# Newsletter 3 - January 2024

Did you know that just even a tiny amount of soil can contain 1 billion microbes? These microbes are vital to ecosystem functions. But what happens when climate change begins to affect the soil and those ecosystem functions? This is where the MICROSERVICES project, an international multidisciplinary research project funded under the ERA-NET COFUND scheme BiodivERsA enters. In order to study the effects of climate change on the dynamic crop-soil-microbiome system, a combination of natural climate gradients and in-situ field manipulations are being used. To learn more about our project, make sure to take a look at our new project video, available on our website: https://www.microservices.ethz.ch/
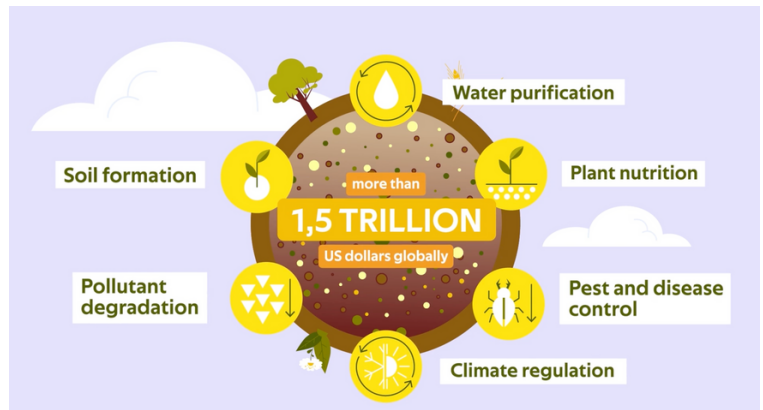
PROJECT RECAP

The main goal of the MICROSERVICES project is to improve the forecasting capacity of the cascading effects of climate change on:
- soil microbial diversity,
- crop-microbe interactions, and
- agricultural ecosystem services delivered by the microbiome in wheat cropping systems.

This is done in the hopes of actively contributing to a sustainable agricultural sector:
- fostering widespread benefits across the agricultural economy, society, and environment,
- positively impacting conservation,
- raising public and political awareness of the importance of soil biodiversity for sustainable agriculture and
- establishing interactions between research institutions, agricultural stakeholders and policymakers via policy briefs to influence policy agendas at the national and European level

The project tasks are divided across 6 Work Packages (WPs):
- WP1: Project management and stakeholder involvement
- WP2: Establishing natural climate gradients in Europe with forecasted progression through Earth Observation based regional climate models
- WP3: Assessing patterns of cropland-associated microbiomes, crop-microbe interactions, and ecosystem multifunctionality across the European Climate gradients
- WP4: Using in-stiu field manipulation to simulate the effect of drought on the crop-soil-microbiome nexus under different long-term agricultural management regimes
- WP5: Evaluating machine learning algorithms to make predictions on climate-related shifts in biodiversity and associated ecosystem services
- WP6: Dissemination, outreach and policy impact

PROJECT METHODOLOGY

The MICROSERVICES project is a multidisciplinary project, bringing together various types of expertise and methodological knowledge in order to tackle a global challenge.

Addressing global sustainability-related issues at the intersection of economy, society, and environment requires refining the institutional research structure and leveraging global expertise and know-how through a transnational and transdisciplinary approach. Climatic threats to soil biodiversity can only be addressed through a collective approach. This allows for more accurate guidance in shaping climate change adaptation strategies.

Within the MICROSERVICES consortium, consortium members cover a wide range of expertise:

- Earth-observation (EO) -based climate modelling to predict region-specific future climatic conditions across Europe (WP2)
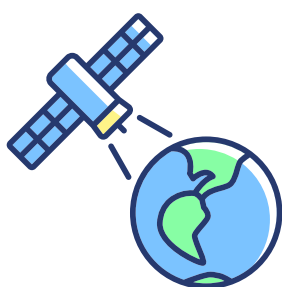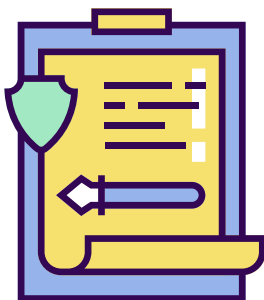

Earth observation
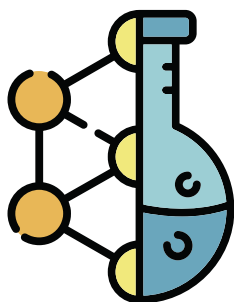
Molecular analysis

Machine learning forecast

Policy work

- Various molecular approaches to monitor diversity and functioning of the microbiome (WP3 and WP4, respectively);
- Machine learning regression models to forecast the delivery of ecosystem services by the crop microbiomes in response to future climatic conditions (WP5);
- Participatory methods in order to engage with an extensive network of both stakeholders and policymakers across the continent (WP6).

On an individual level, the project brings together experts with a specific set of skills, from environmental sciences, to computational sciences, and social sciences.

On top of this, the indirect added value of having such a transnational team relies on considering differentiating view points of project partners as a strength and source of additional knowledge, fostering a European identity through research, and acquiring a new set of skills and capacities that can influence decision making processes across scales.

PROJECT MEETING - DEC/2023

Project partners got together late last year in Zurich to discuss updates on project progression as well as look to the future and adequately plan out the remainder of the project work. The project has made considerable progress since the last meeting and traction is building across the various WPs.

WP3: Assessing Wheat Microbiome

LEITAT presented the progress of the soil biodiversity assessment in LUCAS (the EU's main soil dataset) and its link to climate projections. This included 214 sites from non-permanent croplands, with bacteria and fungi biodiversity assessments, as well as bioclimate and soil multifunctionality data. The outcomes:

- **Microbiome:** the analysed data was restricted to bacteria and fungi, which showed an impact in the community's composition by the agroclimate region in non-permanent croplands. This highlighted a climate gradient observation in microbial biodiversity.
- **Soil multifunctionality:** these are plant productivity, soil/vegetation moisture, soil fertility, soil structure, and organic decomposition. It was found that several soil functions are significantly correlated to soil physico-chemical properties and some bioclimatic variables.

A potential collaboration with another EU project was discussed, as they also use the LUCAS dataset.

WP4: Experimental Drought Scenarios

- **ETH:** All analysis of the DOK trial data (incl. metagenomes and soil fractions if time allows) are on track, and now working on statistical analyses and the possibility of paper writing;
- **UoK:** There is progress in Cmic and EPS in the sampling plot and Cmic, EPS and amino sugars in the microplots - results shown to partners in December;
- **INRAE:** First data set on N-cycling communities (sequencing data) is presented, with a clear effect of farming on bacterial communities and that there is no effect of drought

Figures: Impressions from the rainout-shelter experiment in the DOK long-term trial in 2022 at stem elongation and flowering.

WP5: Machine Learning

WP leaders LEITAT presented the results of their computational progress, showcasing that currently, medium to high correlations values exist between climate variables, microbial biodiversity, and soil functions. Initial training models have achieved commendable accuracy and error levels, which could be improved with a better hyperparametrization. Indeed, it was recommended that alternative methodologies should be used as well as expand to other type of land-use datasets and regression models.

WP6: Outreach

WP co-leaders ELO would like to add a section of the website entitled "Literature" that contains further literature so that audience members can learn more on the topic. The project video has been released and and shown to the consortium. A science-policy-society taskforce is in discussion, with MICROSERVICES being presented becoming a possibility.

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MICROSERVICES

PROJECT PARTNERS

ETH Zurich is a national centre for education and one of the driving forces behind industrialisation in Switzerland. The Sustainable Agroecosystems Group (SAE) at the Institute of Agricultural Sciences in the Department of Environmental Systems Science (D-USYS) is coordinating the MICROSERVICES .

The research of the group focuses on the feedback between ecosystem management, global change, and biogeochemical cycling. It studies the complex interactions between plants, soil biota, and the carbon and nitrogen cycles in terrestrial ecosystems, especially agroecosystems.

Agroscope is the Swiss centre of excellence for agricultural research, and is affiliated with the Federal Office for Agriculture (FOAG). The organisation researches along the agriculture and the food sector. Its goals are a competitive and multifunctional agricultural sector, high-quality food for a healthy diet, and an intact environment. Agroscope researches the continued productivity of the agricultural sector under changed climate conditions. With this, it optimises agricultural production and plant protection according to agroecological principles.

The National Observatory of Athens (NOA) partakes in basic and applied research, the development of services provided to the Greek State and society at large, and the promotion and popularisation of science. It is committed to acquiring and processing data through measurements and computational tools, conducting relevant studies and enhancing provision of innovative services, and providing information and support to public authorities, the private and public sectors, and the general public. It currently operates more than 550 land-based measurement stations for acquiring high-fidelity data. NOA monitors for natural disaster and humanitarian crises management.

INRAE is France's new National Research Institute for Agriculture, Food & Environment, and performs valuable research on numerous topics, including regional agricultural strategies and biodiversity restoration, using research, innovation, and support for public policies as tools to guide the emergence of sustainable agricultural and food production systems.

It also takes into consideration regional issues such as living conditions, farmers' salaries, the economic competitiveness of companies, land use, and universal access to healthy and varied diets.

The University of Kassel (UoK) (DE) is characterized by its openness to new ideas in every single area of its work on nature, technology, culture, and society relating to the future of the planet and humanity's existence such as globalisation, climate change, environmental protection as well as questions regarding the evolution of technical systems, searching for sustainable answers to most important contemporary questions.

LEITAT (ES) is a non-profit organization specialised in production technologies in the areas of material sciences, environment, surface treatments, biotechnologies & low carbon energies for technologic transfers to industrial sectors for sustainable social, environmental, economic & industrial value to companies. It contributes to building fast, efficient, and sustainable growth

The European Landowners Organization is a federation of national landowner associations (landowners, land and forest and building managers, and rural entrepreneurs) from the EU27, representing their interests at the European political level. Its aim is to defend and promote sustainable development, environmental protection, cultural heritage, and responsible use of natural resources. It gathers together rural actors (managers, scientists, political decision-makers, businesses etc.) across sectors, at local, regional, national and European levels through its extensive network, voicing positions shared by a huge number of stakeholders, as well as to analyze the local effects of the implementation of the EU legislation.

PUBLICATIONS AND OUTREACH

As mentioned previously, it was at the meeting in Zurich in December 2022 that it was announced that NOA had published an academic paper utilising the methodologies presented in WP2 of the project. Their paper is titled "Towards assessing agricultural land suitability with causal machine learning" and was co-authored by Georgis Giannarakis, Vasileios Sitokonstantinou, Roxanne Suzette Lorilla, and Charalampos Konteos in EARTHVISION 2022. The open-access paper can be found in this link here and the journal can be found here. It's abstract:

Understanding the suitability of agricultural land for applying specific management practices is of great importance for sustainable and resilient agriculture against climate change. Recent developments in the field of causal machine learning enable the estimation of intervention impacts on an outcome of interest, for samples described by a set of observed characteristics. We introduce an extensible data-driven framework that leverages earth observations and frames agricultural land suitability as a geospatial impact assessment problem, where the estimated effects of agricultural practices on agroecosystems serve as a land suitability score and guide decision making. We formulate this as a causal machine learning task and discuss how this approach can be used for agricultural planning in a changing climate. Specifically, we extract the agricultural management practices of "crop rotation" and "landscape crop diversity" from crop type maps, account for climate and land use data, and use double machine learning to estimate their heterogeneous effect on Net Primary Productivity (NPP), within the Flanders region of Belgium from 2010 to 2020. We find that the effect of crop rotation was insignificant, while landscape crop diversity had a small negative effect on NPP. Finally, we observe considerable effect heterogeneity in space for both practices and analyze it.

TEDx TALK

Our very own coordinator, Dr. Martin Hartmann, presented a TED talk in June 2023 entitled "A colorful tapestry in sustainable agriculture". The caption reads:

"Agricultural intensification is threatening the functioning of our soils as the basic life support system of our planet. Organic agriculture has the potential to regenerate our soils, but it alone cannot meet the global food demand. Future sustainable agriculture therefore requires a colorful tapestry of different solutions to meet global food demand while preserving our planet [...]". Here is the video: https://www.youtube.com/watch?v=reuxjhlGw04

FUTURE NEWSLETTERS

Make sure to stay tuned on our Twitter/X account and website for the release of more information and upcoming newsletters. Our project newsletters are expected to be released every six months and will focus on project updates, interesting aspects of the project, as well as further input from the partners! For any further questions, please email coordinator Martin Hartmann at martin.hartmann@usys.ethz.ch

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DEFINITIONS

- **Agroclimatic zone:** land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use. (FAO)

- **Agroecosystems:** cultivated ecosystems, generally corresponding to the spatial unit of a farm and whose ecosystem functions are valued by humans in the form of agricultural goods and services. It is thus co-produced by nature and humans. (Dico Agroecologie)

- **Amino sugars:** An amino sugar is a sugar molecule wherein the hydroxyl group is replaced by an amine group. It is also referred to technically as 2-amino-2-deoxysugar. There are about sixty amino sugars that have been identified and the predominant amino sugar is N-aceylglucosamine (Biology online)

- **Biodiversity:** Variety of life at genetic, species, and ecosystem levels (FAO)

- **CMIC (Chemical Microbial Influenced Corrosion):** micro-organisms are producing an acid; this acid has corrosive properties and ensures that elemental iron is subsequently converted into other forms (Corrosion Alliance)

- **Diversity (Alpha):** diversity on a local scale, describing the species diversity (richness and evenness) within a functional community. For example, alpha diversity describes the observed species diversity within a defined plot or within a defined ecological unit, such as a pond, a field, or a patch of forest. The scale of such ecological units depends on the organism group of interest (Andermann et al. 2022)

- **Diversity (Beta):** amount of differentiation between species communities across space and time (Andermann et al. 2022)

- **DOK trial:** The DOK trial was set up as a comparative study of conventional and organic agriculture. The aim was to determine whether organic farming is able to perform in the long term and keep pace with conventional agriculture in terms of yield and crop quality. (Agroscope).

- **Earth Observation:** Earth Observation (EO) refers to the use of remote sensing technologies to monitor land, marine (seas, rivers, lakes) and atmosphere. Satellite-based EO relies on the use of satellite-mounted payloads to gather imaging data about the Earth's characteristics. (EUSPA)

- **Ecosystem services:** the benefits provided by ecosystems to humans (FAO)

- **EPS:** extracellular polymeric substances (Di Martino 2018)

- **Hyperparameters:** parameters whose values control the learning process and determine the values of model parameters that a learning algorithm ends up learning. (Towards Data Science, 2020)

- **In-situ:** In the natural or original position or place (Mariam Webster Dictionary)

- **LUCAS (soil data set):** 'Land Use/Cover Area frame statistical Survey Soil' (LUCAS Soil) is an extensive and regular topsoil survey that is carried out across the European Union to derive policy-relevant statistics on the effect of land management on soil characteristics. (Orgiazzi et al. 2018)

- **Machine learning:** field of artificial intelligence that allows systems to learn and improve from experience without being explicitly programmed. (Great Learning)

- **Microbe:** tiny living things that are found all around us and are too small to be seen by the naked eye. They live in water, soil, and in the air (National Center for Biotechnology Information)

- **Microbiome:** a characteristic microbial community occupying a reasonable well-defined habitat which has distinct physio-chemical properties. The microbiome not only refers to the microorganisms involved but also encompass their theatre of activity, which results in the formation of specific ecological niches (Berg et al. 2020).

- **Symbiosis:** the living together in more or less intimate association or close union of two dissimilar organisms (Merriam-Webster Dictionary)

- **Transdisciplinarity:** inclusion of non-academic stakeholders in the process of knowledge production (Rigolot, 2020)