Shaping the future of soil health: The Spanish Living Lab's role in sustainable agriculture

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Keywords: Soil health, Living Labs, Food industry by-products, Collaborative innovation, Sustainable agriculture

1. Introduction

Soil health, defined by optimal chemical, physical and biological conditions of soils, is crucial for food and biomass production[1]. Nowadays, around 50% of arable lands in Europe are considered as 'unhealthy' due to moderate and severe erosion[1], leading to annual agricultural losses of €1.25 billion. Additionally, 24% of food produced in the European Union (EU) is wasted, primarily during processing stages[2]. To combat these issues, food processing residues can be converted into recycled fertilizers or soil improvers, enhancing soil health through circular bioeconomy practices and improving the sustainability of the food production system. A promising solution lies in the implementation of living labs, which foster co-creation and innovation. These collaborative environments offer opportunities to develop and test solutions for soil health to address soil health challenges effectively. In line with the **Soil Deal for Europe's** goal, which aims to establish 100 Living Labs (LLs) and Lighthouses (LHs) across the EU[3], these initiatives are key to scaling sustainable practices and improving soil health.

In this context, DeliSoil project (GA: 101112855) aims to establish 5 LLs around Europe, including in Finland, Denmark, Germany, Italy and Spain, to develop advanced solutions for the valorization of food industry residues and create safe and sustainable soil enhancers and fertilizing products. Each living lab will assess the feasibility of the technologies used to transform the residues, as well as quality, safety and agronomic potential of the end products, while considering sustainability end environmental impacts and potential technical, legal, social and economic barriers (Figure 1). The progress made in the Spanish LL will be highlighted as an example of how local advances are contributing to the overall project goals.

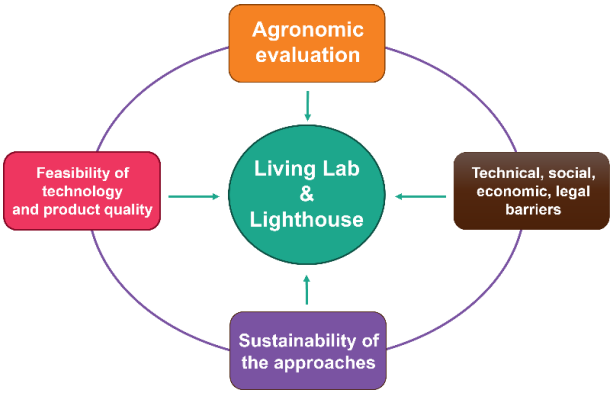

Figure 1. Global overview of activities in each living lab within the DeliSoil project.

2. Establishment of the Spanish Living Lab

The Spanish LL, based in Catalonia (Northeast Spain), focuses on processing mix-food residues using five innovative technologies: anaerobic digestion (AD), solid-state fermentation (SSF), composting, pyrolysis and non-thermal atmospheric plasma (NTAP) (Table 1). Key aspects monitored include feedstock characterization, operational parameters, and product quality. Additionally, the safety of the products is being analyzed, particularly regarding heavy metals and biological hazards. The products derived from these technologies are being tested in pot and field trials to evaluate their effectiveness on plant growth and soil quality. Stability of the products will

also be evaluated using soil respirometry. These trials will provide essential data on how each product contributes to soil improvement, supporting the LL's goal of developing safe, sustainable and effective soil enhancement solutions.

Table 1. Summary of technologies proposed within the Spanish LL of the DeliSoil project.

Technology	Feedstock	Operational mode	Product
Anaerobic digestion	Mix food processing residues, manure, dairy	Continuous	Pelletized digestate
SSF	Agro-industrial residues (vegetable milk residues, meat processing residues)	Batch	Biostimulants (sugar-based/protein hydrolysates)
Composting	Mix food processing residues (meat processing)	Batch	Compost
Pyrolysis	Agricultural wastes (Brewer spent grain/juice bagasse)/meat processing wastes/fish processing wastes	Batch	Biochar
NTAP	Agro-industrial residues (potato and red beet processing residues)	Batch	N-rich fertilizer

3. Stakeholder's engagement

The LL has adopted a **multi-stakeholder approach** based on the quadruple helix model, integrating actors from industry, policy, society, and academia. This includes food processing industries, waste management companies, agricultural training schools, policymakers, universities, and research centers. A regional working group has also been created to align project objectives with local needs and co-develop tailored solutions for soil health. The aim is to create a collaborative platform for sharing insights from technology monitoring and product testing activities. To achieve this, dissemination activities such as training sessions, workshops, and webinars will support collaboration, enabling the group to refine strategies and co-create impactful solutions by leveraging their expertise. This approach will allow stakeholders to co-develop practical solutions and refine strategies to improve soil health, encouraging active participation and fostering a deeper understanding of the project's goals.

4. Conclusions and further steps

To sum up, the Spanish LL serves as a vital platform for developing innovative solutions to improve soil health. Through technology monitoring technologies and agronomic testing, it provides insights that guide the adaptation and enhancement of its strategies. Upcoming dissemination activities will engage stakeholders, promoting knowledge exchange and collaboration. This will ensure practical, scientifically grounded solutions with input from industry experts, academics, policymakers and end-users. Additionally, the LL will support the co-creation of sustainable practices for long-term agricultural resilience and soil health.

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Acknowledgements

This research is funded by the HORIZON EUROPE research and innovation actions program, in the topic HORIZON-MISS-2022-SOIL-01-02 (Grant Agreement No. 101112855).