation soils.

New Zealand imports 2.3 million t/yr of Palm Kernel Expeller (PKE), a by-product of palm oil production, as a supplementary stockfeed on many dairy farms. Many other countries, including those in Europe and Asia import large annual quantities of PKE. PKE is potentially a significant source of TEs into soil, plants and livestock of receiving environments. The use of PKE may have beneficial (correcting soil deficiencies) or deleterious (resulting in soil contamination and plant uptake) effects on soils.

Indonesian production soils, harvested plant material and PKE exported from Indonesia and Malaysia were analysed for TEs. We have measured elevated Fe and Cu concentrations in PKE (up to 634 and 36 mg/kg respectively), as well as elevated Cu and Zn in production soils (up to 28 and 90 mg/kg respectively). Our modelled soil concentrations show that within 20 years, Cu is likely to reach threshold levels in palm production soils, potentially detrimentally affecting soil fertility.

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Functional gene analysis of phosphorus-cycling microbial communities in organic and upper mineral soil horizons from a temperate rain forest chronosequence

Prof Kari Dunfield¹, Dr. Eduardo Mitter¹, Kamini Khosla¹, Jon Gaiero¹, Prof Alan Richardson², Prof Leo Condrón³

¹University of Guelph, Guelph, Canada, ²CSIRO, Canberra, Australia, ³Lincoln University, Lincoln, New Zealand

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanical understanding, M1, August 4, 2022, 09:30 - 11:30

Soil chronosequences are characterized by dynamic changes in N and P biogeochemical cycles that drive the development of above and belowground biological communities. In addition, older soils develop thick organic horizons with significant physical-chemical differences from the underlying mineral soil. Biological P limitation as soils age has been shown to impact P-cycling microbial community dynamics in mineral soils; however, their role in the developing organic soil horizons remains unclear. The Big Bay dune system in New Zealand represents approximately 6,500 years of soil development under temperate rainforest. In this study, soil (0-25 cm) was sampled from the organic and mineral horizons from three dunes ranging from 300 to 3000 yBP. For each dune, the organic soil horizon constituted the uppermost 2 to 12 cm of the soil profile, depending on age. Bacterial, fungal and P-cycling communities were assessed using high-throughput amplicon sequencing and quantitative qPCR targeting 16S, ITS and acid (phoN/C) and alkaline (phoD) phosphatase genes. The organic horizon harboured a more complex microbial community structure compared to mineral soils, with greater network connectivity, and higher number of unique phoN/phoC and phoD -sequences. Putative hub taxa in these soils exhibited positive correlations with acid phosphatase activity, total C and total N. In older, more P limited soils, we identified the highest phosphatase activity driven by lower P-cycling gene diversity compared to younger soils. This study system provides an ideal framework to evaluate the effects of long-term changes in nutrient availability, and soil properties on soil-plant interactions and microbial community development.

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Going deep - Microbial C-turnover in flow path and matric subsoil

Dr. Stefanie Heinze¹, Prof. Dr. Bernd Marschner¹

¹*Ruhr-Universität Bochum, Bochum, Germany*

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Subsoils are characterized by a very heterogeneous distribution of soil organic carbon (SOC) [1] caused by a strong localized input via roots, rhizodeposition and flow path transport. Whereas the importance of root input is proven by many studies [2;3] the contribution of carbon input through and its turnover within the flow paths (FP) reaching the subsoils are not fully understood. Therefore, in Oct. 2021 we conducted a tracer experiment (using brilliant blue) on a 2013 established research site located in a beech forest stand on a Dystric Cambisol close to Hannover, Germany. After 10 hours of irrigation (20 mm/hour), three soil pits were excavated, the distribution of flow path ways were documented and then sampled specifically (FP and matric soil (MS)). Soil material from FP and MS were taken in 6 depth increments (0-10, 10-30, 30-50, 50-80, 80-110, and 110-150 cm) to analyze microbial C-turnover with and without labile C- and nutrient addition by using the MicroRespTM approach and detecting nutrient supply by measuring extracellular enzyme activities from different nutrient cycles. The results will elucidate the relevance of FP for C-cycling within the subsoils and will provide insights into the microbial nutrition status of regions of high input (flow path) and low C- and nutrient contents for C-turnover mechanisms in subsoils. We expect higher microbial activities within the FP regions due to a permanent input of DOC and nutrients but a stronger stimulation of microorganisms through labile C- and nutrient additions within MS where dormant microbes are waiting for substrate.

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Toward a national assessment of soil biodiversity: A framework for systematic data collection

Dr. Tiffany Carter¹, Dr. Skye Wills¹, Mr. David Hoover¹, Dr. David Lindbo²

¹USDA-NRCS, Lincoln, United States of America, ²USDA-NRCS, Washington, United States of America

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Soil biological organisms play a key role in global nutrient cycling and provide various ecosystem services. While biodiversity is known to vary by ecosystem and soil type it has not been captured by most soil and ecosystem hierarchies. Soil survey traditionally collects physical and chemical properties however there is growing interest in soil biology and biodiversity including as a part of conservation planning for soil health. US soil survey has expanded past traditional properties and interpretations to include ecosystem hierarchies including ecological sites and dynamic soil properties that change with land use and management. To meet the increasing demand for biological soil data there is a clear need for the development of efficient and cost-effective methodology that can be used by the National Cooperative Soil Survey (NCSS). To fill this knowledge gap, this presentation aims to provide an overview of methods used globally to assess soil biodiversity and how to test their suitability in a national scale survey. Methods considered must be repeatable, economic, and produce data interoperability across laboratories and locations. A framework will be proposed to organize the collection and analysis of soil by biodiversity data across the conterminous US. Soil survey regions will be utilized to provide logistical divisions. Extensive soils and land uses will be targeted to provide consistent results across regions. Potential products and insights from this work will be discussed.

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Stage free for the Diversity of Soil Eukaryotes: An EU-wide Metabarcoding Analysis correlating Biodiversity with Environmental Drivers

Ms. Julia Köninger^{1,2}, Dr. Panos Panagos², Prof. Maria J. I. Briones¹, Dr. Alberto Orgiazzi²

¹*University Of Vigo, Vigo, Spain*, ²*Joint Research Centre European Commission, Ispra, Italy*

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Despite that all above-ground life depends on the life below-ground (Wagg et al. 2014), soil biodiversity is globally threatened and not adequately protected (Guerra et al. 2021, Köninger et al. 2021). Conservation activities are often inefficient due to the lack of quantitative data. While massive sequencing of soil biodiversity contributes significantly to shining light on below-ground life, broad-scale studies are often biased towards certain groups (bacteria) and not easy to compare because the sampling methods are not standardised, preventing the identification of reliable, quantifiable conservation targets. Therefore, in a first continent-wide effort, we collected diversity data (DNA metabarcoding of the 18S genes) of protists, fungi and animals from 885 sites across Europe. We then clustered sequence reads into amplicon sequence variants (ASVs) using DADA2 (Callahan et al. 2018) to assess alpha and beta diversity and identified indicator species, representing the effect of different drivers on eukaryotic biodiversity. We determined environmental drivers on soil eukaryotes by correlated biodiversity with soil chemical (e.g., pH, nitrogen, phosphorus, potassium, organic carbon), physical (e.g., electric conductivity, coarse fraction) and other biological properties (basal respiration, microbial biomass and respiratory quotient) as well as climate data (e.g., rainfall, annual temperature) gained from the LUCAS Soil survey and the published literature. We used regression, ordination, and variance partitioning analyses. Structural equation models (SEMs) allowed us to quantify relationships between variables in predictive maps. The links between abiotic and biotic patterns will be discussed, pathing the way for quantifiable goals to be included in soil biodiversity conservation activities.

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Progress towards a mechanistic soil enzymology to put the 'bio' in biogeochemistry

Dr. Andrew Margenot¹

¹*University Of Illinois Urbana-champaign, Urbana, USA*

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Enzymes in soils catalyze redox transformations and hydrolytic transformations of carbon, nitrogen, phosphorus and sulfur. The extracellular nature of many soil enzymes (i.e., abiotic) means they integrate biotic and abiotic drivers of P dynamics. However, the potential of enzymes for the study of nutrient element biogeochemistry has been constrained by importation of methods and concepts from traditional biochemistry and microbiology. Using the example of phosphorus (P), edaphically contextualized methodological and conceptual considerations for capitalizing on the promise of enzymes in terrestrial P biogeochemistry are reviewed, and key next steps for integrating soil enzymes as a biological driver of P biogeochemistry are proposed.

n/a

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Shifts in root-associated fungal communities under variations in soil N:P stoichiometry - the effects on forest ecosystem processes

Dr Rodica Pena¹, Prof Mark Tibbett¹

¹*School of Agriculture, Policy and Development, University of Reading, , , UK*

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Temperate and boreal forests are considered to be primarily nitrogen (N) limited. However, anthropogenic N deposition changes the stoichiometry of N relative to phosphorus (P) and gives rise to P co-limitation. The primary strategy of trees to cope with nutrient deficiency is to form symbioses with ectomycorrhizal (EM) or arbuscular (AM) fungi (Marschner and Dell, 1994). It is known that EM colonisation rate and diversity decrease with increasing N deposition, but whether other root-associated fungi take over the nutritional role of mycorrhizas under P co-limitation remains unknown. The objective of this study was to assess the control of soil nutrient availability on plant nutrient acquisition-related symbioses. We hypothesised that with increasing soil N:P ratio, root colonization shifts from (1) EM to AM fungi in plants forming dual AM and EM symbioses, and (2) EM to other root endophytes (e.g., dark septate endophytes) in EM plants. We further hypothesised (3) that these community changes contribute to possible alterations of rhizosphere enzyme activities, soil organic matter decomposition, fungal and bacterial biomass, and tree growth.

Our first results showed that root-associated fungal communities changed with the N:P ratio. EM fungal communities showed less mycelium abundant foraging taxa under high than low N soil concentrations. Data on the relationships between soil nutrients and functional diversity of root-associated fungal communities together with their effects on fungal-driven ecosystem processes will be presented and discussed in the context of adaptive forest management to increase the ecosystem resilience to environmental change.

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The relationship of soil organic matter and bacterial community structure in grasslands across major soil zones

Mr Daniel Wasner¹, Dr. Aline Frossard², Prof. Dr. Erick Zagal Venegas³, Prof. Dr. Sebastian Dötterl¹

¹*Soil Resources, ETH Zurich, Zurich, Switzerland*, ²*Swiss Federal Research Institute WSL, Birmensdorf, Switzerland*,

³*Departamento de Ciencias del Suelo y Recursos Naturales, Concepción, Chile*

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Soil organic matter (SOM) quality and quantity is an important driver of the structure of soil bacterial communities (Fierer, 2017). However, little is known whether - and which - bacterial phylotypes are associated with SOM properties. The complexity of SOM quality and its stabilization differing across major soil orders and climatic regimes might be key to improve our understanding of how SOM affects microbial community structures.

In this study, we use a correlative approach to identify microbial phylotypes that are strongly associated with – soil specific - SOM properties. We sampled 35 topsoils (0 – 10 cm) characterized by varying SOM quality and quantity as well as soil properties along a 4000 km north-south transect in Chilean grasslands. First, we characterized SOM properties using a wide array of approaches, including quantification of extractable and (mineral)stabilized C pools, stable isotope ratios, spectroscopy and Rock-Eval pyrolysis. In a second step, we used soil DNA metabarcoding to assess the bacterial (16SrRNA genes) community diversity and identify dominant phylotypes. Our correlative analysis shows significant and consistent shifts in community structure along gradients of SOM quality and quantity, and identifies phylotypes preferentially associated with specific SOM properties. This provides new insights into the link between soil C dynamics and bacterial community composition. Further, these findings will help to evaluate ecological concepts about substrate specific traits in soil microbial ecology (Krause et al., 2014; Malik et al., 2020). An in-depth analysis is currently conducted, and first results will be presented at the conference.

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1392

Soil metagenomic analysis of different WRB diagnostic units under different management systems for soil health assessment

Mr Benjamin Bukombe¹, Mr Sándor Csenki¹, Mr Gábor Nagy³, **Dr Vince Lang¹**

¹Discovery Center Nkft, Gödöllő, Hungary, ²AgroAIM Hungária Kft, Gödöllő, Hungary, ³Homokkert Kistérségi NKft, Hungary

20 Division 2 Commission 2.3- Soil biology in transition: from descriptive to mechanistical understanding, M1, August 4, 2022, 09:30 - 11:30

Soil metagenomics analysis is one of the latest technologies which could provide great descriptors for the assessment of soil health. With the technological advancements these measurements are faster and cheaper now, thus more available to broader soil research. In a country wide soil survey soil metagenomics analysis was used as a descriptor to understand the changes of microbiological composition of different World Reference Base for Soil Resources diagnostic units, under different management practices such as till, no till and undisturbed field boundaries. Soil samples were collected in the major agricultural areas of Hungary during april in a very short period of time to allow comparison of results and decrease the effect of climatic conditions on the results . Besides the metagenomics analysis soil physical, chemical and morphological characteristics were also measured and observed for the compilation of a complete database to assess soil health. The findings of the research showed that not only soil management has a great influence on the studied soil health indicators, but these indicator's baselines are varying not only by soil type but by lower classification units such as diagnostic horizons, materials or properties, thus a soil health assessment tool should consider these aggregated soil informations in the validation process. Although the study aimed to represent the major soil types of the country further surveys and measurements are envisioned based on the limitations found in the database, and to reach a higher representation of the major agricultural soils.

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Quantitative correlation and implications for pedodiversity assessment
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Vince, Láng ; Márta, Fuchs ; Tamás, Szegi ; Ádám, Csorba ; Erika, Michéli

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Where pedology meets pedagogy

Dr Felicity Crotty¹

¹*Royal Agricultural University, Cirencester, United Kingdom*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

Understanding the importance of soil health has grown across the farming community over the last ten years. However, formal teaching of the idea has been limited. Academics working with stakeholders hosting “soil health” or “soil biology” farm walks and webinars, gathers from a pool of users who are already interested in the notion and keen to learn more. Over the last three years at the Royal Agricultural University, we have redeveloped our soil modules to be more practical (level 4) and develop critical thinking (level 6) within the concept of soil health. The overall aim is for these future farming leaders to be able to implement soil health measures on farm, as part of their inherent understanding in sustainable farming practice. Here, we review the successes, pitfalls and the importance of building strong foundations to underpin undergraduate studies across all teaching levels.

Crotty, FV, (2021). Assessing soil health by measuring fauna. In: Otten, W., Advances in measuring soil health. BDS Publishing, Cambridge, UK

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1627

Changing sides: Experiences with a “flipped classroom” format for teaching soil science to bachelor students in physical geography.

Dr Klaus Jarosch^{1,2}, Liv Klemm², Dr Jeannine Wintzer²

¹*Agroscope, Zurich, Switzerland*, ²*University of Bern, Bern, Switzerland*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

Methods of teaching are increasingly shifting from an “instructors paradigm” with classical lectures to an “learning paradigm”, providing the students with sufficient tools and support to acquire the knowledge themselves by different means. The applicability of this approach for teaching fundamentals in soil science was analysed by using a flipped classroom approach in a lecture for ~140 bachelor geography students. Topics of the course included i) soil formation, ii) soil properties iii) soil classification, and iv) soil functions, threats and protection. One week before each lecture, students were provided with a) a pre-recorded video by the lecturer where the content of the lesson was provided, b) supporting material such as textbook chapters, videos for visualisation of different methods and c) an online self-evaluation tool. During the lecturing unit first remaining questions were jointly discussed. After that, students were provided with an exercise sheet covering the content of the current lesson. Exercises included checks on current knowledge, application of concepts under new situations and practical exercises. At the final lecture we conducted an anonymous survey among all participating students, inquiring on their perception of which teaching method was fitting them best. The survey was combined with a trial exam, where students could test their current status of knowledge, reflecting also the different used teaching methods. By combining the subjective perception on the utility of different teaching approaches with the actual knowledge obtained by different teaching methods we aim to identify suitable techniques(s) for teaching soil science for university undergraduate students.

Barr, Robert B. and Tagg, John (1995): From Teaching to Learning. A New Paradigm for Undergraduate Education.

Network-Based Approaches for Adoption of Soil and Agronomic Management Practices

Associate Professor Abbey Wick¹, **Jean Haley**², Dr Marisol Berti¹

¹North Dakota State University, Fargo, United States, ²Haley Consulting Services LLC, Bloomington, United States

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

On-farm adoption of sustainable soil and agronomic management practices is critical to the future of agriculture and preservation of our soil resource. University programs are one avenue used in the United States to encourage practice adoption. With a focus on network-based models, programs are developed using technical, social and experiential learning pathways. Universities then serve as (1) boundary organizations to create opportunities for conversations to occur, (2) network managers to facilitate learning and (3) builders of social capital to encourage trust in the network. The soil health program at North Dakota State University (NDSU) will be used to illustrate the above approach. Informal discussion groups, called Cafe Talks, were held across eastern North Dakota between 2014 - 2019. A knowledge network was developed using NodeXL, where scientists, farmers, crop consultants and Extension were all influential individuals in the network. Farmer respondents manage nearly 64,000 hectares and crop consultants influence nearly 132,500 hectares of land. Cover crop practices and conservation tillage practices were being adopted or considered for adoption by farmer respondents (for example, diverse cover crop mixes 62% and strip tillage 38% of respondents). For crop consultant respondents, 67% are now recommending or plan to recommend reducing fall tillage and 65% recommend or plan to recommend interseeding cover crops into standing corn. Network-based approaches have been proven to be successful in encouraging on-farm adoption of agronomic practices which enhance and protect the soil resource.

None

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Do we need to new set of soil principles to guide general soil education

Professor Damien Field, Professor Alexander McBratney

¹*The University Of Sydney, Eveleigh, Australia*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

The importance of and role that soil plays in ensuring the future sustainability of human and planetary health and the emerging soil security concept clearly identifies that education is a crucial a component. Traditionally, soil science education has been limited to developing discipline expertise. To be truly effective we need to go beyond the boundaries and explore the types of learning that engages the whole community and raise our collective soil connectivity.

Previously the theoretical framework of to 'know', 'know of' and 'be aware' of soil is accepted, along with experiential learning practices using the teaching-research-Industry-learning (TRIL) models. To socialize this do we need a set of newly proposed set of principles, in the same way principles have been developed for disciplines in biology and geology.

Starting with the Pedon this elementary level will ensure awareness of soil. Coupled with outward focused responsibility of providing salient knowledge together with the social intelligence will use the second principle of Processes to provide resolution to soil related problems. Traditionally, this knowledge is often used to tackle well know threats, but more recently the advances in digital soil mapping and decreasing soil modelling have enabled greater interdisciplinary opportunities to solve soil knowledge based around the principles of variation and ultimately forecasting soil change.

This paper will align the set of principles against the current soil science education practices and how these can be used to engage with the broader community outside of academia.

None

Soil cakes: unexplored resources to improve soil awareness

Prof. Rosa M Poch¹, Ms Paulina Brena², Ms Daniela Álvarez¹

¹*Universitat de Lleida, Lleida, Spain*, ²*Pint of science, Mexico DF, Mexico*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

Among the most common activities to improve soil knowledge and awareness we find stories for children, drawings and paintings, movies, quizzes...; but the 3D representation of soils is still missing when we want to convey what soils are to the common public. Moreover, most of the attention is given to what soils “do” (environmental services) but not much to what soils “are”, as objects. Very often, when describing soils, field soil scientists find similarities between a given soil material and a particular food or cake. So, soil cakes are a creative way to bring soils close to everyday life because, with some cooking expertise, we can represent e.g. soil colours, textures, structures, consistencies, degrees of cementation or distribution of horizons, which are explored in a 3D model when we eat them. They also represent a didactic resource for both formal and non-formal education, as they can be incorporated into the design of learning experiences, promoting the acquisition of scientific knowledge through a bidirectional dialogue. They also have the advantages of presenting soils as a nice and tasty thing that everybody likes compared to the dirt with which they are usually associated, and of connecting soils to other disciplines and social contexts, besides being sustainable (zero residue). In this way, the public could be involved in soil cake contests, or in a collection of recipes of soil cakes next to some information on the featured soils, or in making soil cakes of a region showing the most representative soils.

No references

THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION

Ednalva Dantas rodrigues da Duarte¹, THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION João Carlos Coelho Filho^{1,2}, THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION Carlos Henrique Matos^{1,3}, THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION Luciano Silva^{1,4}, THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION José Frutuoso Vale Junior^{1,5}, THE VIRTUAL RORAIMA SOIL MUSEUM TO SUPPORT SOIL EDUCATION Valdinar Melo^{1,6}

¹Universidade Federal de Roraima, Boa Vista, Brazil, ²Universidade Federal de Roraima, Boa Vista, Brasil, ³Instituto Federal de Educação, Ciência e Tecnologia de Roraima, Caracará, Brasil, ⁴Universidade Federal de Roraima, Boa Vista, Brasil, ⁵Universidade Federal de Roraima, Boa Vista, Brasil, ⁶Universidade Federal de Roraima, Boa Vista, Brasil

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

The Roraima Soil Museum (MSRR) is an important space for on-site Soil Education actions that aim to promote care and attention to the soil. Face the current scenario of a COVID-19 pandemic, attendance to the museum was suspended, but the importance of having an alternative form of access to the MSRR collection was still perceived. This work presents the Virtual Roraima Soil Museum (MVSRR), an immersive virtual reality museum to support education in soils, based on the Roraima Soil Museum of the Agricultural Sciences Center of the Federal University of Roraima, developed from January to May 2021, through digitalization of its collection, with the objective of disseminating Soil Science in a non-presential manner. Preliminary results of visits to MVSRR indicate that this alternative museum can be a good option to support education in soils, not only in the current scenario of confrontation with COVID-19, but in a permanent and complementary way to MSRR.

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1825

Farmer field schools for improved soil literacy among Mediterranean dryland farmers: Insights from the ConServeTerra project

Ms Emmeline Topp¹, Dr Harun Cicek², Dr Rachid Dahan³, Dr Oussama El Gharras^{3,4}, Dr Mohamed Boughlala⁴, Dr Cristina Quintas-Soriano⁵, Professor Tobias Plieninger¹

¹*Social-Ecological Interactions in Agricultural Systems, University of Kassel, Witzenhausen, Germany*, ²*Research Institute of Organic Agriculture (FiBL), Frick, Switzerland*, ³*Association for Agriculture, Environment and Development for the Future (AGENDA), Settati, Morocco*, ⁴*National Institute for Agronomic Research (INRA), Settati, Morocco*, ⁵*Andalusian Center for the Assessment and Monitoring of Global Change (CAESCG), Department of Biology and Geology, University of Almeria, Almeria, Spain*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

Understanding of soil as a living entity and essential resource is a prerequisite for the uptake of soil conservation practices by farmers. Farmer field schools (FFS) are a key pillar of the ConServeTerra project, which aims to increase the soil literacy and uptake of Conservation Agriculture (CA) practices among Mediterranean dryland farmers. CA is one of the most commonly promoted farming systems to improve soil health and function through reduced soil disturbance, permanent soil cover and crop diversification. However, these practices are not yet widespread among dryland Mediterranean farmers facing soil and water conservation challenges where, paradoxically, CA has been shown to be most effective. Thus, ConServeTerra is conducting FFS across four Mediterranean countries. Diverging from the common FFS focus on crops, ConServeTerra is highlighting the fundamental understanding of soil and its function as the key pillars of soil literacy. We present the ConServeTerra FFS approach, including on-farm trial plots and the demonstration of a rainfall simulator to illustrate soil function under different conditions. We share some experiences and insights from the FFS undertaken so far in Morocco and Spain, and identify farmer soil knowledge strengths and gaps.

NA

Soil Skills: A Problem-Based Field Challenge Towards Active Learning Ethos for Undergraduate Soils Students

Dr. Said Al-Ismaily¹, Mr. Ahmed Al-Mayhai¹, Mr. Hamad Al-Busaidi¹, Prof. Anvar Kacimov¹, Dr. Daniel Blackburn¹, Dr. Ali Al-Maktoumi¹, Mrs. Buthaina Al-Siyabi¹

¹*Sultan Qaboos University, Al-Khoud, Oman*

25 Division 4 Commission 4.4: Soil education – in School, university and In-Service training, Forth, August 4, 2022, 09:30 - 11:30

In this pedological work, we illustrate an interactive problem-based learning environment, “Soil Skills contest (SSC)”, for senior students majoring in Soil Sciences, BSc program at Sultan Qaboos University, Oman. This five-day component of a compulsory field-course amplifies students’ self-learning through a series of questioning-researching-verifying field activities that intellectually link the different factual information, scientific concepts, and related domain knowledge to form a collaboratively logical solution path (e.g. conceptualize soil formation and morphological features of waterlogged Aridisols in a coastal sabkha of Oman)

The pedagogical strategies of our SSC integrate the notions of: (i) Inquiry-Based Learning, (ii) Scaffolding, (iii) Competition of students’ teams, and (iv) Data–information–knowledge–wisdom. The outcome-based learning competencies were evaluated through a robust field evaluation scheme by a multidisciplinary jury of Soil Science faculty. The pros-cons and magnitude of satisfaction of the SSC were investigated through a combination of an online questionnaire sent to registered students and peer-assessment among students conducted by the group leaders. Teaching evaluations, when SSC was first implemented, showed that the course earned a high rating of 3.93/4.0 while the College average for all other courses (about 150/semester) during the same period was 3.16/4.0. The course scored 3.06/4.0 while the College average score was 3.30 before introducing SSC.

The questionnaire-based survey showed that the contest improved various students’ transferable and interpersonal metacognitive skills. Our SSC pedagogy approach is in line with the call towards enriching geoscience students with the skills and competencies necessary to address real-world problems of complex Earth systems.

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Brevik et al. 2015. The Interdisciplinary Nature of Soil. *Soil*, 1(1), 117-129.

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Developments and Open Challenges of Information Model for Global Soil Information System

Prof. Tomas Reznik¹

¹Masaryk University, Brno, Czechia, ²Data Cove, Vienna, Austria, ³European Environmental Agency, Copenhagen, Denmark, ⁴Wageningen University & Research, Wageningen, The Netherlands, ⁵Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Germany, ⁶Wageningen University & Research, Wageningen, The Netherlands, ⁷Masaryk University, Brno, Czechia, ⁸Manaaki Whenua – Landcare Research is the Crown ... <https://www.landcareresearch.co.nz> ⁹Manaaki Whenua – Landcare Research, Lincoln, New Zealand, ¹⁰Wageningen University & Research, Wageningen, The Netherlands, ¹¹Food and Agriculture Organization of the United Nations, Rome, Italy, ¹²Wageningen University & Research, Wageningen, The Netherlands, ¹³Food and Agriculture Organization of the United Nations, , Italy, ¹⁴Manaaki Whenua – Landcare Research, Lincoln, New Zealand, ¹⁵Commonwealth Scientific and Industrial Research Organisation, Canberra, Australia, ¹⁶Poznan Supercomputing and Networking Center, Poznan, Poland, ¹⁷Poznan Supercomputing and Networking Center, Poznan, Poland, ¹⁸Aristotle University of Thessaloniki, Thessaloniki, Greece, ¹⁹Chinese Academy of Sciences, Nanjing, China, ²⁰Ghent University, Ghent, Belgium, ²¹Masaryk University, Brno, Czech Republic, ²²Masaryk University, Brno, Czech Republic, ²³Lesprojekt - sluzby, Martinov, Czech Republic, ²⁴Lesprojekt - sluzby, Martinov, Czech Republic, ²⁵Aristotle University of Thessaloniki, Thessaloniki, Greece

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1, August 4, 2022, 09:30 - 11:30

Our presentation summarises the developments towards an information model that is intended as an exchange mechanism between the Global Soil Information System and third party (soil) information systems. This information model, developed under the auspices of the Food and Agriculture Organization of the United Nations (FAO) and the Global Soil Partnership, (1) follows FAO Guidelines for Soil Description and (2) further evolves concepts originating from ISO 28258:2013 - Soil quality standard, ISO 19156:2011 - Observations and measurements, SOSA-SSN and GeoSPARQL. Previous national and international initiatives were discussed and incorporated where appropriate, e.g. ANZSoilML, INSPIRE, the Open Geospatial Consortium Soil Interoperability Experiment and the Federation of ESIP Soil Ontology and Informatics Cluster. The achievements are publicly available under an open license and presented as a series of UML class diagrams, XML schemas and, thanks to an EU-China research & innovation project, also in the form of a network of OWL ontologies providing the base for the publication of linked data related to soil and land use. Special attention is aimed at open challenges at both levels, technical and organisational.

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Open Geospatial Consortium's Soil Data Interoperability Experiment (OGC Soil IE)

Řezník, T., Schleidt, K., Baritz, R., Bulens, J., Mendes De Jesus, J., Eberhardt, E., Van Elburg, E., Kempen, B., Kozel, J., Medeckyj-Scott, D., Ritchie, A., Sousa, L., Yigini, Y., Van Egmond, F., Whitehead, B., & Wilson, P. (2020). Final report Data Model Development for the Global Soil Information System (GloSIS). 45 p. [A subject of open publishing at the FAO so far].

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Integrating information and inference systems

Dr José Padarian¹, Edward Jones¹, Alex McBratney¹

¹*The University of Sydney*

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1,
August 4, 2022, 09:30 - 11:30

Soil information systems, in their role of storing and distributing soil data, have proven to be an important component of modern soil science research. However, collating and organising data is just a small fraction of the capabilities of a computer system. An inference engine, as part of such system, is capable of using the knowledge extracted from the data to generate new information. Here, we present an implementation of a soil inference system (SPEC-SINFERS) that combines deep learning spectral models with conventional pedotransfer functions as its knowledge base. We share some of the design and implementation experiences and present some examples on how to link SINFERS with a soil inference system.

NA

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On soil data sharing: legal framework and general sharing policies resulting from the investigation done in EJP SOIL H2020 programme

Dr Maria Fantappiè¹, Dr Ginevra Peruginelli², Dr Sara Conti², Dr Stephanie Rennes³, Dr Christine Le Bas³, Dr Fenny van Egmond⁴

¹CREA, Florence, Italy, ²CNR, Sesto Fiorentino, Italy, ³INRAE, Paris, France, ⁴WR, Wageningen, Netherlands

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1, August 4, 2022, 09:30 - 11:30

The objective of the work package 6 of the EJP SOIL programme (<https://ejpsoil.eu/>, 2020-2025, 862695) is to support soil data sharing in Europe, which implies the overcoming of legal constrains. An analysis of EU legal framework was performed, and a questionnaire on soil data ownership and sharing was elaborated and distributed among EJP SOIL partners, and, through them, to relevant stakeholders, external to the consortium. A deliverable (D6.2), in the form of a public report, was elaborated, which consisted in an introduction to the EU legal framework, an analysis of questionnaire results, and a general agreement for soil data sharing. The responses to the questionnaire and the elaboration of the soil data sharing agreement involved the contribution from 62 authors, 32 institutions, of 22 European countries, which are all listed in the D6.2 deliverable. The questionnaire evidenced the lack of specific national transpositional laws in relation to the sharing of soil information, the lack of officially appointed soil officers, and the lack of networking between the soil data owners/holders and the public institutions officially appointed for the INSPIRE implementation. A divergent interest between public and private rights was evidenced, and the D6.2 final agreement suggests general best practices to overcome these constrains: to get the consent from landowners for the open disclosure of point georeferenced soil data, with the only exception given by the data on emissions of pollutants into the environment, to respect the intellectual property rights of authors, and/or an economic payment in case of soil maps.

Fantappiè et al. (to be published). Report on the national and EU regulations on agricultural soil data sharing and national monitoring activities. Deliverable 6.2 of EJP SOIL programme.

1532

Establishment of the Hungarian Soil Spectral Library

Dr Adam Csorba¹, Mohamed Zein¹, Dr Tamás András Szegi¹, Viktória Labancz¹, József Attila Tóth¹, Prof Erika Michéli¹

¹*Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary*

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1, August 4, 2022, 09:30 - 11:30

The focus of our research is the development of the first, middle-infrared (MIR) spectroscopy-based spectral library of Hungary. Our paper presents the first steps in the implementation of the spectral database that is based on soil samples collected from the soil archive of the Hungarian Soil Conservation Information and Monitoring System (SIMS). Diffuse reflectance spectra of ~6400 soil samples were acquired by Bruker Alpha II Fourier Transform Infrared Spectrometer with Diffuse Reflection (DRIFT) accessory in the wavelength range of 2500 – 25000 nm (4000 – 400 cm⁻¹). As reference data for the calibration a wide range of physical and chemical soil parameters were used. Wawire, A.W., Csorba, Á., Kovács, E., Mairura, F.S., Tóth, J.A., Michéli, E. (2021): Comparing farmers' soil fertility knowledge systems and scientific assessment in Upper Eastern Kenya. *Geoderma* 396: 115090

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Soil 'Data-Hyperlooping': An Automated Framework for Curating Soil Data

Tegbaru Gobezie¹, Dr. Asim Biswas¹, Mr. Daniel Saurette²

¹University of Guelph, Guelph, Canada, ²Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Guelph, Canada

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1, August 4, 2022, 09:30 - 11:30

Access to well-harmonised, machine readable quality soil data is most important of scientific investigations into properties and functions of soils and subsequent decision-making. In predictive digital soil mapping, establishing standards to share and make use of different legacy datasets has remain one of the scientific challenges to harmonize and combine soil data (Borůvka et al., 2017). As a result, scientists invest more than two-third of their active time in harmonizing different datasets (Batjes et al., 2019). In addition, time differences between soil sample gathering have not been well-captured in predictive digital soil mapping yet. Thus, understanding the impact of soil data collation from different available and accessible data-sets and/or databases that had been gathered over different periods of time to predict current trends in soil properties necessitates improved methods in the overall data curation processes. Therefore, this study aimed at developing algorithms to embrace different soil data types, sources and age of data while harmonizing using the Konstanz Information Miner (KNIME) and semantic matching process (Pezoulas et al., 2019). Using this framework, soil data from more than seven thousand sites in Ontario were harvested, which could be scaled up at national and global levels.

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Borůvka, L., Penížek, V., Kozák, J., Marhoul, A.M., Vacek, O., Šrámek, V., Žížala, D., Poláková, Š., Smatanová, M., Fiala, P., Penížek, V., Kozák, J., Marhoul, A.M., Vacek, O., Šrámek, V., Žížala, D., Poláková, Š., Smatanová, M., Fiala, P., 2017. Combining and harmonizing soil data from different sources: Problems and approaches [WWW Document]. GlobalSoilMap - Digital Soil Mapping from Country to Globe. <https://doi.org/10.1201/9781351239707-6>

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Computers in Biology and Medicine 107, 270–283.

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EJP SOIL: Working towards a European soil data infrastructure

Msc Fenny van Egmond¹, dr. Maria Fantappiè², Jandirk Bulens¹, Marc van Liedekerke³, Christine le Bas⁴, Clement Lattelais⁴, Rachid Yahiaoui⁴, Katrien Oorts⁵, Giovanni l'Abate², Luis de Sousa⁶, Paul van Genuchten⁶, Linton Donovan⁷

¹Wageningen Environmental Research, Wageningen, Netherlands, ²CREA, Florence, Italy, ³JRC-ESDAC, Ispra, Italy, ⁴CREA, Orleans, France, ⁵Vlaams Planbureau voor omgeving, Brussel, Belgium, ⁶ISRIC - World Soil Information, Wageningen, Netherlands, ⁷Inetum-RealDolmen, Belgium

32 WG1.6: Soil information standards and systems - current initiatives and advances, Alsh 1, August 4, 2022, 09:30 - 11:30

Given the understood importance and increased attention for soil at present, the European Union funded a large H2020 research project, the European Joint Programme on Soil 'Towards climate-smart sustainable management of agricultural soils', EJP SOIL (<https://ejpsoil.eu/>, 2020-2025, N° 862695), with the aims to foster European research collaboration and to advance on all soil related topics. One of the major and cross-cutting topics is soil information availability, standardisation, harmonisation, provision and exchange of soil data. Given the European context, the framework is the INSPIRE directive for information provision. The first aim is to provide generic support and tools to the 26 partners for soil data organisation and soil information system development. The second is to align with global efforts. Work is underway to create reference materials on the terminology and guidance on workflows, develop cookbooks for various implementation options indicating their relative merits, provide training courses, resolve INSPIRE soil issues, create codelists and standardised soil property lists for international soil standards, provide support for countries to create national ones, create an entry-level option to countries to serve data online, provide an access point where systems can link to, and assist with tools for the workflows. This effort happens in collaboration with other project activities on data policies, soil mapping, soil monitoring networks, soil indicators and soil sensors. It also supports the work at the European Commission Joint Research Centre to investigate how data and metadata from EJP SOIL could best be integrated with the European Soil Observatory (launched December 2020).

EJP SOIL D6.1 Report on harmonized procedures for creation of databases and maps

Effects of subsoil injection of ultrafine-grained limestone, peat and urine on geochemistry and crop/root growth in an acid sulfate soil

Dr. Peter Österholm¹, Dr. Eva Högfors-Rönholm², Dr. Pekka Sten³, Dr Miriam Nystrand¹, Dr. Sten Engblom²

¹*Åbo Akademi University, Åbo, Finland*, ²*Novia University of Applied Sciences, Vasa, Finland*, ³*Vaasa University of Applied Sciences, Vasa, Finland*

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Sulfidic sediments drained for agricultural use may develop a deep (up to 1.5 m or more) oxidized well-structured soil profile with pH < 4 (acid sulfate soil) that leach very large quantities of acidity and metals to watercourses. Surface liming or other neutralizing agents can neutralize acidity in the plough layer (0 – 0.4 m) in order to create good growth conditions for crop roots. While this makes these farmlands highly productive, it has no effects on the geochemistry of the deeper soil where the main mobilized acid/metal pool is located, since the neutralizing agents do not penetrate below the plough layer. To overcome this problem, in previous multi-year PRECIKEM- and PRECIKEM2-projects, neutralization agents (including ultrafine-grained limestone) and potential oxidation inhibitors (including ground peat) has on a large field scale (1 ha fields) been injected via subsurface drain pipes (c. 1.3 m deep) to the hydrologically active macropores (most relevant for discharge water) of the subsoil. In this study, we demonstrate a less tedious two-year field-testing approach where “test fields” were substituted by 18 isolated pipes (inner diameter 28 cm) in situ to a depth of 1.9 m and where injections were conducted with vertical injection pipes instead of subsurface drain pipes. Limestone injected at 1.3 m was transported upwards in the soil with subsurface irrigation water and reduced soil acidity. However, none of the treatments reduced water-soluble metals in the soil. Urine injection at 0.7 m had positive effects on crop and doubled the root mass.

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<https://doi.org/10.1016/j.apgeochem.2018.12.005>

Modelling geochemical processes and transport in acid sulfate soils under steady state inflow and variable drainage depths

DSc (in Tech) Heidi Salo¹, Dr Seija Virtanen², Dr Hanne Laine-Kaulio^{3,1}, Prof Harri Koivusalo¹, Dr Teemu Kokkonen¹

¹Aalto University, Espoo, Finland, ²Drainage Foundation sr, Helsinki, Finland, ³Academy of Finland, Helsinki, Finland

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

In Finland, acid sulfate soils have been artificially drained for cultivation practices resulting to oxidation of pyrite and monosulfides which is harmful for the environment. To study the effects of field drainage on the oxidation state, water flow and geochemical processes in an acid sulfate soil profile was modelled by HP1 software (coupled HYDRUS 1D and PHREEQC-3). The objective was to investigate the key processes for geochemical modelling and to estimate how different drainage depths affect the pH and solute concentrations in pore water.

The model was built to describe the geochemical changes in the Söderfjärden agricultural field after open ditches were replaced by subsurface drains (depth ca. 1.2 m, spacing 35–50 m) installed in 1950's. The simulations with two drain depths (1.20 m and 0.60 m) with spacing of 37 m were carried out for the next 100 years with constant inflow describing the mean annual infiltration. The model describes long-term oxidation of pyrite and monosulfide, cation exchange surfaces, and water flow through six hydrologically and geochemically different soil layers.

Deeper drainage led to faster and more efficient oxidation of pyrite and monosulfide compared to more shallow drainage: after 100 years the oxidized profile reached the depth of 1.5 m and 1.0 m with the drainage depths of 1.2 m and 0.6 m, respectively. The model developed here will provide a basis for a field-scale tool for comparing the long-term effects of oxidation processes in acid sulfate soil fields with different drainage methods and in changing climate conditions.

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Seawater inundation induces trace metal mobilisation in freshwater soils: Impact of sea level rise on metal biogeochemistry in coastal environments

Ms Emily Leyden¹, Dr John Hutson, Dr Juraj Farkas, Associate Professor Luke Mosley

¹*The University of Adelaide, Adelaide, Australia*

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Climate change is leading to global sea level rise. As mean sea level increases, frequent storm surges and higher tides will begin to 'pulse' seawater into coastal ecosystems. To examine the effects of the seawater inundation on soil geochemistry, 12 soils from three distinct environments (fresh water streams and lakes, hypersaline saltmarsh and mangroves, and acid sulfate soils) were examined under laboratory conditions. Following inundation by seawater, the five freshwater streams encountered a significant increase in Mn, Fe, As, Cu, Ni, Cd and Co; while Zn and Pb were less mobilised. Concentrations of metals released from studied soils exceeded water quality guidelines to protect aquatic ecosystems in most cases. The hypersaline sites did not respond as strongly, with only slight increases in Mn, Fe, Cd and Ni at some sites. Metal concentrations (Mn, Fe, As, Cu, Ni, Cd & Co) increased in the porewaters of the moderately acidic acid sulfate soil (pH 5.41) following seawater inundation. In contrast, almost all metal species decreased in the porewaters of the strongly acidic acid sulfate soil (pH 2.77), indicating the importance of considering a range of geochemical factors when examining seawater inundation in acid sulfate soils. Two key mechanisms are discussed to account for the release of trace metals from soils following seawater inundation, (1) reductive dissolution of Fe and Mn-oxyhydroxides, and (2) cation exchange competition. This is the first study to examine the impact of seawater intrusion on the concentrations of metals in coastal freshwater soils in the Southern Australian context. Church JA, White NJ. (2006). A 20th century acceleration in global sea-level rise. *Geophysical Research Letters*

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Microbial N₂O production in a peaty acid sulphate soil derived from black schists

Msc Minna Mäkelä¹, PhD Asko Simojoki¹, PhD Sanna Kanerva¹, MSc Kazi Md Jahangir Kabir², Professor Markku Yli-Halla¹

¹University of Helsinki, Helsinki, Finland, ²University of Barisal, Barisal, Bangladesh

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Emission of N₂O and the factors limiting its production were investigated in a cultivated peatland which has an acid sulphate mineral subsoil derived from black schist. Emissions were measured biweekly by dark static chambers on three locations with peat varying in thickness between 15-60 cm overlying the mineral subsoil. The emissions varied greatly with time, with peaks in emission coinciding with spring thaw. Overall, the emissions were notably low compared with typical emissions from both peat and acid sulphate soils. During the emission peaks, the site with the thinnest peat layer and acid sulphate subsoil closest to the soil surface exhibited the largest emissions. Mechanisms controlling the production of N₂O at the site were investigated in laboratory experiments using soil samples from three or four soil horizons. Drainage seemed to increase N₂O production, whereas in wet soil, the production of N₂O in the mineral subsoil was small and the peat horizon was a sink of N₂O. Lowering of temperature from 20 to 5 °C had almost no role in the aerobic N₃O production. Lack of carbon source limited anaerobic N₂O production in the uppermost peat horizon, while in the other horizons, nitrate was the most limiting factor. It is concluded that peatlands with black schist derived acid sulphate subsoil, such as in this study, have high microbial activity and N₂O production in the peaty topsoil but little microbial activity in the mineral subsoil. These findings contradict with previous results obtained in sediment-derived acid sulphate soils.

Mäkelä, M., Kabir, K. M. J., Kanerva, S., Yli-Halla, M., Simojoki, A. 2022. Factors limiting microbial N₂O and CO₂ production in a cultivated peatland overlying an acid sulphate subsoil derived from black schist. *Geoderma* 405.

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Long term effects of groundwater management and subsurface irrigation on the water quality from boreal acid sulfate soil farmland

Dr. Miriam Nystrand¹, Dr. Seija Virtanen², Emeritus Professor Markku Yli-Halla³, Dr. Jaana Uusi-Kämppä⁴, Dr. Kari Ylivainio⁴, Anna Bonde⁵, Associate Professor Peter Österholm¹

¹*Åbo Akademi University, Geology and Mineralogy, Åbo, Finland*, ²*Drainage Foundation sr, Helsinki, Finland*, ³*University of Helsinki, Environmental Soil Sciences, Helsinki, Finland*, ⁴*Natural Resources Institute Finland, , Finland*, ⁵*ELY Centre, South Ostrobothnia, Vasa, Finland*

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Upon drainage, sulfide-bearing sediments oxidize and develop into acid sulfate soils (pH < 4) mobilizing acidity and soluble metals into watercourses with serious environmental consequences. Being among the most productive agricultural soils, there is an urgent need to find economically viable solutions for managing acid sulfate soils in an environmentally sustainable way (Österholm et al, 2015). Options to manage the release of acidic metal-rich drainage waters were examined in 2010-2021 on a boreal acid sulfate soil farmland with controlled subsurface drainage (CD), controlled drainage with subsurface irrigation (CDI) and conventional subsurface drainage (REF). All fields were hydrologically isolated with vertical plastic sheets to prevent bypass flow. In CD and especially in CDI a groundwater level drop into the sulfidic layer was slowed down or prevented during normal weather conditions and without dredging. The groundwater level responded, however, fast to dredging (i.e., dredging of the main drain near the fields) and summer drought, but with sub-irrigation, the groundwater drop into the sulfidic layer could mostly be avoided. During the 11-year period, the drainage water quality improved considerably in all fields, while variations between different treatments were minor in comparison. The improvement may be due to changed water flow path caused by the isolating plastic sheets and/or a depletion of the acid soluble metal reserve after one of the most severe droughts in 2006. Nevertheless, at least with CDI, more reducing conditions were obtained, which was indicated by occasional spikes in dissolved Fe concentrations.

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<https://doi.org/10.1080/09064710.2014.997787>

Mapping of acid sulfate soils in Finland

Mr Jouni Pihlaja¹, Mr Jaakko Auri³, Dr Anton Boman², Mr Stefan Mattbäck², Ms Pauliina Liwata-Kenttälä¹, Mr Hannu Hirvasniemi¹

¹Geological Survey of Finland, Rovaniemi, Finland, ²Geological Survey of Finland, Kokkola, Finland, ³Geological Survey of Finland, Espoo, Finland

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils; Alsh 2, August 4, 2022, 09:30 - 11:30

Acid sulfate soils (ASS) are in Finland defined as soils, sediments (including glacial till), organic material (e.g. peat) containing hypersulfidic materials which upon oxidation, either naturally or during incubation in the laboratory, form sulfuric acid that significantly lowers soil-pH to <4 for mineral soil materials and <3 for organic soil materials.

The sulfidic sediments responsible for ASS formation have been depositing after the latest deglaciation in parts of the Baltic Sea particularly during the Littorina Sea (c. 8000–3000 years ago) and today continuing in shallow coastal waters. Post-glacial isostatic uplift has brought these sediments above sea level. In Finland, ASS are disturbed in agriculture, forestry, peat production, dredging and infrastructure developments.

Aiming to develop mitigation and adaptation dealing with the problems caused by ASS, Geological Survey of Finland (GTK) did systematic mapping and characterization of ASS during 2009-2020. During the mapping process, total potential ca. 5 million hectares has been studied. 23 000 observation points (observation density c. 0.5/km²; Fig 1.) and 10 000 chemical analyses and 40 000 incubation analyses have been made. The overview mapping was finished during the summer of 2020 and based on the data it can be concluded that there exists about 1 million ha of ASS in Finland. The results from the mapping (incl. probability maps, site descriptions and analyses) are made public at <http://gtkdata.gtk.fi/Hasu/index.html>.

Palko, J. 1994. Acid sulphate soils and their agricultural and environmental problems in Finland. PhD Thesis, University of Oulu, Finland. 58 p.

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Response of nitrous oxide and carbon dioxide production to liming in different horizons of boreal acid sulfate soil

Dr. Asko Simojoki¹, Ms. Chang Xu², Dr. Vanessa, N.L. Wong², Ms. Anna Tuovinen¹

¹*Department of Agricultural Sciences, University of Helsinki, Helsinki, Finland,* ²*School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia*

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Organic rich topsoil and subsoil horizons with variable acidity and moisture conditions and interconnected reactions of sulfur and nitrogen make acid sulfate (AS) soils potential sources of greenhouse gases (GHGs). Liming of subsoil can reduce the acidification of sulfidic subsoils in the field but the response of GHG production to liming in different horizons of AS subsoils is poorly known. For this reason, we added increasing amounts of calcite (0, 12.5 or 25 mg/g) to samples from different AS horizons to study the effects of lime on N₂O and CO₂ production at 70% water-filled pore space during a 56-day oxic incubation and a subsequent 72-hr anoxic incubation in the laboratory. Liming to pH ≥ 7 decreased oxic N₂O production by 97-98% in Ap1 horizon, 38-50% in Bg1 horizon, and 34-36% in BC horizon, but increased it by 136-208% in C horizon, respectively. Liming lowered the N₂O/(N₂O+N₂) product ratio of denitrification in all horizons. Nevertheless, liming decreased anoxic N₂O production by 86-94% and 78-91% only in Ap1 and Bg1 horizons, but increased it by 100-500% and 50-162% in BC and C horizons, respectively. Overall, liming reduced the proportion of N₂O in GHGs in most horizons under oxic and anoxic conditions but reduced the total GHG production as CO₂ equivalents only in Ap1 horizon. The results suggest that liming of subsoil would not effectively mitigate GHG emissions in the field due to concurrently increased CO₂ production and denitrification.

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From sulfidic sediment to acid sulfate soil: novel results from a microbiological perspective

Dr Eva Högfors-Rönholm¹, Dr Daniel Lundin², Mr Diego Brambilla², Dr Stephan Christel², Mr Tom Lillhonga¹, Dr Sten Engblom¹, Dr. Peter Österholm³, Professor Mark Dopson²

¹Novia University of Applied Sciences, Vaasa, Finland, ²Linnaeus University, Kalmar, Sweden, ³Åbo Akademi University, Turku, Finland

38 WG3.1: Acid sulfate soils, sulfidic materials and wetland soils:, Alsh 2, August 4, 2022, 09:30 - 11:30

Geochemical reactions that occur in acid sulfate soils (ASS) have largely been elucidated. In contrast, the microbial population structure is only beginning to be understood. In this study, we aimed to take advantage of 'multi-omics' and geochemical data to gain insights into the metabolic landscape and the molecular mechanisms underlying microbial life in this extreme environment.

Soil samples were collected from a depth profile of an acidic oxidized boreal ASS, the transition zone that has a steep pH gradient from acidic to near neutral, and the pH neutral parent sulfidic sediment in Vaasa, Finland. The study used 16S rRNA gene amplicons (DNA), metagenomes (DNA), and metatranscriptomes (RNA) to investigate the microbial community structure, metabolic potential, and activity in the three soil types. Complementary geochemical data (pH, EC, redox, Fe- and S-speciation, multi-elements) was collected at the same time and used in microbial data interpretations.

The assembled genomes along with RNA transcript based activity data clearly demonstrated partitions in the sulfidic sediment, transition zone, and ASS communities including many poorly characterized taxa not previously identified in ASS or acid mine drainage communities.

Prominent populations in the three soil zones included Candidate Caldatribacteriota in the sulfidic sediment, iron and sulfur oxidizing Proteobacteria in the transition zone, and uncharacterized Gammaproteobacteria in the oxidized zone. In conclusion, we present a comprehensive study of the conversion of potential to actual ASS and establish the importance of novel taxa. Models of metabolic processes furthermore summarize the biogeochemical reactions occurring in the different zones.

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Exploring the environmental implications of micro- and nano-plastic debris on agricultural soils

Dr Charlotte Chivers¹, Professor Julie Ingram¹, Dr Jane Mills¹, Mr Nicolas Beriot², Prof Violette Geissen², Prof Esperanza Huerta Lwanga²

¹University Of Gloucestershire, Gloucestershire, United Kingdom, ²Wageningen University & Research, The Netherlands

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Plastics are ubiquitous in our environment. Whilst several studies have identified the environmental risks posed by plastic debris in aquatic environments, there have been fewer studies exploring the environmental health risks associated with the micro- and nano-plastic debris present in agricultural soils. This is despite their widespread use in agriculture, both intentional (e.g., plastic-based mulches, bale wrap) and unintentional (degradation of machinery). MINAGRIS, an EU-funded Horizon 2020 project, is investigating the impacts of micro- and nano-plastics present in agricultural soils on biodiversity, plant productivity and ecosystem services and their transport and degradation in the environment. This will be achieved by conducting multidisciplinary research in 11 case study sites across Europe. Here, we will introduce plastics as a potential source of land contamination and degradation resulting from both intentional use of plastic-containing materials and unintentional sources, drawing on existing evidence and preliminary findings from the project. We will then comment on the extent to which land managers are being provided with advice and information surrounding ways of transitioning away from reliance on plastics. We will present findings from interviews with farmers and experts alongside an inventory of existing extension efforts to describe the current use of advice surrounding agricultural plastic use across Europe and identify future knowledge and support needs. We will also explore the extent of plastic reliance in agriculture and determine whether farmers are experimenting with alternatives or plan to do so in the future.

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Using of Vis-NIR and FTIR spectroscopy to identify microplastics in biosolids produced in New York City

Dr Luana Circelli^{1,2,3}, Prof. Zhongqi Cheng^{3,4}, Dr. Evan Garwood³, Dr Kerem Yuksel³, Dr Jennifer McDonnell⁵, Dr Erika Di Iorio², Prof. Ruggero Angelico², Prof. Claudio Colombo²

¹Research Centre for Agricultural Policies and Bioeconomy, Council For Agricultural Research And Agricultural Economy Analysis, Rome, Italy, ²Department of Agricultural, Environmental and Food Sciences, University of Molise, Campobasso, Italy, ³Environmental Sciences Analytical Center, Brooklyn College of the City University of New York, New York, USA, ⁴Graduate Center and Advanced Science Research Center of the City University of New York, New York, USA, ⁵New York City Department of Environmental Protection, New York, USA

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Biosolids, processed from sewage sludge in wastewater treatment plants (WWTPs), are recently considered as source of microplastic (MP) pollution in soil, due to widespread land application as organic amendments. Once in the soil, MPs undergo a continuous and unpredictable change in size and degree of aggregation, negatively affecting micro and macrobiota and soil biomass. Moreover, the standard separation methods of MPs from biosolids or soils are very few, laborious and time consuming. Here, we propose a spectroscopic and chemometric approach to identify the MPs in the biosolid samples produced in six WWTPs of New York City. Prior to spectral analysis, biosolids have been subjected to wet sieving procedure to separate plastic debris >2 mm in size, which made up about 0.04% of each sample. MPs <2 mm were separated according to H₂O₂ oxidation procedure. Both MPs fractions were analyzed by Vis-NIR (200-2500 nm) and FTIR (2500-25000 nm) techniques with the chemometric multivariate analysis after spectra preprocessing. The principal component analysis allowed to obtain an interpretable overview of the main information from Vis-NIR and FTIR spectra and was able to discriminate the MPs samples, by comparing them with several plastic samples as reference. From a first qualitative evaluation, the analyzed MPs were found to be mainly composed of high and low density polyethylene (LDPE and HDPE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS) and polyamide (PA) fibers. Further tests are needed to consolidate the ability of the proposed method to identify and quantify MPs in biosolids samples.

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Toluene biodegrading microbial communities associated with soil and roots of a poplar phytoremediation system in an urban landscape

Prof Kari Dunfield¹, Dr. Eduardo Mitter¹, Dr Elizabeth Haack², Dr David Tsao³, Kamini Khosla¹, Prof Beth Parker¹

¹University of Guelph, Guelph, Canada, ²EcoMetrix Inc, Mississauga, Canada, ³BP Corporation North America Inc., Naperville, United States

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Phytoremediation is a sustainable and eco-friendly technology for the recovery of contaminated lands. However, evaluating the efficacy of these systems is particularly challenging due to the complexity of plant–microbe interactions and biodegradation mechanisms. This study was carried out at a manufacturing facility in a mixed residential/industrial neighborhood in urban South-Western Ontario, Canada with historic toluene subsurface impacts to a fractured bedrock aquifer system. A 51-tree hybrid poplar (*Populus deltoides* × *nigra* OP-367) phytoremediation stand was planted at the site in 2008 as a remediation and containment strategy. In 2020, we harvested 4 trees and their accompanying root systems in an effort to evaluate root-associated and toluene-degrading microbial community structure of bulk soil, rhizosphere and endosphere communities. Using high-throughput sequencing and quantitative PCR, we detected differences in all microbial communities, associated with historical toluene groundwater levels at the site. For example, biodegradation activity (i.e., aerobic and anaerobic toluene degradation gene expression) was significantly greater on highly impacted soils at shallow depths (0- 80 cm). In these soils, transcripts for Benzylsuccinate synthase alpha subunit (BssA) and phenol hydroxylases (PHE) were 20 and 30% higher, respectively, when compared to low impacted areas. Moreover, poplar trees were highly selective for *Pseudomonas* spp., which corresponded to nearly 78% of endophytic bacteria and mostly of *Pseudomonas putida*. Similarly, fungal communities in the endosphere were predominantly colonized by Ascomycota while restrictive of Rozellomycota and Mortierellomycota. Together, these results will offer new insights for industries and regulators to further develop rapid and effective phytoremediation monitoring strategies.

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Presence of antibiotics in sludge from wastewater treatment plants and amended soils and crops

Dr Ana Barreiro¹, Msc Raquel Cela-. Dablanca¹, Msc Lucía Rodríguez-López², Professor Manuel Arias-Estévez², Dr María Josefa Fernández-Sanjurjo¹, Dr Avelino Núñez-Delgado¹, Professor Esperanza Álvarez-Rodríguez¹

¹University of Santiago de Compostela, Lugo, Spain, ²University of Vigo, Ourense, Spain

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

The elevated use of antibiotics worldwide ((Wang and Tang, 2010) triggers the accumulation of these substances in the sludge from wastewater treatment plants (WWTP) and the possible contamination of soils amended with it, as well as of crops growing in those soils. In this research we analysed the presence of antibiotics in sludge from different WWTP in Galicia (NW Spain), in sludge composted by waste managers, and in soils where the composted sludge was applied, as well as in crops (corn, vineyard) growing on it. The antibiotics were quantified by means of HPLC-MS/MS. The results indicate that almost all the sludge samples presented some type of antibiotic, but the most abundant ones were ciprofloxacin and levofloxacin with maximum values 623 ng/g and 893 ng/g, respectively. The sludge treatment reduced significantly the number and the amount of antibiotics present. In the soils where sludge was applied, some antibiotic was detected in small amounts, but just in 17% of the samples. Regarding the crops, no antibiotic was detected in the roots, stalk, leaves and grain of corn, neither in the grapes sampled in vineyards. We can conclude that the treatments currently applied in the WWTP under study are not totally effective in removing antibiotics from the sludge, although our findings suggest that the additional specific treatment of the sludge derived from these WWTP is effective in reducing the risk of environmental pollution due to antibiotics, and specifically in the case of soils amended with these organic materials and crops growing on it.

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Characterization and quantification of microplastics on agricultural fields amended with municipal compost.

Miss Jordan Grigg¹, Dr. James Longstaffe¹, Dr. Adam Gillespie¹

¹*University Of Guelph, Guelph, Canada*

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Significant concern has been raised both in the scientific community and the general public about the environmental effects of microplastics (1). Most research in the field of microplastics has been conducted in aquatic ecosystems; however, there is growing concern about the implication of microplastics in terrestrial systems. In the Canadian province of Ontario, the Ontario Compost Standards allow for up to 0.5% plastic by weight in finished compost products, which are often applied to agricultural land as an organic amendment. As compost is usually applied at high rates and over multiple years, this represents a significant potential source of plastic contamination to agroecosystems.

For this project, topsoil was sampled from 10 compost-amended fields in southern Ontario, focused on the Lake Simcoe watershed. Two methods of microplastic extraction were compared; density flotation and comestible oil extraction. Microplastic composition and bond structure were determined using Fourier transformed infrared spectroscopy to determine plastic types and if plastic structure was altered during the composting process. This research will help to quantify the amount of microplastic loading as well as monitoring the dynamics of plastics as they undergo commercial composting processes. These findings will help policy makers, compost facility operators and farmers in determining how best to use compost as a valuable resource for agricultural production and soil health promotion.

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Spatial variation of organic pollutants in French soils

Mrs Claire Froger¹, Dr Nicolas P.A. Saby¹, Dr Claudy Jolivet¹, Mrs Line Boulonne¹, Dr Giovanni Caria³, Dr Xavier Freulon², Dr Chantal de Fouquet², Mrs H  l  ne Roussel⁴, Mr Franck Marot⁴, Dr Antonio Bispo¹

¹INRAE Infosol, 45075 Orl  ans, France, ²MINES ParisTech, Centre de G  osciences, 35 Rue Saint-Honor  , France, ³INRAE US 0010 Laboratoire d'analyses des sols, 273 Rue de Cambrai, France, ⁴ADEME International, 20 Ave Gresille, France

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Anthropogenic activities have led to the release of multiple organic contaminants including polycyclic aromatic hydrocarbons (i.e. PAHs), massively released during the golden age of heavy industries in the 1950's or more recently released pollutants such as polychlorinated biphenyls (i.e. PCBs). The ubiquity of those pollutants associated resulted in the long-term contamination of all environmental compartments including soil. The characterizations of the spatial variation of those contaminants at a national scale contribute to the production of background values for policies and soil pollution assessment as well as risk assessment. Several organic contaminants including PAHs and PCBs were measured in the 2154 soil samples collected from 2001 to 2010 by the French Soil Quality Monitoring Network (Arrouays et al., 2002). The sum of 15PAHs were mapped relying on non linear geostatistical approach and showed a clear pattern among the territory with higher PAHs in soils of the North-Eastern part of France resulting in higher risk for local population. The PAH molecular ratios identified PAHs contamination as legacy contamination from the emissions linked to the industrialisation of Europe that started in 1850. The same work done with PCBs underlined a different pattern with highest values in the Parisian conurbation known for its high density of industries. However, a distinct pattern between light and heavy PCBs revealed by PCA suggested two main origins of those molecules in soils interpreted as regional deposition over Europe and local contamination by industries.

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Circular urban land-use: Bringing brownfields back in use as Urban Greenspaces (UGS) by integrating Nature-Based Solutions (NBS)

Ms Shaswati Chowdhury¹, Jenny Norrman¹, Mr Paul Drenning¹, Ms Yevheniya Volchko¹

¹*Chalmers University of Technology, Gothenburg, Sweden*

Interdivisional 10 - Land contamination and degradation, including Urban Land:, Lomond Auditorium, August 4, 2022, 13:00 - 15:00

Circular Economy (CE) takes place in a loop where non-renewable resources are in circular movements within a system of production and consumption while shifting promoting resources from a bio-based origin. Soil and land can be considered a non-renewable resource due to its extremely slow formation and recovery processes as well as providing the surface for sourcing bio-based resource input in the CE systems. A 'Circular Urban Land-use' concept (Chowdhury, 2020, p. 9) is proposed where brownfields i.e., contaminated and potentially contaminated land, can be considered as a resource in transition from abandonment to redevelopment and reuse. Brownfields can be transformed into Urban Greenspaces (UGS) to foster a bio-based circular economy in urban areas. UGS can also be potentially combined with Nature-based solutions (NBS) to manage the contamination risk and ensure a more sustainable transition of the brownfields. Gentle remediation methods are such NBS for low-cost, long-term methods without negative secondary impacts with potential to manage risks and improve soil ecology. This contribution intends to present recent research outputs to assess the feasibility of UGS opportunities on brownfields across different time frames and we discuss the scope of interpreting the numerous ecosystem services provided by the UGS as bio-based products in an urban context (Chowdhury et al., 2020). Possibilities of combining GRO with UGS to support phytomanagement strategies at brownfields are also explored (Drenning et al., 2022). The contribution also intends to outline ongoing work on stakeholder engagement and development of a comprehensive work procedure for facilitating brownfield to greenspace transformation.

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Investigating the link between soil water repellency and biological soil crust surface dynamics upon wetting

Dr. Vincent J. M. N. L. Felde¹, MSc Lennart Hinz², BSc Lucas Freudenthal¹, Dr. Susanne Woche¹, Dr. Emilio Rodriguez-Caballero³, Dr. Shubin Lan⁴, Prof. Dr. Eduard Reithmeier², Prof. Dr. Stephan Peth¹
¹Leibniz University Hannover, Institute of Soil Science, Soil Biophysics Group, Hanover, Germany, ²Leibniz University Hannover, Institute of Measurement and Automatic Control, Hanover, Germany, ³University of Almeria, Department of Agronomy, Almeria, Spain, ⁴Chinese Academy of Sciences, Institute of Hydroecology, Wuhan, PR of China

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

Biocrusts are topsoil microbial communities that are estimated to cover > 10 % of the global land surface. They play key roles in ecosystem functioning by increasing soil stability and reducing erosion. In drylands, one of their most important functions is the regulation of hydrological processes, such as water infiltration and redistribution via run-off. This strongly depends on their surface properties. Depending on many factors such as organismal composition, biocrusts exhibit strong differences in microtopography, which affects, among others, the connectivity of pathways for surface run-off and ultimately controls soil erosion. While the connection between biocrust development and microtopography has been well documented, little is known about the dynamics of biocrust surface properties, especially in relation to hydrophobicity. To investigate the link between wettability and differential surface swelling after wetting, we scanned different biocrusts from study sites in Spain and China before and after a wetting event. High-resolution 3D data of the biocrust surfaces was obtained with a structured-light 3D scanner (80 µm resolution). Since especially in hydrophobic soils, swelling of the surface may only occur once the hydrophobicity was overcome, we repeated the scans 10 times in 3 min intervals. Point measurements of contact angles were interpolated via Kriging to relate them with changes in biocrust microtopography. Most of the changes occurred directly after wetting, i.e. during the first 3-6 minutes and differences between wettability and changes in surface microtopography were strongly related to crust type and study site. Implications for water redistribution and erosion control are discussed. Rodriguez-Caballero, Emilio, Jayne Belnap, Burkhard Büdel, Paul J. Crutzen, Meinrat O. Andreae, Ulrich Pöschl, und Bettina Weber. „Dryland Photoautotrophic Soil Surface Communities Endangered by Global Change“. *Nature Geoscience*, 26. Februar 2018.

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Organic matter induced soil structure formation generates distinct architectural features at the microscale

Dr. Franziska B. Bucka¹, Dr. Steffen A. Schweizer¹, B.Sc. Anne Böhm¹, Dr. Carmen Höschen¹, Prof. Dr. Ingrid Kögel-Knabner^{1,2}

¹Soil Science, Technical University of Munich, Freising, Germany, ²Institute for Advanced Study, Technical University of Munich, Freising, Germany

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

To understand the complex process of soil structure formation, it is necessary to explore the spatial interaction of organic matter (OM) and mineral particles. We used a short-term lab incubation experiment with artificial model soils to produce soil aggregates, formed in presence of a distinct OM residue. The mineral mixture, consisting of quartz grains, clay minerals and goethite particles, was designed to mimic an arable Cambisol with sandy loam texture. The OM was either present as plant litter (POM; 0.63-2 mm), or bacterial necromass (*Bacillus subtilis*), and there was a control without OM addition.

Both OM residues were able to induce water-stable aggregates, which were stabilized by some small and distinct glue spots of OM occupying <17% of the mineral surface area in the soils. Mineral-mineral interactions (N₂-BET) accounted for the majority of the surface interactions, but did not induce large water-stable aggregates.

A combined approach of fluorescence microscopy and nanoscale secondary ion mass spectrometry (NanoSIMS) was used to map and quantify the aggregate architecture, bacterial colonization, and OM distribution using thin sections of isolated, resin-embedded aggregates.

The obtained images show that goethite-rich, fine particle coatings allowed the incorporation of large sand grains into the formed aggregates. The size and shape of the distinct OM residues defined the local size and spatial pattern of the OM gluing spots within the aggregates. The bacterial necromass induced numerous, small OM spots, whereas the larger POM pieces built few, but larger connecting bridges within the mineral matrix.

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Functional habitat connectivity in soils: more than just pore sizes

Dr Xavier Portell Canal¹, Prof Ruth Falconer², Dr Valérie Pot³, Prof Wilfred Otten¹

¹Cranfield University, Cranfield, United Kingdom, ²Abertay University, Dundee, United Kingdom, ³INRAE, Thiverval-Grignon, France

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

Activity of the microorganisms involved in decomposition of soil organic matter takes place within the complexity of soil. Soil structure determines how microorganisms and the physical environment they inhabit are interconnected. Connectivity between habitats is often considered a driver for diversity both above and below ground (e.g., Carson et al. 2010). However, when a function is affected by multiple processes, such is the case of C dynamics in soil, the question of what constitutes a connected habitat and how this affects soil processes is more complicated than the simple consideration of connected pore space.

For fungal mediated processes, we introduce functional habitat connectivity as determined by physical, chemical and biological characteristics, namely: (i) the total volume of the connected pore space; (ii) the connected air-filled pore volume, through which fungal spread predominantly occurs, (iii) the connected water phase volume, through which dissolved C diffuses, (iv) the distribution of particulate organic matter that fuels fungal growth, and (v) biological traits such as those enabling translocation through fungal hyphal networks.

Full understanding how these multiple characteristics affect connectivity within soil and the outcome of processes can only be understood by models. We present a mechanistic pore-scale model for the effect of habitat connectivity on microbial growth and CO₂ evolution. We demonstrate how various aspects of habitat connectivity differentially impact on two contrasting fungal species, representing R and K strategists. The results redefine our understanding of connectivity in soil and allow us to understand how habitat connectivity will select for fungal traits.

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Experimenting hydraulic fatigue of soil biopores

Mrs Nermine Marzouki¹, **Narmine MARZOUGUI**

¹Ird, France

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

The objective of the 3xSWM project is to develop a non-destructive test to evaluate the sustainability of water flow phenomena in biopores in intermediate (B) horizons of soils. The hypothesis to be tested through the project is that in a B horizon, soil texture exerts a control on the stability of earthworm galleries. The stability of the galleries will be characterized by means of a hydraulic test of vertical absorption-infiltration from the upper surface of a column of a soil analog of manufactured texture, including a permanent saturated zone at the base, by declining the test on a gradient of textures and by respecting a precise schedule of conditions. The stability approach will consist in detecting the failure of a gallery by inducing it by fatigue by means of a non-destructive hydraulic solicitation. This hydromechanical approach will be put at the service of an ecological problem, that of the durability of earthworm galleries. The questions addressed answer the call for proposals through the study of an elementary process, the instability of biopores in the soil, which intervenes in the critical zone, especially in the dynamics of water and the reactivity of the water-soil-organism system, with an innovation in the tools of exploration of biopores in situ. The 3xSWM project, complementary to the team's activity in this field (Jouquet et al., 2012; Capowiez et al., 2021), will be a further step in the understanding of the hydrostructural behavior of soil analogues, which will be applicable to real soils in general. Jouquet P, Huchet G, Bottinelli N, Doan TT, Duc TT (2012). Does the influence of earthworms on water infiltration nitrogen leaching and soil respiration depend on the initial BD ? A mesocosm experiment with the endogeic species *Metaphire posthuma*. *Biol. Fertil. Soils* 48 : 561-567.

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Modelling the interactions between soil structure, carbon cycling, hydrological processes and crop production

Dr. Nicholas Jarvis¹, Dr. Katharina Meurer¹

¹*Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden*

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

Models of soil organic matter (SOM) storage and turnover are useful tools to analyze the effects of soil and crop management practices and climate change on soil organic carbon stocks. The aggregated structure of soil is known to protect SOM from decomposition, and thus influence the potential for long-term sequestration. In turn, the turnover and storage of SOM affects soil aggregation, physical and hydraulic properties and the productive capacity of soil. These two-way interactions have not yet been explicitly considered in modelling approaches. Here, we present a new model of the dynamic feedbacks between SOM storage, soil structure and soil physical and hydraulic properties (e.g. porosity, bulk density, pore size distribution, soil water retention and profile thickness). We show the results of a preliminary test using measurements of bulk density, SOM, soil water retention and soil surface elevation, made during 63 years in a field trial at Uppsala (Sweden) in three treatments with contrasting inputs of OM (bare fallow, animal and green manure). The results suggest that it should be worthwhile to incorporate our model approach into more comprehensive models of the soil-crop system that also include descriptions of soil hydrological processes and crop growth. Such a model should prove useful in analyses of, for example, the rates and potential for carbon sequestration and soil recovery under land use and climate change. To illustrate this, we will present a "toy" soil-plant model developed for demonstration purposes, together with the results of some preliminary scenario simulations. Meurer, K., Chenu, C., Coucheney, E., Herrmann, A., Keller, T., Kätterer, T., Nimblad Svensson, D. & Jarvis, N. (2020a). Modelling dynamic interactions between soil structure and the storage and turnover of soil organic matter. *Biogeosciences*, 17, 5025-5042.

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1514

Soil structure of peat and its role in ecosystem functioning

Dr. Haojie Liu¹, Dr. Fereidoun Rezanezhad², Dr. Bernd Lennartz¹

¹University of Rostock, Rostock, Germany, ²University of Waterloo, Waterloo, Canada

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

The soil structure of peat determines water flow and solute transport patterns, and regulates the carbon cycles in peatlands. Compared with mineral soils, our understanding of the soil structure of peat is limited, especially its role in the ecosystem functioning. In the past years, both laboratory and field experiments as well as meta study were conducted to investigate the role of peat structure on water storage and biogeochemical processes. We found that the soil structure of peat is closely related to the degradation stage of the peat. In natural peatlands, the soil pore structure is dominated by a large proportion of interconnected macropores and peatland drainage substantially decreases the macroporosity and thereby the hydraulic conductivity. The soil structure of drained peat is not static but also undergoes continuous changes due to biotic and abiotic drivers (e.g., freeze-thaw cycles, FTCs). The results of our recent study show that the saturated hydraulic conductivity (Ks) of peat generally decrease with increasing FTC and the maximum changes in Ks (50% reduction) occurred after few successive FTCs. Peatland drainage not only changes the soil structure of peat but also the ecosystem functions (e.g., water storage). We estimated that the conversion of pristine peatlands into agricultural land in Germany resulted in a water storage loss of approximately 20.3 km³. In conclusion, the soil structure of peat plays an important role in peatland ecosystem services in terms of water storage capacity and conductance and more research is needed to uncover its role in carbon and nutrient cycling.

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The soil structure - soil organic carbon interaction as controlled by agricultural management

Dr Andy Gregory¹, Dr Chris Watts¹, Dr Xiaoxian Zhang¹, Dr Andy Macdonald¹, Dr Andy Neal², Dr Marc Redmile-Gordon³

¹Rothamsted Research, Harpenden, United Kingdom, ²Rothamsted Research, North Wyke, United Kingdom, ³Royal Horticultural Society, Wisley, United Kingdom

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure - Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 13:00 - 15:00

Soil structure and soil organic carbon (SOC) have a symbiotic relationship: soil structure is, in part, created and stabilised by SOC components, and SOC can be sequestered in stabilised aggregates, or can turn over in a well-structured soil to support beneficial soil functions. In agricultural systems, soil structure and SOC are controlled by management.

We present the findings of past and current research that have examined the soil structure–SOC interaction on well-characterised long-term agricultural experiments in a temperate region. We show that extreme changes between annually-cultivated arable management and perennial uncultivated grassland management have a significant impact on SOC content and soil structure, including a range of properties controlled by soil structure such as aggregate stability and the ability to retain and transmit water. Such management changes can result in subtle differences in the spatial distribution of SOC within a structured soil. We also show that even within long-term arable systems, differences in inorganic fertiliser management can have small effects on SOC content that are manifest in disproportionately greater effects on soil structure-controlled properties. This relates to the general acceptance that certain components of SOC are more important than total SOC per se in their effect on soil structure.

Future research should exploit developing methodologies in the non-destructive characterisation of soil structure and the biochemical characterisation of SOC to close knowledge gaps on the mechanisms that control the soil structure–SOC interaction so that future agricultural management interventions may address soil health, food security and climate change challenges.

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Will root biomass degrade faster in deep soil under +4°C in temperate forests? Lessons from a long-term field incubation experiment

Binyan Sun¹, Cyrill Zosso¹, PD Dr. Guido Wiesenberg¹, Dr. Margaret Torn², Prof. Dr. Michael Schmidt¹

¹The University of Zurich, Zurich, Switzerland, ²Lawrence Berkeley National Laboratory, Berkeley, USA

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Climate models suggest 4°C warming until 2100, which could accelerate soil carbon loss, greenhouse gas release, and thus promote global warming. Despite low carbon concentrations, subsoils (> 30 cm) store more than half of the total global soil carbon stocks. Retaining this is crucial to mitigate soil carbon greenhouse gas release. However, how deep soil carbon will respond to warming and how increased root-derived carbon could contribute to carbon stabilization in subsoils is under-studied and largely unknown. We aim to i) quantify the decomposition rate of root-litter at different depths with 4°C warming, ii) assess whether there is a difference in the rate of decomposition between various plant polymers, iii) identify decomposition products remaining after three years of incubation.

In a multi-year field experiment in a temperate forest, ¹³C labelled root-litter has been added at different soil depths (10-14, 45-49, 85-89 cm) and removed after three years of field incubation. So far, we measured bulk soil carbon concentrations and $\delta^{13}\text{C}$ -composition of individual microbial biomarkers (PLFA).

Results confirm that bulk carbon concentrations and $\delta^{13}\text{C}$ values follow typical depth trends, except for the three horizons containing ¹³C labelled root-litter incubations. Next, we will quantify various biomarkers for microbial and plant biomass, above- and below-ground biomass and determine compound-specific ¹³C-composition in each molecular fraction in heated and control plots. We suspect that the presumably difficult to degrade compounds (cutin, suberin, and lignin polymers) will degrade slower than bulk organic matter over the observation period, and likely faster in heated than control plots.

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Microbial carbon use efficiency as affected by land use conversion from boreal forest to agricultural land

MSc Julia Schroeder¹, MSc Tino Peplau¹, Prof Dr Christoph C. Tebbe², PD Dr Christopher Poeplau¹

¹Thünen Institute of Climate-Smart Agriculture, Braunschweig, Germany, ²Thünen Institute of Biodiversity, Braunschweig, Germany

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Due to climate change, it is likely that agriculture expands towards north. It is unknown how cultivation affects the dynamics of soil organic carbon (SOC) in the cold and nutrient limited soil of subarctic regions. Studying parameters of microbial metabolism, such as the microbial carbon use efficiency (CUE), provides valuable information on how land use change is affecting SOC dynamics. Here, we investigated if land use conversion affects CUE and whether stoichiometry, soil texture, soil pH and the relative abundance of bacteria, archaea and fungi influence CUE. In addition, we studied whether potential shifts in CUE with warming or N-addition depend on land use type. We quantified microbial CUE by the ¹⁸O-labelling method and relative abundances of domains by qPCR of 19 forest, 14 grassland and 16 cropland soils from 19 farms distributed over the main centres of agricultural activity in the Yukon, Canada. First results show that CUE significantly increased under agricultural use. CUE was strongly positively correlated to soil pH ($p < 0.001$). Further results on CUE and community abundance will also be presented. Microbial response to + 10°C warming or N-addition were assessed in an additional incubation experiment. Unexpectedly, short-term warming increased CUE (+ 30 %), and N-addition reduced CUE (- 7 %). Microbial growth was the major driver of CUE response to treatments. Rather than land use type, site-specific parameters were driving the warming response of microbial metabolism. Whereas, growth response to N-addition was depending on the prevailing relative abundances of fungi and bacteria.

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Differential response of carbon, nitrogen and phosphorus pools after conversion from native forest to exotic plantation in soils of contrasting origin.

PhD Felipe Aburto^{1,2}, Mr Oscar Crovo², Ms Pamela Castillo², Mr Alejandro Atenas², Ms Maria Fernanda Albornoz²

¹Department of Soil & Crop Sciences, Texas A&M University, College Station, USA, ²Universidad de Concepción, Concepción, Chile.

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Even though there is a significant number of studies that highlighted the effects of forest substitution on C sequestration, the role of soil in the impact on ecological stoichiometry and biogeochemical cycling has not been well assessed. The sites considered in this study encompass the main forest soil types found in south central Chile representing a range of soil properties and mineralogy (crystalline to amorphous ash derived soils). To reduce confounding factors due to site history, we exclusively selected pair sampling sites (native versus plantation) that shared a similar land-use history and had close to identical soil and geomorphic conditions in which two independent plots were established at adjacent Native Forests (NF) and Pine Plantations (PL). We determined the C:N:P inventories of the whole ecosystem (Aboveground and belowground pools) alongside the principal ecosystem C input and output fluxes such as Litterfall, litter decomposition, root input, CO₂ efflux and nutrient loss by percolation (DOC/DON).

Overall, total ecosystem C was significantly higher ($p < 0.05$) in NF. NF has significantly higher C inputs by roots ($p < 0.05$) while PL showed higher litterfall and litter accumulation although not significant. NF showed higher losses by CO₂ efflux, while PL showed higher losses by DOC.

When comparing each soil type individually, disregarding forest type, the Young Ash soil displayed significantly higher C and N than all the other studied soils. On the contrary, the Recent Ash soil displays changes in the C:N:P stoichiometry. Our result indicates that contrasting soils plays a major role in the ecosystem biogeochemical pools alterations.

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Linking roots to soil carbon: methods, data and models

Dr. Avni Malhotra¹

¹*University Of Zurich, Zurich, Switzerland*

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Root-derived carbon inputs are more likely to be stabilized as soil organic matter (SOM) than aboveground inputs (1). Roots also often respond faster to abiotic change than their aboveground counterparts (2). Yet our understanding of root trait linkages to SOM and their responses to abiotic change is limited, in part, due to historically limited belowground data. Recent efforts synthesizing root trait and soil data across observational gradients and global change experiments make it increasingly possible to harmonize these data towards improved conceptual understanding and terrestrial biosphere model (TBM) representation (3). I will summarize results from three working groups focused on linking roots and soil carbon on regional to global scales. First, we evaluate how well current methods measure and detect global change responses in root-derived organic matter. Second, we review processes that bridge root traits to SOM formation and stabilization, detail their current TBM representation and suggest future model improvements (4). Lastly, we provide examples where harmonized root and soil data can be used to understand mechanisms of root-carbon stabilization into soils and variation across abiotic gradients. Root-soil interactions represent a key unknown in our understanding of how the terrestrial biosphere and global carbon cycle will respond to abiotic change. Our work addresses this urgent knowledge gap through improved conceptual frameworks, databases and models.

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Above and belowground biotic responses to long-term acidification of pH neutral grasslands

Dr Sarah Duddigan¹, Prof Anita Diaz², Dr Iain Green², Prof Mark Tibbett¹

¹University of Reading, ²Bournemouth University

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Reversion of agricultural land to heathland and acid grassland systems is a priority for the conservation of these habitats. Application of elemental sulphur to acidify pasture can reverse the effects of long-term liming and fertiliser application during agricultural production, allowing heathland species to recolonise. In the wider context of heathland restoration, we investigated how large scale experimental acidification with sulphur affected soil biodiversity and function over a period of 17 years. A field experiment was conducted using ferrous sulphate and elemental sulphur as acidifying agents. We tested the contribution made by differing components of the soil biota using a biotic-size-partitioning litterbag experiment and examined changes in soil biology at a range of scales including key components of the macro and micro-biota and their respective activities. Other variables that may be affected by changes in soil biodiversity and function were also assessed, including the effect on soil nutrient availability, mycorrhizas and plant community composition. We found that elemental sulphur had a considerable and persistent effect on soil pH, lowering it to levels found in the surrounding reference acid grassland and heathland sites. The varying acidifying effects of sulphurous amendments also presented us with an experimental pH gradient. To build a more holistic understanding of soil pH change we also effect of a contrived pH gradient on soil chemistry, plant biomass and elemental composition and the effect of these changes on soil fauna (earthworms, nematodes rotifers and tardigrades) and biological indexes (based on ecological group structures for earthworm and nematodes).

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Soil quality regulates litter decomposition and soil CO₂ emission in chestnut stands

Prof. Gloria Falsone^{1,2}, Dr. Mauro De Feudis¹, Prof. Alberto Agnelli³, Dr. William Trenti¹, Dr. Chiara Poesio¹, Prof. Livia Vittori Antisari^{1,2}

¹*Dipartimento di Scienze e Tecnologie Agro-alimentari, Alma Mater Studiorum Università di Bologna, Bologna, Italy,*

²*CIRI Agroalimentare, Alma Mater Studiorum Università di Bologna, Cesena, Italy,* ³*Dipartimento di Scienze Agrarie, Alimentari ed Ambientali, Università degli Studi di Perugia, Perugia, Italy*

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Chestnut plantations are semi-natural forest ecosystems, which are widely distributed throughout the world and where the largest source of soil organic matter (OM) is represented by the leaf litter transformation. Our hypothesis is that soil quality, assessed through biological fertility index [1,2,3], by regulating organic residues degradation, can drive C-use efficiency, stable OM formation and, finally, CO₂ emission. To test this hypothesis, considering three chestnut stands with different soil quality, we quantify the amount of C and N remained in litterbag after 310-day of incubation in the soil (A horizon) or on forest floor of each stand. Stable isotope analysis (¹³C, ¹⁵N) and their shift in leaf litter at the end of incubation were also evaluated. The soil CO₂ emission was measured in the field during one month in the summer season.

Our findings suggested that soil quality is able to affect both the litter decomposition and the retention of litter-derived C and N in litterbag incubated in the soil. The soils having a good quality and ¹⁵N-rich leaf litter provided favorable conditions for microbial utilization of the organic substrata. These resulted in lower proportion of litter C and N retained (from 60% to 77% of C and from 28% to 97% of N in the richest and the poorest soils, respectively), likely resulted in the ability to stabilize litter residues in humified OM pools. This was coupled to a higher C-use efficiency, as recorded by the C-CO₂ emitted from soil per unit of soil organic C stored.

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Inorganic carbon mediates tillage effects on soil organic carbon stocks in arid agricultural soils

Dr. Kirsten Ball¹, Dr. Susan Crow², Dr. Chris Brien³, Dr. Asmeret Asefaw Berhe⁴, Mr. Samuel Rathke¹, Dr. Joseph C Blankinship¹

¹University Of Arizona, Tucson, United States, ²University of Hawaii Manoa, Honolulu, United States, ³University Of Adelaide, Urrbrae, Australia, ⁴University of California Merced, Merced, United States

18 Division 2 Commission 2.2 – Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 13:00 - 15:00

Reduced tillage is a universally recommended practice for improving degraded agricultural lands and their storage of soil organic carbon (SOC) by minimizing soil disturbance and thus reducing SOC loss via microbial decomposition. In mesic systems, the protection of SOC is primarily controlled by organo-mineral associations and aggregation of soil particles by products of organic matter decomposition, and abiotic processes. In contrast, xeric systems, which store approximately 46% of the world's soil carbon stocks, have lower plant inputs, little SOC to begin with, and SOC accumulation is likely mediated by carbonates. Despite their global importance, little scientific knowledge around the quantification and management of soil organic carbon (SOC) has been developed in arid, alkaline soils. Therefore, we examined the influence of soil inorganic carbon (SIC) on total SOC in xeric cropping systems under long-term conventional tillage, 25 years of reduced tillage, and a relatively undisturbed native desert system. We found that SOC:SIC ratio positively correlated with total SOC concentration, and beyond a threshold value of 1.5, increasing SOC:SIC ratios led to far greater SOC increases when soils were tilled. As agriculture in arid regions expands worldwide, our results indicate the need for further investigation around the influence of SIC in SOC stabilization processes and highlights the cursory nature of a one-size-fits-all approach to SOC management.

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1511

The RMQS-Biodiversity as a project of large-scale soil biodiversity monitoring in France

Dr Camille Imbert¹, Dr Lucia Santorufo², Ms Carole Ortega¹, Dr Claudy Jolivet¹, Dr Apolline Auclerc³, Dr Nolwenn Bougon⁴, Dr Yvan Capowiez⁵, Dr Nathalie Cheviron⁶, Dr Daniel Cluzeau⁷, Dr Jérôme Cortet⁸, Ms Gaëlle Deronzier⁴, Dr Mickaël Hedde⁹, Dr Antoine Lévêque¹⁰, Dr Florence Maunoury-Danger¹¹, Dr Laurent Palka¹², Dr Guénola Pérès¹³, Dr Lionel Ranjard¹⁴, Dr Benoît Vanhee¹⁵, Dr Cécile Villenave¹⁶, Mr Stanislas Wroza⁴, Dr Antonio Bispo¹

¹INRAE-Infosol, Orléans, France, ²Department of Biology University of Naples Federico II, Naples, Italy, ³INRAE Lorraine University ENSAIA, Nancy, France, ⁴OFB, Vincennes, France, ⁵INRAE EMMAH, Avignon, France, ⁶INRAE EcoSys Biochem-Env Plateform, Versailles, France, ⁷Rennes University ECOBIO, Plélan le grand, France, ⁸University Paul Valéry Montpellier 3 CEFE, Montpellier, France, ⁹INRAE Montpellier SupAgro Cirad, Montpellier, France, ¹⁰OFB CNRS MNHN Patrinat, Paris, France, ¹¹INRAE Université de Lorraine ENSAIA LIEC, Metz, France, ¹²MNHN CESCO, Paris, France, ¹³INRAE Agrocampus Ouest SAS, Rennes, France, ¹⁴INRAE Agroécologie, Dijon, France, ¹⁵Catholic University of Lille Ecologie et biodiversité, Lille, France, ¹⁶Elisol Environnement, Congénies, France

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

A quarter of the planet described species live underneath our feet and we still badly know them. In France, with the support of the French Biodiversity Office, we proposed to fill this gap by testing the addition of a monitoring program for soil biodiversity to the French Soil Quality Monitoring Network (RMQS, Jolivet et al. 2018).

We first gathered soil biodiversity experts to determine whether the coupling to the RMQS was possible, the taxa and functions to be monitored and the protocols to use. This working group concluded that adding a soil biodiversity monitoring on the RMQS was feasible. Five protocols were proposed to assess both taxa composition and functions: 1) the surface composite sample on a 400m² site for microorganisms, nematods, enzymatic activities, organic matter degradation and seed bank, 2) 5 cm-diameter cores for the mesofauna, 3) soil columns (16 cm-diameter) for soil porosity, 4) spade tests for the macrofauna and mustard application and 5) pitfall traps for the surface meso and macrofauna.

We tested those selected protocols on field to challenge the existing sampling design, precise the costs and train the teams. Feedback from the field samplers and results are currently being collected. Biodiversity data will be confronted to soil physical-chemical characteristics and management practices also collected on the RMQS.

This exercise will help us in defining how to spread those biodiversity protocols on all French monitoring sites to answer several issues such as the species biogeography, links with agricultural practices and even the discovering of new species.

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Machine learning in space and time for global modelling of soil organic carbon change

Dr Gerard Heuvelink¹, Dr Laura Poggio, Dr Jonathan Sanderman, Dr Dominic Woolf, Dr Johannes Lehmann, Dr Deborah Bossio

¹*ISRIC - World Soil Information and Wageningen University, Wageningen, Netherlands*

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

Spatially resolved estimates of change in soil organic carbon (SOC) stocks are necessary for supporting national and international policies aimed at achieving land degradation neutrality and climate change mitigation. In this presentation we report on the development, implementation and application of a data-driven, statistical method for global mapping of SOC stocks in space and time. We used Quantile Regression Forest machine-learning to predict annual SOC stock at 0-30 cm depth at 250 m resolution between 1982 and 2017. The model was calibrated using over 49,000 SOC stock values from the 36-year time period and 65 environmental covariates. We pre-processed NDVI dynamic covariates using a temporal low-pass filter to allow the SOC stock for a given year to depend on the NDVI of the current as well as preceding years. Predictions had modest temporal variation and spatial patterns that agreed well with those of static SOC stock maps. Prediction uncertainties turned out to be substantial, mainly due to the limited number and poor spatial and temporal distribution of the calibration data, and the limited explanatory power of the covariates. Cross-validation confirmed that SOC stock prediction accuracy was limited, with a Mean Error of 0.5 t/ha and a Root Mean Squared Error of 32.8 t/ha. In spite of the large uncertainties, this work showed that machine learning methods can be used for space-time SOC mapping and may yield valuable information to land managers and policy makers, provided that SOC observation density in space and time is sufficiently large.

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Digging into the bulk density and coarse fragment data of the French soil quality monitoring network

Dr Jose Luis Munera-echeverri¹, Dr Manuel Martin¹, Dr Line Boulonne¹, Dr Nicolas Saby¹, Dr Dominique Arrouays¹

¹INRAE, Orléans, France

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

Bulk density (BD) and coarse fragment (CF) content are needed to assess changes of carbon (C) stocks in soils. Understanding the evolution of BD is needed to calculate stock changes based on equivalent mass. Factors such as land use and management practices have an effect on BD. However, quantifying those effects is challenging due to uncertainties linked to determination methods and spatial variability. Additionally, large uncertainty in CF content in some soils can compromise the validity of C stocks changes, particularly in stony soils. Here, we discuss the lessons learnt from the first and second campaigns of the French soil quality monitoring network (RMQS) regarding the measurements of BD and CF, focusing on the volumetric ring (500 cm³) and the excavation methods. We discuss the situations in which the methods are preferred, their pros and cons. The ring method was the most frequent and it was preferred in soils with 0% CF to less than 50 % (weight content). The excavation method was used as well between 0% to 50 % CF content but less frequently. When CF content is > 50%, excavation was the preferred method. The regression fit between the values of the first and second campaign was consistently better for BD and CF measured by the volumetric ring than by the excavation method. This suggests that the volumetric ring is more accurate for assessing changes of BD and gives more consistent results of CF across campaigns. Yet, its inapplicability in highly stony soils limits its widespread use.

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Germany's National Forest Soil Inventory: results of accompanied studies to harmonise soil sampling and lab analysis

Dr Erik Grüneberg¹, Dr Nicole Wellbrock¹

¹*Thünen Institute of Forest Ecosystems, Eberswalde, Germany*

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

The goal of the National Forest Soil Inventory (NFSI) is to generate reliable data on the current state and changes in forest soils which are representative on regional scale and comparable across the country. The NFSI was conducted on a systematic grid of 8 x 8 km at about 1,900 soil sampling sites. The surveys took place from 1987-1992 and from 2006-2008. The third survey is planned for 2023/24. Around a centralised soil profile, volume-based samples were taken at eight satellites and mixed for every depth level and plot. Guidelines were developed to consider the compatibility of the methods for field and laboratory work. Various accompanied studies focused on the variability of physicochemical soil parameters in respect to sampling equipment and effects of various laboratorial separation techniques on the representativeness on bulk soil samples. It was shown that mixed satellite samples reduced the variability of the C concentrations of the plot while the dry bulk density was sufficiently determined at the soil profile in the centre of the plot. Compared to the core cutter method augaring reduced the variability of the C concentrations but enhanced the bulk density. Mixed soil samples increase the possibility to detect differences between the inventories approving the applied inventory sampling schema. Nevertheless, all studies showed a greater variability within compared to between inventory plots. Various physicochemical analyses of soil were applied over time. The re-analyses showed that most of the parameter were comparable and interpretable across laboratories and time.

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Changes in carbon and nitrogen soil stocks according to the sampling protocol by the ICOS over the last decade.

Dr Maryam Gebleh-Goydaragh², Dr Nicolas P.A. Saby¹, Dr José-Luis Munera-Echeverri¹, Dr Pauline Buysse², Dr Sébastien Lafont³, Ms Céline Ratié¹, Mr Jean-Philippe Chenu¹, Dr Claudy Jolivet¹, Dr Nicolas Proix⁴, Mme Brigitte Durand², Dr Benjamin Loubet²

¹Infosol, Orléans, France, ²ECOSYS, Grignon, France, ³UMR ISPA, Bordeaux, France, ⁴UE LAS, Arras, France

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

The soil is a major component of the terrestrial carbon cycle and monitoring the temporal changes in the soil organic carbon (SOC) and soil organic nitrogen (SON) stocks is required in order to close the ecosystem mass balance of these elements and to assess the role of terrestrial ecosystems in the global carbon cycle. In ICOS ecosystem sites, the SOC and SON stocks are monitored within the target area of the eddy covariance (EC) flux tower, based on soil observations collected following a probability sample allowing design-based estimates of the statistical indicators and their associated uncertainty.

In this study we compared soil stock changes over several years to the carbon balance approach based on the Eddy Covariance (EC), incoming and outgoing carbon fluxes. The stocks were computed following two approaches: equivalent soil mass (ESM) and fixed-depth (FD).

In this presentation, we illustrate the methodology used for the SOC and SON stocks evaluated by ETC, discuss their uncertainties, indicate their temporal changes impacted by the equivalent soil mass and FD, and compare these changes over the last decade. Thus, we exemplify the methodology with the dataset obtained on a crop rotation in Grignon (France, near Paris) and propose a preliminary comparison with previous evaluations of the carbon balance by EC. Arrouays, D., Saby, N. P. A., Boukir, H., Jolivet, C., Ratié, C., Schrumpf, M., Merbold, L., Gielen, B., Gogo, S., Delpierre, N., Vincent, G., Klumpp, K., & Loustau, D. (2018). Soil sampling and preparation for monitoring soil carbon. *International Agrophysics*, 32(4), 633-643. <https://doi.org/10.1515/intag-2017-0047>

Monitoring increases in soil pH in response to sulphur deposition at a national scale

Dr Fiona Seaton¹, David Robinson¹, Don Monteith¹, Paul Bürkner², Inma Lebron¹, Sam Tomlinson¹, Bridget Emmett¹, Simon Smart¹

¹UK Centre For Ecology & Hydrology, United Kingdom, ²University of Stuttgart, Germany

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

Across Europe, reducing sulphur emissions since the 1970s have given ecosystems an opportunity to recover from acidification, however the extent and ecological impact of this recovery is still unclear particularly when considered in the context of changing climate and land use. Here we present data from thousands of sites across Great Britain surveyed from 1978-2019 and use Bayesian modelling to evaluate change in soil pH and plant acidity preference (Ellenberg R) in response to sulphur deposition. This statistical approach allows us to incorporate information on measurement error throughout the survey, and to jointly model change in soil pH and Ellenberg R in response to atmospheric deposition and changes in rainfall. Soil pH measured in H₂O increased in low and high-intensity management habitats from 1978 to 2007, but in 2019 had decreased from 2007 levels. However, measurements of soil pH in CaCl₂ showed less change than measurements in H₂O from 2007 to 2019, and in semi-natural habitats showed no change. In semi-natural habitats decreasing sulphur deposition was linked to soil pH increases that were in turn associated with increasing Ellenberg R, while in intensive grasslands there were lower impacts of sulphur deposition upon pH. Differences in rainfall between the field seasons proved to be an important predictor of pH (H₂O) changes between field surveys. Our results show the importance of considering long-term variation in measurement methodologies and integrating soil and plant information in monitoring long-term recovery of natural ecosystems from atmospheric pollution.

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A review of existing soil monitoring systems to pave the way to the EU Soil Observatory

Dr Antonio BISPO¹, Dr Zsófi Bakacsi, Dr Fenny van Egmond, Dr Bozena Smreczak, Dr Grzegorz Siebielec, Dr Johanna Wetterlind, Dr Rudi Hessel, Dr Arwyn Jones, Dr Maria Fantappiè

¹*INRAE - InfoSol, ORLEANS, France*

33 WG1.7 – Advances in soil monitoring:, Alsh 1, August 4, 2022, 13:00 - 15:00

Soils are constantly evolving due to natural factors as climate and living organisms (pedogenesis), but also due to external pressures linked mainly to human activities (e.g. urbanization, management practices, diffuse inputs of nutrients or contaminants through atmospheric deposits or waste spreading). The evolution of soils makes it necessary to set up monitoring programmes. Designing and implementing a Soil Monitoring System (SMS) requires at least to choose: the statistical sampling design, the field sampling strategy in time and space, the entity that is sampled (i.e. pedogenic horizons or fixed depths) and how (e.g. pits, augering, spade), the total thickness over which soil is sampled, the way the samples are managed (e.g. composite sample), prepared and analysed and the metadata is to be collected and stored (data about the sampling itself, its location and surroundings) to interpret the results. All those choices represent possible variations that enable the results to be compared.

Since 20 years, several projects and initiatives underlined the existing difficulties to compare and share data from national SMS, either due to technical issues (e.g. sampling designs and protocols, analytical methods, data format) but also on motivations (e.g. why to share the data, for what purpose) and legal requirements (e.g. are we allowed to share the data). With the objective of overcoming this blockage a questionnaire was designed and circulated within EJP SOIL. Its analysis allows to identify the main technical issues (e.g. major differences between SMS) and possible ways of harmonization/collaboration in the frame of the EU Soil Observatory.

Bispo et al., 2021. Proposal of methodological development for the LUCAS programme in accordance with national monitoring programmes. EJP SOIL - Deliverable 6.3. 133p

Gender Equity in Soil Science: A View from Multiple Countries

Dr Eric Brevik¹, Dr. Laura Bertha Reyes-Sánchez², Dr. Lorna Dawson³

¹College of Agricultural, Life, and Physical Sciences, Southern Illinois University, Carbondale, United States of America,

²Agricultural Engineering Department, National Autonomous University of Mexico, Mexico City, Mexico, ³Environmental and Biochemical Sciences Department, The James Hutton Institute, Aberdeen, United Kingdom

IUSS Gender Balance Meeting: How to move towards gender equality?, Dochart 2, August 4, 2022, 13:00 - 15:00

Gender diversity is a top priority of IUSS. There is very limited gender equity data for soil science. Before we can move towards gender equity, we need a baseline. This study was conducted as a preliminary exploration of international gender equity issues using data from national soil science society memberships, international conferences, and journals. Membership data was supplied by 44 soil science societies for the year 2020. Thirty-seven of the 44 societies had more male members than female. Overall, 32% of the members were women; the highest female percentage for an individual society was 69%. Asia had the lowest regional female membership (22%) while Africa had the highest (40%). Only 20% of the soil science societies who are members of the IUSS had female presidents and women were underrepresented as keynote speakers at conferences (6% and 21% for WCSS and Soil Science Society of America, respectively) and on many editorial boards (average 30%, range 24-53%). These findings indicate women are underrepresented in the top leadership roles in our professional societies. This preliminary study demonstrates there is a global need to address gender equity within the soil science profession. However, it is also important to note that gender equity extends beyond just the number of women in our profession: it also includes equal access to wages, leadership roles and decision making. It is critical that studies are conducted in individual countries so we have a more complete picture of the national and international scale of gender equity in soil science.

Dawson, L., Brevik, E.C., Reyes-Sánchez, L.B. 2021. International gender equity in soil science. *European Journal of Soil Science* 72,1929–1939. DOI:10.1111/ejss.13118

Imaging of roots and pore networks in soil systems by using high resolution X-ray micro-CT

Mr. Gerhard Zacher¹, Thilo Eickhorst², Hannes Schmidt³, Matthias Halisch⁴

¹*Baker Hughes Digital Solutions GmbH, Wunstorf, Germany*, ²*University of Bremen, Bremen, Germany*, ³*University of Vienna, Centre for Microbiology and Environmental Systems, Vienna, Austria*, ⁴*Leibniz Institute for Applied Geophysics, Hannover, Germany*

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Today's high-resolution X-ray CT lends itself naturally to geological and pedological applications. Those include the non-destructive interior examination and textural analysis of rock and soil samples and measurement of their permeability and porosity. Especially spatial distribution and geometry of pores, mineral phases and fractures are important for the evaluation of hydrologic and aeration properties in soils as well as for root development in the soil matrix. The possibility to visualize a whole soil aggregate or root tissue in a non-destructive way is undoubtedly the most valuable feature and is a challenging area for routine application of this method.

We will address visualization and quantification of porous networks in 3D in different environmental samples ranging from sedimentary rock to soil cores and individual soil aggregates. As processes and habitat functions are related to various pore sizes, imaging of the intact soil matrix will be presented on different scales – from mm-scale representing the connectivity of macro-pores down to micro-scale representing the space of microbial habitats. Therefore, soils were impregnated with resin before scanning. Scans at higher resolution were obtained from sub-volumes cut from these blocks and from crop roots surrounded by rhizosphere soil. Within these structures we will highlight pore-solid and soil-root interfaces. The latter will be linked to fluorescent microscopy and scanning electron microscopy revealing additional biological and chemical information in the respective micro-environment. Based on the combination of all 3D and 2D imaging data, habitat features of soils can be characterized and combined with studies analyzing microbial rhizosphere colonization.

Kaufhold, A., Halisch, M., Zacher, G., and Kaufhold, S.: X-ray computed tomography investigation of structures in Opalinus Clay from large-scale to small-scale after mechanical testing, *Solid Earth*, 7, 1171–1183, <https://doi.org/10.5194/se-7-1171-2016>, 2016.

Soil deformation – how far are shear induced coupled mechanical and hydraulic processes fundamental for the predictions of trafficability

Dr. Rainer Horn¹, Dr. Tusheng Ren, Dr. Xinjun Huang

¹CAU Kiel, Kiel, Germany, ²College of Land Science and Technology, China Agricultural University, Beijing 100193, China, Beijing, China, ³College of Land Science and Technology, China Agricultural University, Beijing 100193, China, Beijing, China

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Soils are the most critical life-supporting compartments of the biosphere. They provide numerous ecosystem services such as habitat for biodiversity, water and nutrients, as well as producing food, feed, fiber and energy. However, soils undergo intense and irreversible changes due to a non-site adjusted land management and improper application of machinery and techniques in its broadest sense. In combination with the growing population (until 2050 we will have approx. 9 Billion people) the urgent need for a more reliable dataset of soil properties and soil functions gains in importance in order to even prepare more reliable models for various requests. Deformation processes during stress application are the more pronounced the higher the shear component of the total stress, and may even result in a complete liquefaction if soil water cannot be drained off adequately. Shear and vibration induced soil deformation therefore enhances the deterioration of soil properties especially if the soil water content and the internal soil strength are very low. The same is true for animal trampling in combination with overgrazing of moist to wet pastures, which subsequently causes denser (i.e. reduced proportion of coarse pores with smaller continuity) but still structured soil horizons and will finally end in a compacted platy structure. In combination with high water content and shearing due to trampling results in a complete muddy homogeneous soil with no structure at all. Thus, the consequence of dilatation (like compaction) and shearing in combination affect the internal soil strength and ecological functions.

11. Horn, R. 2021. Soils in Agricultural Engineering: Effect of Land-use Management Systems on Mechanical Soil Processes. In Hydrogeology, Chemical Weathering, and Soil Formation; Hunt, A., Egli, M., Faybishenko, B. (Eds.) Chapter 10A, 187-199; Wiley & Sons: Hoboken, NJ, USA ISBN: 978-1-119-56396-9

12. Huang, X., Horn, R., Ren, T. 2021. Deformation and pore water pressure change during static and cyclic loading with subsequent shearing on soils with different textures and matric potentials Soil and Tillage Res. 104909, doi.org/10.1016/j.still.2020.

13. Faloye, T., Ajayi, A., Zink, A., Fleige, H., Dörner, J., Horn, R., 2021. Effective stress and pore water dynamics in unsaturated soils: Influence of soil compaction history and soil properties, Soil and Tillage res. 211 <https://doi.org/10.1016/j.still.2021.104997>

ImageSol: a new database to boost explorations of the links between soil structure and soil functioning.

Mrs Marine Lacoste¹, Yvan Capowiez², Isabelle Cousin¹, Patricia Garnier³, Nicolas Moitrier², David Montagne³, Guenola Peres⁴, Valerie Pot³, Antoine Schellenberge⁵, Françoise Watteau⁶
¹INRAE, URSOLS, 45075, Orléans, France, ²INRAE, Avignon Université, UMR EMMAH, F-84000, Avignon, France, ³Université Paris-Saclay, INRAE, AgroParisTech, UMR EcoSys, Thiverval-Grignon, France, ⁴UMR SAS, Institut Agro, INRAE, 35042, Rennes, France, ⁵INRAE, InfoSol, 45075, Orléans, France, ⁶Université de Lorraine, INRAE, LSE, F-54000, Nancy, France

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Soil structure, whatever the scale, is a key element to understand soils functioning. The quantitative characterization of the pore network and its dynamics, together with soil organism activity and interactions with their environment, provides an understanding of the links between soil structure and functions (Konig et al., 2016, Pore et al. 2016). Cutting-edge imaging methods are thus increasingly needed and developed. They are diverse, from non-invasive (X-ray or neutron (micro)tomography) to destructive (optical, electronic, chemical microscopy...), in constant evolution, increasingly accessible, and produce always more data. It can be 2D or 3D images, time series images (to follow dynamic processes) or one-time images (to study the soil at a given time). To centralize these images in a unique information system, to facilitate and secure their storage along with their metadata, their publication and citation, and promote their sharing with the scientific community, we are building the ImageSol database, which aims to be complementary to the Soil Structure Library (Weller et al., 2021). ImageSol stores raw or processed images with i) their pedological metadata (sampling location and date, soil profile/horizon description...), ii) image acquisition metadata (image tools including beam characterization, pixel/voxel properties...), and iii) image analysis metadata (software, segmentation thresholds....). Soil images can also be linked through their metadata to National Information System storing soil properties. With ImageSol, we aim to enable soils scientists worldwide to share their soil image data and promote further analyses of these newly available images, especially (but not exclusively) to answer questions requiring soil structure information.

Konig, S., Vogel, H. J., Harms, H., & Worrlich, A. (2020). Physical, Chemical and Biological Effects on Soil Bacterial Dynamics in Microscale Models. *Frontiers in Ecology and Evolution*, 8, 10. doi:10.3389/fevo.2020.00053

Porre, R. J., van Groenigen, J. W., De Deyn, G. B., de Goede, R. G. M., & Lubbers, I. M. (2016). Exploring the relationship between soil mesofauna, soil structure and N₂O emissions. *Soil Biology & Biochemistry*, 96, 55-64. doi:10.1016/j.soilbio.2016.01.018

Weller, U., Albrecht, L., Schlüter, S., & Vogel, H. J. (2021). An Open Soil Structure Library based on X-ray CT data. *SOIL Discuss.*, 2021, 1-13. doi:10.5194/soil-2021-96

Modeling soil structure dynamics in compacted soils induced by livestock treading

Mr Alejandro Romero-Ruiz¹, Dr. Kevin Coleman¹, Dr. Andy Whitmore¹

¹*Rothamsted Research, Harpenden, United Kingdom*

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Soil compaction by livestock treading is a major environmental hazard because it adversely impacts soil mechanical and hydraulic properties, and is often linked to increases in greenhouse gases (GHG) emissions. However, we lack a quantitative understanding of the extent of GHG emissions from such compacted soils. This is partially due to gaps in our knowledge of how treading-induced compaction impacts soil properties spatially and temporally. To address this challenge, we developed a framework for systematic modeling of soil compaction by animal treading. We considered random movement of cattle in a confined area that is discretized in square cells with given properties. We then used a rheology model based on Bingham's law to infer compaction-induced changes in soil bulk density and porosity. An associated reduction of saturated hydraulic conductivity is obtained from soil porosity predictions by (1) using a model based on Koseny-Carman equation and (2) by empirically accounting for macroporosity reduction using a dual-porosity permeability model. This framework is coupled with an empirical model of soil structure development to account for wetting-drying cycles and biological activity. Literature values of relative change in bulk density are used to calibrate model properties such as numbers of grazing days or steps per grazing day. Relative changes in saturated hydraulic conductivity fall within predicted ranges. This model can (1) be extended to predict the impact of compaction on denitrification and (2) be used in an agro-ecosystems model to assess the environmental impact of livestock-grazing systems and suggest management strategies for ameliorating this impact.

NA.

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Application of Structure Function Analysis to Quantifying Soil Micromorphology from X-ray CT Imagery

Dr. Richard Heck¹, Dr. Daniel Gimenez², Dr. Eddie Ma¹

¹University of Guelph, Guelph, Canada, ²Rutgers University, New Brunswick, USA

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Semivariance analysis is a widely-used technique in landscape pedology, with semivariogram modeling serving as the basis for kriging. Directional semivariance analysis is employed to detect and characterize structural anisotropy. Various specific parameters can also be calculated directly from the semivariogram, to gain further insight on the spatial variability of a given property. Semivariance is special case of structure function analysis, built around the statistical moment of order 2 for a given distribution. In its generalized form, the structure function permits assessment of spatial dependence through a range of statistical moments. Thus, structure function can potentially provide a deeper insight, than semivariance alone, on the scaling behavior of a system. A three-dimensional implementation of structure function analysis, designed specifically for the characterization of 3D x-ray CT imagery of soil, will be presented. The algorithm, written in Java for ImageJ, works with both greyscale (representing radiodensity) and binary (representing segmented soil phases) imagery. Its functionality will be discussed from the perspective of quantifying soil microstructure, in terms of pedogenesis and the impact of management practices.

Multi-scale study of soil structure in relation to nitrous oxide emissions

Mr. Emile Maillet¹, Ms. Agnès Grossel¹, Ms. Marine Lacoste¹, Ms. Isabelle Cousin¹

¹INRAE, URSOLS, 45075 Orléans, France, Orleans, France

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Nitrous oxide (N₂O) is a potent GHG and a dominant ozone-depleting substance. Currently, more than half of global anthropogenic N₂O emissions come from cultivated soils and are mostly linked to nitrogen fertilizer use.

Soils N₂O emissions is a multifactorial phenomenon, with a large spatio-temporal variability whatever the scale. To explain this variability, many deterministic studies focus either on the soil microstructure scale, i.e. the scale of microorganism habitat and N₂O production (Schlüter et al., 2018), or on the macrostructure scale, to focus on fluids transfers (water, N₂O) (Rabot et al., 2015). However, the multiscale influence of soil structure on N₂O emissions is still poorly understood, and consists in the objective of our work.

In this study, we assessed a multiscale approach to gain a more detailed understanding of the N₂O emissions determinism. The field-scale variability of N₂O emissions has been estimated during a snap-shot campaign in soils with contrasted structure, induced by different agricultural practices (4 soil modalities crossing strip-till and tillage with compacted or uncompacted areas). 24 soil cylinders were collected in low and high N₂O emission zones and were then scanned by using both X-ray macro- and micro-tomography. The soil structure was then described at macro and micro-scale by using quantitative morphological tools. Associated relevant soil properties were analyzed (mineral nitrogen, soil texture, pH, C/N, etc.). The 4 different soil modalities showed highly contrasting macrostructures and N₂O emissions. The ongoing work is intended to clarify the relationships between other soil factors, microstructure and N₂O emissions.

Rabot, E., Lacoste, M., Hénault, C., & Cousin, I. (2015). Using X-ray Computed Tomography to Describe the Dynamics of Nitrous Oxide Emissions during Soil Drying. *Vadose Zone Journal*, 14(8), vzj2014.12.0177. <https://doi.org/10.2136/vzj2014.12.0177>

Schlüter, S., Henjes, S., Zawallich, J., Bergaust, L., Horn, M., Ippisch, O., Vogel, H.-J., & Dörsch, P. (2018). Denitrification in Soil Aggregate Analogues-Effect of Aggregate Size and Oxygen Diffusion. *Frontiers in Environmental Science*, 6, 17. <https://doi.org/10.3389/fenvs.2018.00017>

Cover crop effects on μ CT-measured geometrical pore characteristics

Dr. Ranjith Udawatta¹, Dr. Lalith Rankoth¹, Dr. Clark Gantzer¹, Dr Stephen Anderson¹

¹*University Of Missouri, Columbia, United States*

15 Divisions 1 and 2 Commission 1.1, Commission 2.1– Soil structure: Observation, resilience and its role in ecosystem functioning, M1, August 4, 2022, 15:30 - 17:30

Cover crops (CC) improve soil physical, chemical and biological properties; however, the micrometer scale quantification of geometric pore characteristics in CC soil is limited in the literature. The objective of this study was to differentiate geometrical pore characteristics between CC and no cover crop (NCC) by Computed Tomography (CT). The study design consisted of winter CC and summer corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotation with no-till management at the University of Missouri Bradford Research Center located in Columbia, MO (38°89'N and 92°21'W). Six, 0-65 mm long soil cores (28 mm diam.) were imaged at 29 μ m resolution and 3D volumes were analyzed using Fiji-ImageJ2 software. Slice thickness was 29 μ m, and the minimum achievable voxel size was 90 nm. Images within the top and bottom 7.25 mm were removed and two depths within a core were analyzed for soil pore parameters. The total pore volume was significantly greater ($P < 0.05$) in CC compared to NCC with 8.4- and 2.5-times greater values in CC at 7.25-27.25- and 37.25-57.25-mm, respectively. The total (individual+branched) and the individual pore count were significantly greater ($P < 0.05$) in CC compared to NCC for both depths. The porosity of CC soil at 7.25-27.25 mm depth was 10 times greater than that of NCC. The branched pore count was not significantly different between two treatments. Overall, the micrometer scale determination of geometrical pore network characteristics showed added benefits of CC use compared to NCC, thus the use of CC can be beneficial in improving soil pore networks.

Soil microbial necromass as an essential carbon, nitrogen and phosphorus reservoir in forest soils

Prof. Sandra Spielvogel¹, Dr. Sebastian Loepmann¹, Dr. Klaus Jarosch², Thomas Zilla³, Jan Tegtmeier¹, Marius Schmitt⁴, Prof. Michaela Dippold³

¹University Kiel, Kiel, Germany, ²University Bern, Bern, Switzerland, ³University Tuebingen, Tuebingen, Germany, ⁴ETH Zurich, Zurich, Switzerland

18 Division 2 Commission 2.2 :– Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

The role of microbial necromass (MN) for forest nutrition (P, N) was barely studied so far (Plassard & Dell, 2010). To investigate the nutrition potential of MN for trees and microbes, we created a protocol to produce ¹⁴C, ¹⁵N and ³³P labeled MN. We used the MN in a rhizotron experiment with *Fagus sylvatica* seedlings to investigate competitive uptake strategies of trees and microbes. The rhizotrons were labeled with different spatial patterns of MN. In contrast to ³³P-Iron(III)phosphate, patchiness of MN did not affect ³³P incorporation of beeches, indicating that the spatial distribution of P impacts tree access in case of low-available inorganic-P while the spatial pattern of MN-P is of lower importance. Another experiment with T-shaped pots allowed to create i) an intact rhizosphere and ii) a hyphosphere by using PTFE gauze not permeable by roots. Thus, beech P and N uptake directly via roots or via mycorrhizal hyphae could be differentiated. ¹⁴C-, ¹⁵N-, and ³³P-labelled MN was added to both compartments of the T-pots. MN-P uptake by beeches was higher the lower the ecosystems' P stocks, suggesting that for ecosystems with efficient nutrient recycling the MN pool is of high relevance. At all sites, fungal hyphae alone were as potent as the combination of roots and their mycorrhizal partners in mobilizing MN-P. These results reveal that MN as dynamic nutrient reservoir for ecosystem nutrition was strongly underestimated up to now and that the ecosystem's demand on exploiting MN may control its function as C sink in soils.

C. Plassard & B. Dell (2010): Phosphorus nutrition of mycorrhizal trees. *Tree Physiology* 30, 1129-1139.

1406

The Priming Arena: soil mineralogy and structure interact with the chemical composition of plant-derived inputs to mediate priming effects.

Mr Luke Harrold¹

¹*University of Aberdeen, Aberdeen, Scotland*

18 Division 2 Commission 2.2 :– Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

Soil organic matter priming is defined as the change in rate of organic matter mineralisation after fresh substrate addition. Priming investigations have focussed largely on biological stimulation using only a narrow subset (labile substrates) of the thousands of compounds exuded by roots. Little attention has been paid to the physical and chemical environment in which these biological activities occur. This approach may have missed abiotic, chemical and physical mediation of biological activity thus leaving our understanding of priming incomplete. In two separate experiments, two soils of differing mineralogy were treated with ¹³C-labelled glucose and oxalate to measure the priming effect. In the first, chemical complexity of mineral associated organic matter and dissolved organic carbon was measured to identify the primed pools and changes in chemistry which may alter biological activity. In the second, the soils were set to two different structures and the influence of pore size distribution and connectivity, as well as the interaction with substrates, on the priming effect were examined. In the kaolinitic soil, oxalate stimulated positive priming whereas glucose triggered negative priming. In the Fe-dominated soil both treatments caused positive priming, albeit of a lower magnitude than the oxalate treated kaolinitic soil. The substrates varied in their effect on MAOM chemistry only in the kaolinitic soil, with oxalate showing a removal of functional groups from the mineral phase. Appreciation of the soil physical and chemical environment as well as the role of other root exudates may lead to a better understanding of soil organic matter priming.

Kuzyakov Y. 2010. Priming effects: interactions between living and dead organic matter. *Soil Biology and Biochemistry* 42 (9), 1363-1371.

Mixing cover crop residues increases soil microbial biomass with no resultant priming of SOM decomposition

Dr Xin Shu¹, Dr Yiran Zou¹, Professor Liz J. Shaw¹, Dr Lindsay C. Todman², Professor Mark Tibbett², **Dr Tom Sizmur¹**

¹*Department of Geography and Environmental Science and Soil Research Centre, University of Reading, Reading, United Kingdom*, ²*Department of Sustainable Land Management and Soil Research Centre, School of Agriculture, Policy and Development, University of Reading, Reading, United Kingdom*

18 Division 2 Commission 2.2 :- Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

Increasing the botanical diversity of the crops grown in arable systems has been promoted to improve the delivery of multiple ecological functions. We hypothesised that mixing the residues from different crops grown in polyculture results in more carbon entering the microbial biomass and therefore more potential to become microbially-derived stable soil organic carbon. We used ¹³C isotope labelled cover crop residues (buckwheat, clover, radish, and sunflower) to track the microbial assimilation of plant residue-derived carbon and quantify microbial biomass carbon derived from the priming of native SOM. All treatments received the same amount of plant residue-derived carbon (1 mg C g⁻¹ soil). Our results indicate that the microbial biomass carbon attributed directly to the plant residue was significantly greater, by 132% (3.61 μg C g⁻¹), in the soil receiving the residue mixture than the average microbial biomass observed in treatments receiving the four individual components of the mixture one day after applying residues. However, there was no evidence that the mixture resulted in any more priming of native SOM than average priming observed in the individual residue treatments. Our study demonstrates that applying a mixture of crop residues increases soil microbial biomass to a greater extent than would be expected from applying individual residues. Therefore, growing crop polycultures (e.g. cover crop mixtures) and incorporating mixtures of the resulting crop residues into the soil could be an effective method to increase microbial biomass and ultimately C stocks in arable soils.

Shu, X., Zou, Y., Shaw, L.J., Todman, L., Tibbett, M. and Sizmur, T., 2021. Mixing crop residues induces a synergistic effect on microbial biomass and an additive effect on soil organic matter priming. bioRxiv.

Soil Organic Carbon Response to Different Management Practices Following Conversion to No-till in an Arable System

Dr Ana Natalio¹, Dr Matthew Back¹, Mr Andrew Richards², Dr Simon Jeffery¹

¹Harper Adams University, Newport, UK, ²Agrii, Andoversford, UK

18 Division 2 Commission 2.2 :– Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

No-till in agricultural arable systems is a practice that offers benefits to soil health. Combined with the incorporation of crop residues and manures, no-till can influence soil organic carbon (SOC) dynamics. There is a lack of diachronic large-scale field studies that include baseline data and seasonal variations in an arable system. This study aimed to investigate the interaction between microbial and soil physicochemical properties as they evolved over time during the transition from full-inversion tillage to no-till. It utilised a combination of soil microbial assays (microbial biomass carbon, MBC, and nitrogen, MBN) with physicochemical analyses (SOC, soil texture, pH, gravimetric water content, total nitrogen (%tN) and calcium concentration (Ca^{2+}) to assess soil over a two-year period. Two experiments were established within the same field, Experiment-1 on a level area and Experiment-2 on a slope. Treatments consisted of Farmyard Manure (FYM), Green Manure (GM) and Standard Practice (Control), but Experiment-2 excluded FYM. Soil was sampled twice per crop season, in Spring and Autumn, in Experiment-1, and in Autumn only in Experiment-2. The results were influenced by spatial and temporal variations that were not always linked to management practices. This study demonstrated that SOC was a poor predictor of change in management practices over a two-year timeframe, but that microbial biomass responded quickly to FYM. SOC was affected by texture, extractable Ca^{2+} and %tN, but not significantly by inputs. This diachronic study increases our understanding of SOC, MBC and MBN dynamics and the short-term impact of change in management practices.

PhD Thesis: Natálio, A. I. M. (2021) The Impact of Agricultural Management Practices on Soil Health with Focus on Biological Responses. Harper Adams University.

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Abiotic and biotic controls on microbial derived carbon cycling

Dr. Kirsten Hofmockel¹, Sheryl Bell, Dr. Christopher Kasanke, Dr. Qian Zhao

¹*Pacific Northwest National Laboratory, Richland, United States*

18 Division 2 Commission 2.2 :- Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

Microbial necromass is considered a dominant source of soil organic matter (SOM). Therefore, understanding which microbial taxa and classes of microbial-derived compounds are selectively preserved may enhance SOM management. This requires identification of the microbiological and geochemical reactions leading to the formation and stability of microbial-derived SOM. We tested the hypothesis that microbial communities shape the composition of microbial-derived SOM, and soil properties influence the persistence of microbial residues. Using a ¹³C-labeling incubation experiment, we tracked the formation and turnover of microbial residues for 1 year. Our experiment tested the relative importance of biotic (annual and perennial microbiomes) and abiotic (sandy and silty loams) drivers of microbial necromass accumulation and persistence. We found that plant selection on soil microbiomes is reflected in SOM production and soil geochemistry drives the stability of microbial residues. On average ~40% of the microbially processed ¹³C remained in the soil after 1 year. Approximately 30% of this soil ¹³C pool was recovered in microbial lipid, protein, and metabolite pools, illuminating the possibility that diverse microbial derivatives can contribute to SOM annually. We further revealed that ~30% of the remaining C was recovered in a previously undescribed insoluble complex associated with microbial protein. Significantly greater retention of microbial residues occurred in silty compared to sandy loams and in perennial compared to annual cropping systems. Our results provide novel quantitative evidence of the contribution of microbial residue pool to SOM. This evidence demonstrates the importance of plant selection and soil properties in building stable SOM stocks. Wang, B., An, S., Liang, C., Liu, Y., & Kuzyakov, Y. (2021). Microbial necromass as the source of soil organic carbon in global ecosystems. *Soil Biology and Biochemistry*, 162, 108422.

Leichty, S. I., Kasanke, C. P., Bell, S. L., & Hofmockel, K. S. (2021). Site and Bioenergy Cropping System Similarly Affect Distinct Live and Total Soil Microbial Communities. *Frontiers in Microbiology*, 12.

Kasanke, C. P., Zhao, Q., Bell, S., Thompson, A. M., & Hofmockel, K. S. (2021). Can switchgrass increase carbon accrual in marginal soils? The importance of site selection. *GCB Bioenergy*, 13(2), 320-335.

Kögel-Knabner, I. (2002). The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. *Soil biology and biochemistry*, 34(2), 139-162.

1014

Molecular Characterisation and Pb-210 Dating to Explore Carbon Accumulation in Peat

Dr Eleanor Reed^{1,2}, Dr Geoffrey Abbott²

¹Natural England, Newcastle, United Kingdom, ²Newcastle University, Newcastle, United Kingdom

18 Division 2 Commission 2.2 :– Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

Global warming is predicted to intensify the global hydrological cycle, which in turn will alter peatland vegetation; two of the dominant controls on the carbon cycle. Sphagnum is regarded as extremely recalcitrant and is the dominant peat forming moss. There are also non-Sphagnum mosses, as well as vascular plants associated with peatlands which will contribute lignin and other polyphenols to the peat.

Eight peat cores were sampled across a chronosequence within Wark Forest, England and analysed for vegetation composition by thermally assisted hydrolysis and methylation (THM) using ¹³C-labelled tetramethylammonium hydroxide (¹³C-TMAH), which yielded methylated phenolic and oxygenated aromatic products, enabling the separate identification of vascular, Sphagnum and non-Sphagnum moss inputs in one analysis (Abbott et al., 2013). These markers were evaluated downcore against the carbon stock, with Pb-210 dating undertaken to provide carbon accumulation rates.

We demonstrate the ability of ¹³C-TMAH thermochemolysis to be utilised as a screening method for the rapid characterisation of biomacromolecules in peat to identify the key vegetation inputs. This technique in combination with peat dating will demonstrate the change in vegetation over time and how it relates to carbon storage, enabling future studies to investigate the degradation patterns of these inputs and associated carbon dynamics, providing information on the resilience of current peat deposits to climate change and changing peat conditions.

Abbott, G., Swain, E., Muhammad, A., Allton, K., Belyea, L., Laing, C., and Cowie, G. (2013). Effect of water-table fluctuations on the degradation of Sphagnum phenols in surficial peats. *Geochimica et Cosmochimica Acta* 106 (2013) 177-191 <http://dx.doi.org/10.1016/j.gca.2012.12.013>

Characteristics of dissolved organic matter in agricultural mineral soils in Boreal region

M.Sc. Noora Manninen¹, Ph.D. Oili Kiiikkilä¹, Ph.D. Helena Soinne², Ph.D. Sanna Kanerva¹

¹*University Of Helsinki, Helsinki, Finland*, ²*Natural Resources Institute Finland, Helsinki, Finland*

18 Division 2 Commission 2.2 :– Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

Soil organic matter consists of a wide variety of compounds that differ in their affinity to soil minerals and lability. The most mobile and readily degradable fraction of SOM is thought to be dissolved organic matter (DOM). DOM is a heterogeneous mixture of compounds that is continuously involved in dynamic soil processes driven by many physicochemical and biological factors. In mineral soils under agriculture, soil disturbance, fertilization, and the addition of organic amendments are likely to change the characteristics and dynamics of DOM. Agricultural soils, rich in organic matter, release DOM that discharges into surface waters, and the chemical properties of DOM determines the effects of it in the receiving waters. To understand its ecological role, DOM can be characterized by fractionating the compounds into groups according to their molecular weight, as carried out in peatlands previously. Ecologically, the most meaningful compound groups are aromatic compounds, proteins and carbohydrates, which we measured from different molecular weight fractions of DOM. Combining these two sets of analyses gives us relevant information about the degradability and mobility of DOM in agricultural mineral soils in Finland. Here we present preliminary results to assess whether different agricultural practices affect the fate of DOM, and whether it has potential adverse effects on surface waters when DOM is leached. Evans, L.R., Pierson, D. & Lajtha, K. (2020). Dissolved organic carbon production and flux under long-term litter manipulations in a Pacific Northwest old-growth forest. *Biogeochemistry*, 149: 75–86.

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Reponses of organic carbon fractions and phosphorus distribution at microscale to land use change in Amazonian Dark Earth and Acrisol

Dr. Steffen Schweizer¹, **Dr. Luis C. Colucho Hurtarte^{1,3}**, Alena Chilian¹, Irina Beer⁴, Dr. Aleksander Westphal Muniz^{5,6}, Prof. Christoph Müller^{6,7}, Dr. Gerrit Angst⁸, Dr. Carmen Höschen¹, Dr. Hiram Castillo-Michel³, Dr. Konstantin Gavazov⁹, Dr. Klaus A. Jarosch²

¹TU Munich, Soil Science, Freising, Germany, ²University of Bern, Bern, Switzerland, ³ESRF, Grenoble, France, ⁴TU Munich, Analytical Chemistry and Water Chemistry, Munich, Germany, ⁵Embrapa Amazônia Ocidental, , Brazil, ⁶Justus-Liebig University Giessen, Experimental Plant Ecology, , Germany, ⁷School of Biology and Environmental Science and Earth Institute, University College Dublin, Dublin, Ireland, ⁸Institute of Soil Biology and the Soil & Water Research Infrastructure, Biology Centre CAS, České Budějovice, Czech Republic, ⁹WSL, Biogeochemistry, Birmensdorf, Switzerland

18 Division 2 Commission 2.2 :- Biogeochemical cycles in the soil - processes linking the abiotic and biotic realms, Forth, August 4, 2022, 15:30 - 17:30

The conversion of tropical forest for cassava cultivation is known to decrease soil organic carbon (OC) and nutrient contents of highly weathered soils in the tropics. Amazonian Dark Earth (ADE) may be resistant to this degradation because of their historical anthropogenic amelioration leading to higher soil OC and P concentrations. In this study, we assessed the effect of land use change on OC dynamics under tropical conditions and how this is related with P distribution at the microscale. We analyzed ADE and an adjacent Acrisol from Manaus (Brazil), both under forest and cassava plantation. The land use change induced a decrease of OC related to both particulate and mineral-associated organic carbon. Simultaneously the P content decreased by approximately 80% by land use change, whereas the relative proportion of organic P increased. This indicates a legacy effect of anthropogenic amelioration in the ADE for P but not for OC. Land use change tightened the OC-P relations in the mineral-associated OC fractions, which was also reflected at the microscale. Using NanoSIMS we found μm -sized P hotspots that were more co-localized with OC-dominated areas by land use change. Correlative measurements with synchrotron-based $\mu\text{-XRF}$ and $\mu\text{-XANES}$ demonstrate a high spatial heterogeneity of different P species. A short-term incubation experiment with ^{13}C glucose showed a delayed and lower respiration through land use change. In our contribution, we will discuss distinct C and P interactions in microscale compartments and how these respond to land use change in highly weathered tropical soils.

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Radish growth and N₂O emissions using a N-enriched biochar-based fertilizer

Mr. Raúl Castejón-del Pino, Dr María Sánchez-García, Dr Miguel Angel Sánchez-Monedero, Dr Maria Luz Cayuela¹

¹Csic

23 Division 3 Commission 3.3 – Effects and processes of biochar and soil organic matter on plant nutrition, Lomond Auditorium, August 4, 2022, 15:30 - 17:30

Excess of reactive nitrogen applied to agricultural soils cause important environmental issues (Lassaletta et al., 2014), as the contamination of fresh water sources and the production of certain gases, such as ammonia (Ma et al., 2021) and nitrous oxide (Xu et al., 2021). The objective of this study was to evaluate the effectiveness of a N-enriched biochar as a slow release fertilizer, in comparison to a conventional N fertilizer on radish crop. A wood derived biochar was doped with N to produce a biochar-based fertilizer (Castejón del Pino et al., 2021). Plants were cultivated in soil pots inside a temperature-controlled greenhouse. Four treatments were tested: non-fertilized control soil, biochar-based fertilizer, urea and untreated biochar + urea. All treatments, except the control, received the same amount of N and were supplemented with P and K to reach plant requirements. The evolution of leaf width and length, number of leaves, radish diameter and crop yield were monitored as well as soil N₂O emissions. Further analyzes are being carried out to fully describe the N balance of the different treatments.

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Systematic analysis of biochar performance on plant growth in soybean cropping system at marginal area in Germany and China

Dr. Hua Ma¹, **Dr. Dilfuza Egamberdieva**², Dr. Ansong O. Richard³, Dr. Stephan Wirth², Prof. Sonoko D. Bellingrath-Kimura^{2,3}

¹Chongqing University, Chongqing, China, ²Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, ³Humboldt University of Berlin, Berlin, Germany

23 Division 3 Commission 3.3 – Effects and processes of biochar and soil organic matter on plant nutrition, Lomond Auditorium, August 4, 2022, 15:30 - 17:30

Soybean (*Glycine max* L.) is the most versatile plant in the agricultural system due to its high protein and oil content and the ability to associate rhizobium for biological nitrogen fixation (BNF). The cultivation of soybean is expanding on marginal areas. Special cultivation measures are required in those areas to facilitate sustainable cropping system establishment. This study used biochar as soil amendment material and aimed to investigate the potential effect of biochar and irrigation on soybean plant growth, crop yield formation, N budgets variation, plant nutrients uptake, and soybean-rhizobium symbiotic performance based on the analysis of soil structure, soil nutrients dynamics, and soil enzyme activities.

Our result indicated that 1) The biochar application caused a significant increase in the nodule number by 35% in the irrigated condition. 2) Shoot biomass, acid phosphomonoesterase (APM), and soil fluorescein diacetate (FDA) hydrolytic activity were significantly increased by irrigation. 3) Biochar increased soybean shoot biomass in loamy clay soil. 4) The soybean cropping system revealed a much less N deficit than the barley cropping system.

We conclude that 1) Biochar may enhance the soybean-rhizobium symbiotic performance in irrigated condition. 2) Sufficient water supply is crucial for plant growth, FDA hydrolytic activity, and APM activity in sandy soil. 3) The N uptake of soybean plants was likely more from BNF after biochar addition. 4) Biochar application may promote soybean plant growth in loamy clay soil. 5) Soybean cropping system is more flexible and sustainable than barley cropping system due to its more stable N budget.

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Biochar improves crop nutrient uptake and economic viability of tropical cropping systems

Prof Vincent Logah¹, Prof Janviewer Bashagaluke, Prof Joseph Sarkodie-Addo, Dr Andrews Opoku

¹*Kwame Nkrumah University of Science and Technology, Kumasi, Kumasi, Ghana*

23 Division 3 Commission 3.3 – Effects and processes of biochar and soil organic matter on plant nutrition, Lomond Auditorium, August 4, 2022, 15:30 - 17:30

There is limited research on biochar use under various cropping systems in sub-Saharan Africa. To bridge this gap, we assessed nutrient uptake, and crop yields under integrated application of biochar in selected cereal and legume-based cropping systems in Ghana. We also evaluated the economic viability of the integrated use of biochar using the value-cost ratio approach. The research was a field experiment conducted in 2016 and 2017 and comprised two factors (soil amendments and cropping systems). The soil amendments consisted of biochar (BC), NPK fertilizers, biochar+ NPK at half rate each [(50%(BC+NPK))], and a control. The cropping systems tested were sole maize, sole soybean, maize-soybean intercrop and sole cowpea. Our results showed that mineral fertilizers applied alone increased ($p < 0.05$) maize grain yield more than its combined application with biochar. Conversely, the combined application of biochar and NPK at half rates generally produced yields of cowpea and soybean, which were statistically at par ($p > 0.05$) with the yield obtained under sole 100% NPK rate. Generally, the 50% (BC+NPK) increased maize biomass yields more than the sole NPK and sole biochar applications. Nitrogen, phosphorus and potassium uptake in maize crop were greater in sole NPK and 50%(BC+NPK) under the sole cropping than in intercropping systems. The pecuniary benefit obtained from application of NPK exceeded the economic threshold ($VCR > 2.0$) from the cropping systems. For 50%(BC+NPK), economic viability was only obtained under intercropped system, signifying appreciable intercropping benefits under the integrated approach.

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Characterisation of Biochar: the Power of Combining FTIR and SEM/EDS Analysis

Ms Evelyne M Delbos¹, Dr A H Jean Robertson¹, Mrs Laura-Jane Strachan¹, Mrs Angela M Main¹

¹*The James Hutton Institute, Aberdeen, Scotland*

23 Division 3 Commission 3.3 – Effects and processes of biochar and soil organic matter on plant nutrition, Lomond Auditorium, August 4, 2022, 15:30 - 17:30

Much research has been done into the effects of additions of biochar to soil, and many studies are ongoing. However, when studying the processes of biochar within the soil, and the effects on plant nutrition, it is essential that the variable nature of biochar is considered. The many different starting materials and diverse conditions of pyrolysis can lead to products with widely varying chemical composition and morphology. These variations undoubtedly have a great impact on the functions of the biochar within the soil. For example, some biochars have a high carbonate content which will result in an increase in soil pH with the consequent changes in soil processes. A powerful means of characterisation of biochar is by combining the techniques of FTIR (Fourier Transform Infrared) spectroscopic analysis and SEM/EDS (Scanning Electron Microscopy/Energy-dispersive Spectroscopy) analysis. The FTIR is an analytical technique which can give the overall chemical profile or “fingerprint” of the material while the SEM/EDS analysis can provide high resolution imaging of the morphology and surface area of the biochars and their mineral constituents, together with a detailed measurement of the elemental composition. In this presentation we will illustrate how we have studied biochar samples using these methods and give examples of the differences in both chemical composition and morphology that can be detected.

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Biochar co-compost can promote sustainable agricultural intensification in highly weathered Ghanaian soils

Prof Kwame Frimpong¹

¹*University Of Cape Coast, Cape Coast, Ghana*

23 Division 3 Commission 3.3 – Effects and processes of biochar and soil organic matter on plant nutrition, Lomond Auditorium, August 4, 2022, 15:30 - 17:30

Addition of biochar pyrolysed from agricultural residues and domestic wastes composts offers potential improvements in soil quality, crop yield and nutritional qualities. In the past five years, we have conducted pot and field trials with soils amended with biochar (produced from corn cob or rice husk) solely, in combination with compost or inorganic fertilizer, or as biochar co-compost (at different biochar loading rates) on different crops (maize, lettuce, sweet potato, cowpea, cabbage, and amaranth). We found 11% to 35% yield increases for pineapple, and 150% and 800% increases for maize, with or without supplemental irrigation and nutritional composition improvements. We observed enhanced soil pH, cation exchange capacity, water-holding capacity, and greater release and uptake of micro and macro essential nutrients. Our studies showed that sole or combined applications of compost, biochar, or biochar co-compost increased aggregate stability against fast wetting by up to 33% compared to the un-amended control; increased the basal respiration by 200 %, and significantly decreased qCO₂, compared with the untreated plots. Biochar (20 tons/ha) application increased microbial biomass carbon (MBC) and nitrogen (MBN) by 83%, and 27%; potentially mineralizable carbon and nitrogen by 1.7 and 1.2 fold, respectively; active carbon by 253-270%, active nitrogen by 105-270%, and soil total organic by 37% -117% compared to the un-amended control. Soil carbon reduced depending on the stabilities of the organic materials added. In conclusion, biochar and/ or fertilizer addition increased crop yields and nutritional composition.

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Rapid response of soil functions to soil covers after rehabilitation of a Fly-Ash Landfill.

Mr Oscar Crovo¹, **Ph.D. Felipe Aburto Guerrero^{1,2,3}**, Mr Francisco Montecino¹, Mr Enzo Alvarez¹, Ms Natalia Aguilera^{1,3}, Mr Alejandro Atenas^{1,3}

¹INICIATIVA FORESTA NATIVA, Universidad de Concepción, Concepción, Chile, ²Department of Soil & Crop Sciences, Texas A&M University, College Station, USA, ³LISAB, Universidad de Concepción, Concepción, Chile

42 WG 3.3 – SUITMA: Soils of Urban, Industrial, Traffic, Mining and Military Areas, Alsh 1, August 4, 2022, 15:30 - 17:30

We tested the efficacy of different soil covers to accelerate the recovery of soil functions, such as C and nutrient cycling and erosion control in a fly ash landfill as preliminary assessments for restoration projects. The fly-ash was confined with geomembranes and covered with one meter of sandy-clay sediment mixed with compost. Five native tree species were planted in four plots considering different soil cover treatments (hydroseeding, traditional seeding, coconut fiber geomantle, and no cover).

We evaluated chemical soil indicators (C, N, and P total and available pools, pH, EC, CEC), microbial biomass, and physical indicators (bulk density, texture, and infiltration). These indicators were measured at three sampling intervals (0-20, 20-40, and 60-80 cm) immediately after plantation and for the following two years (n=117 per year). In addition, triplicated erosion plots for each cover were installed to quantify erosion control and runoff mitigation.

After two years, total carbon and nitrogen content significant increases were found at the 0-20 cm in contrast with year zero ($p < 0.01$) and in the 20 to 40 cm interval for nitrogen ($p=0.02$). In contrast, available nutrients showed a significant decrease in the first two depth intervals for the same period ($p<0.001$). The no-cover treatment showed significantly higher runoff and soil erosion ($p=0.04$) than the other three treatments.

Our results show that soil's chemical indicators are sensitive to different cover types and respond rapidly after one year of implementation. Additionally, all tested soil covers effectively reduced runoff and erosion compared to the control.

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Summary of four years of research on urban soils in Santiago de Compostela (Spain)

Dr. Remigio Paradelo Núñez¹, Dr. María Teresa Barral¹, Cecilia Herbón¹, María Roo¹, Dr. Xabier Pontevedra-Pombal¹, Dr. Eduardo García-Rodeja¹, Dr. María Celeiro², Dr. Carmen García-Jares², Dr. Maraike Probst³, Dr. María Gómez-Brandón⁴

¹*Departamento de Edafología e Química Agrícola, Universidade de Santiago de Compostela, Santiago de Compostela, Spain,* ²*Departamento de Química Analítica, Nutrición e Bromatoloxía, Universidade de Santiago de Compostela, Santiago de Compostela, Spain,* ³*Department of Microbiology, University of Innsbruck, Innsbruck, Austria,* ⁴*Grupo de Ecología Animal (GEA), Universidade de Vigo, Vigo, Spain*

42 WG 3.3 – SUITMA: Soils of Urban, Industrial, Traffic, Mining and Military Areas, Alsh 1, August 4, 2022, 15:30 - 17:30

The main results of a research project on the morphology, classification, physical, chemical and biological properties and pollution of the urban soils in Santiago de Compostela (northwestern Spain) are presented. Several classes of soils exist in the city, including soils developed on naturally-deposited materials, which are classified as Umbrisols and Leptosols, and soils developed on “anthropic” human-altered and transported materials, classified as Skeletic Regosols, Urbic Technosols and Ekranic Technosols. In general, the soils of the city are acid, rich in organic matter, with medium to coarse textures dominated by sandy loams, with presence of poorly-crystalline Fe and Al compounds. As a result of high organic matter and Fe contents, the soils present high aggregate stability and infiltration rates, with variable compaction issues depending on land use, although erosion risk is overall low. The typically high soil heterogeneity of urban ecosystems is the main driving force of soil microbiome characteristics: whereas microbial activity is strongly determined by soil organic matter content, factors such as soil pH and land use are more decisive for shaping microbial community composition. Regarding pollution, PAH concentrations are overall low and in the range of other cities with similar size and population density. Heavy metals and As are present in concentrations higher than natural backgrounds, although heavily polluted soils do not happen. Concentrations of Pb, Cu and Zn are clearly related to anthropic sources, whereas Cr and Ni are from lithological origin, mainly associated to the presence of amphibolites. Urban ecosystems; Urban soils; Soil health; Soil pollution; Microbial communities.

Fostering a sustainable use of soil and enhancing food quality and safety in urban agricultural areas of Naples

Dr Antonio Giandonato Caporale¹, Dr Marina Ceruso², Dr Luigi Ruggiero¹, Prof Paola Vitaglione¹, **Prof. Paola Adamo¹**

¹Department of Agricultural Sciences, University of Naples Federico II, Naples, Italia, ²Department of Veterinary Medicine and Animal Productions, University of Naples Federico II, Naples, Italy

42 WG 3.3 – SUITMA: Soils of Urban, Industrial, Traffic, Mining and Military Areas, Alsh 1, August 4, 2022, 15:30 - 17:30

Urban soil is a non-renewable resource, threatened by anthropic activities, infrastructure sprawl and sealing. UrbanSoilGreening project (financed by the University of Naples Federico II through the Programma per il Finanziamento della Ricerca di Ateneo 2020 - Linea A) aims to: i) assess soil properties/fertility and crop quality in urban agricultural areas of Naples, selected on geographical distribution and proximity to potential sources of contamination; ii) increase public awareness on soil ecosystem services and social benefits of urban farming; iii) disseminate guidelines for a proper and sustainable management of urban green spaces. The project thus tackles the main issues of urban farming, such as soil degradation/contamination, loss of ecosystem services and food safety. Soil characterisation evidenced sandy-loam texture, neutral-to-sub-alkaline pHs and overall good fertility in terms of organic matter content, cation exchange capacity and availability of macro and micronutrients. As well, a low-to-moderate bioavailability of potentially toxic elements such as copper, lead and zinc was found. After soil characterisation, crop species were planted and managed by site-specific sustainable cultivation practices, such as organic farming and synergistic techniques. On-site composting of vegetable waste was encouraged to promote the circular economy. The active involvement of local citizens and associations in crop growing phases makes these vegetable gardens pleasant meeting places for the neighbourhood, favouring social aggregation. Ongoing chemical and microbiological analyses are evaluating food quality (content of minerals and bioactive compounds such as polyphenols, carotenoids and vitamin E) and safety (possible presence of contaminants and pathogenic microorganisms such as *Listeria* and *Salmonella* spp).

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Pb and Sb transfer processes in soils contaminated by ancient mining activities in the Pb-Ag mine of Peisey-Nancroix (France)

Ms Floriane Guillevic¹, Magali Rossi¹, Jérôme Poulenard¹, Fabien Arnaud¹, Eléonore Resongles², Rémi Freydier², Cécile Quantin³, Gaël Monvoisin³

¹EDYTEM, University of Savoie Mont-Blanc, CNRS, Chambéry, FRANCE, ²HSM, University de Montpellier, CNRS, IRD, Montpellier, FRANCE, ³GEOPS, University of Paris-Saclay, CNRS, Gif-sur-Yvette, FRANCE

42 WG 3.3 – SUITMA: Soils of Urban, Industrial, Traffic, Mining and Military Areas, Alsh 1, August 4, 2022, 15:30 - 17:30

The former Pb-Ag mine of Peisey-Nancroix (Northern French Alps, 1644-1866) is an excellent target to study the long-term environmental impacts of former mines and the processes of trace metals (TMs) dispersal and persistence in the critical zone.

6 soil profiles were sampled along a contamination gradient downward mine wastes to investigate the vertical and horizontal dispersal of TMs. For each profile, the highest TMs content is observed in the sub-surface horizon. The most contaminated profile is the closest to the slag heap; it contains 840 mg/kg to 3.6% Pb and 16 to 300 mg/kg Sb. The least contaminated profile contains 123 to 531 mg/kg Pb and 2,6 to 5 mg/kg Sb. There the deepest sample horizon has a Pb content similar to the background (ca. 80 to 120 mg/kg Pb and ca.2 mg/kg Sb). TMs contents rapidly decrease vertically and horizontally suggesting a very localized contamination.

Mineralogical observations allow to discuss the processes involved in TMs dispersal and their possible remobilization. Slags fragments and galena were only identified in the vicinity of the waste heaps suggesting limited particle translocation. Pb-rich Mn-Fe (hydr-)oxides are the most common Pb-bearing minerals; their occurrence suggests lixiviation and precipitation of Pb at the scale of the study area. Similarly, Pb adsorbed on organic matter and clays suggest Pb lixiviation and reprecipitation. These phases are the most likely to be remobilized downward.

Additionally, Pb and Sb isotopes have been used as proxies to constrain the anthropogenic contamination.

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