SOILRES: an on-farm, variability-centred project to translate biodiversity-based soil health innovations into precision management

M. Canicatti, D. Cammarano

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

A paper from the Proceedings of the
17th International Conference on Precision Agriculture and 11th Brazilian Congress on Precision and Digital Agriculture
13-15 July 2026
Porto Alegre, Brazil

Abstract.

SOILRES (Multi-Faceted Biodiversity Integration for a Healthy Soil and Resilient Crop Management) is a Horizon Europe project. It aims to improve soil health by a combination of agroecological practices and soil improvers which will be tested in on-farm experiments and monitored with proximal and remote sensors, as well as modelling. On-farm experiments are implemented through six use cases spanning Europe's major pedo-climatic zones: Atlantic (Denmark), Boreal (Finland), Continental (France), Pannonian (Hungary), and Mediterranean (Italy and Portugal), across arable systems including wheat, maize, barley, peas and sunflower.

A key bottleneck for regenerative and agroecological transitions is the strong within-field and between-field variability of soil physical, chemical and biological functioning. Uniform management can mask degradation hotspots, dilute treatment effects, and reduce the cost-effectiveness of soil improvers. This project will implement on-farm frameworks specifically designed to characterise, explain and manage soil health variability, with direct relevance for precision and digital agriculture.

SOILRES adopts an explicit "on-farm first" approach. Through National Task Forces and co-design workshops, farmers, advisors, researchers and policymakers jointly define practical indicators, sampling densities and decision thresholds that can be embedded in routine farm operations. The variability-centred workflow will integrate (i) stratified soil sampling and rapid in-field indicators, (ii) proximal sensing (e.g., apparent electrical conductivity and soil moisture mapping), and (iii) multi-source Satellite and UAV-based products, coupled with weather and management records.

Within each use case, biodiversity-based interventions, such as crop diversification, cover crops, intercropping, reduced or strip tillage, compost and biochar options, integrated pest management, and microbial bioinoculants and biostimulants, are evaluated not only for their mean effects on soil and crop performance, but also for their capacity to reduce or manage heterogeneity, stabilise productivity under weather extremes, and improve nutrient-use

efficiency. Variability-centric metrics (e.g. spatial components and stability indices) are used to translate observations into monitoring dashboards and actionable management strategies.

Outputs (maps, zone definitions and variability dashboards) are delivered through a user-friendly web platform to support site-specific recommendations, monitoring productivity, soil health trajectories, and scalable best-practice tailored to local conditions.

Overall, by integrating multi-actor co-creation, on-farm trials across contrasting pedo-climatic zones, and advanced digital tools for soil health and biodiversity assessment, SOILRES will contribute to the generation of scientific evidence and validated strategies that inform sustainable soil and crop management under real farming conditions.

Keywords.
Soil health, biodiversity, on-farm experimentation, spatial variability, proximal sensing, remote sensing, precision agriculture, Horizon Europe.

Introduction

Soil degradation is accelerating across Europe, driven by the overuse of synthetic inputs and unsustainable management, with serious consequences for food security and for the capacity of agricultural soils to act as natural climate defences. Biodiversity-based practices, including crop diversification, cover cropping, reduced and strip tillage, organic amendments such as compost and biochar, and microbial bioinoculants and biostimulants, are promising levers to restore soil functioning, but their adoption is hampered by inconsistent performance across and within farms. A key and often overlooked bottleneck is the strong within-field and between-field variability of soil physical, chemical and biological properties (Bünemann et al., 2018). Under uniform management, this heterogeneity can mask degradation hotspots, dilute the measured effects of treatments, and reduce the cost-effectiveness of soil improvers.

SOILRES (Multi-Faceted Biodiversity Integration for a Healthy Soil and Resilient Crop Management) is a Horizon Europe project that addresses this bottleneck by combining agroecological practices and soil improvers with monitoring frameworks explicitly designed to characterise, explain and manage soil health variability. This short paper presents the design of the project's on-farm network and its variability-centred monitoring workflow, and outlines its relevance for precision and digital agriculture.

The SOILRES On-Farm Network

The consortium brings together 21 partners from 10 European countries and Jordan. Innovations are tested directly in farmers' fields through six use cases (UCs) and seven demonstration sites that are representative of the main crops and pedo-climatic zones of Europe (Fig. 1): Atlantic (UC1, Denmark: perennial cropping systems with microbial biostimulants), Boreal (UC2, Finland: minimum tillage, intercropping and cover cropping with green manure and inoculants), Continental (UC3, France: strip cropping and agro-prairies with biostimulants), Pannonian (UC4, Hungary: intercropping, soil cover and reduced tillage), and Mediterranean (UC5, Italy: strip tillage on living mulch with compost-based inputs, amendments and biochar; UC6, Portugal: cover cropping and minimum tillage with inoculants). Target arable systems include wheat, maize, barley, oats, peas, rapeseed, sunflower, soybean, sorghum and forage crops.

SOILRES adopts an explicit "on-farm first" approach. Farmers were involved from the proposal stage, and National Task Forces and co-design workshops bring together farmers, advisors, researchers and policymakers to jointly define practical indicators, sampling densities and decision thresholds that can be embedded in routine farm operations, increasing the likelihood that the resulting tools are both technically sound and operationally feasible.

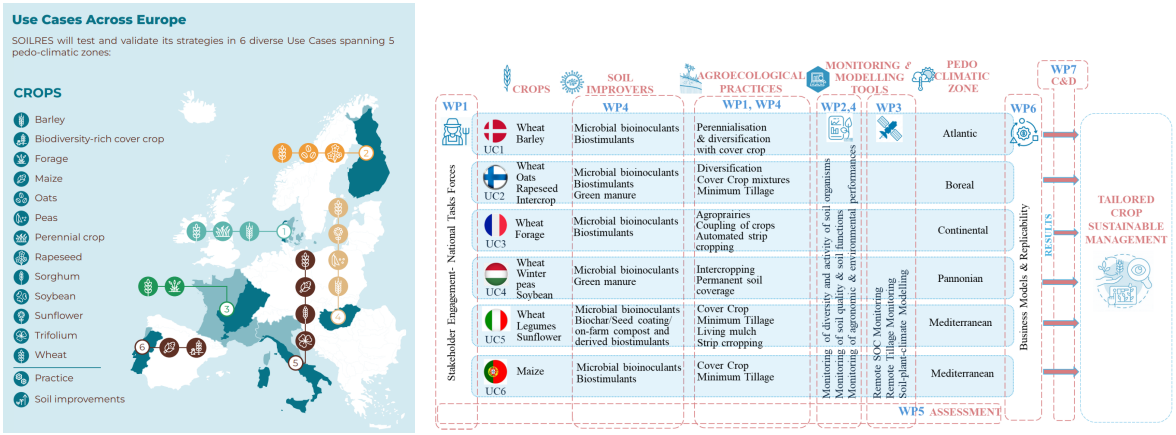

Fig 1. The six SOILRES use cases across five European pedo-climatic zones, with the crops, practices and soil improvers tested at each demonstration site.

A Variability-Centred Monitoring Framework

Within each use case, a common workflow integrates three complementary data streams: (i) stratified soil sampling and rapid in-field indicators of soil functioning; (ii) proximal sensing, such as apparent electrical conductivity and soil moisture mapping, to resolve within-field patterns at high spatial density; and (iii) multi-source satellite and UAV-based products (Mulla, 2013), coupled with weather and management records. Sampling is stratified according to the spatial structure revealed by sensing layers, so that laboratory analyses are concentrated where they are most informative.

Crucially, the biodiversity-based interventions are evaluated not only for their mean effects on soil and crop performance, but also for their capacity to reduce or manage heterogeneity, stabilise productivity under weather extremes, and improve nutrient-use efficiency. Variability-centric metrics, such as spatial variance components and temporal stability indices, are therefore treated as primary response variables alongside conventional agronomic indicators.

From Monitoring to Decision Support

Observations are translated into maps, management zone definitions and variability dashboards delivered through a user-friendly web platform, in line with the broader vision of digital agriculture as a means to design sustainable agricultural systems (Basso & Antle, 2020). These outputs support site-specific recommendations, the monitoring of productivity and soil health trajectories, and the identification of scalable best practice tailored to local pedo-climatic conditions, contributing directly to the objectives of the EU Green Deal and the Farm to Fork strategy.

Summary

By integrating multi-actor co-creation, on-farm trials across contrasting pedo-climatic zones, and advanced digital tools for soil health and biodiversity assessment, SOILRES will generate evidence and validated strategies for sustainable soil and crop management under real farming conditions, demonstrating how precision agriculture can accelerate the adoption of biodiversity-based soil health innovations.

Acknowledgments

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101218994.

References

Basso, B., & Antle, J. (2020). Digital agriculture to design sustainable agricultural systems. Nature Sustainability, 3(4), 254–256.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., et al. (2018). Soil quality – A critical review. Soil Biology and Biochemistry, 120, 105–125.

Mulla, D. J. (2013). Twenty five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. Biosystems Engineering, 114(4), 358–371.