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Living labs as collaborative action for soil health: examples in Sweden for agriculture, forestry and urban land

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Summary

Soil degradation remains a critical challenge across Europe, threatening environmental sustainability, agricultural productivity, and human well-being. In response, the European Commission's Mission Soil initiative aims to establish 100 Living Labs (LL) and Lighthouses by 2030 to promote innovative and sustainable soil management. Living Labs are defined by three core principles: co-creation, user-centered innovation, and real-world setting, enabling diverse stakeholders to jointly develop, test, and scale solutions that address soil-related challenges and soil health.

This report explores how the principles of LL are reflected in three existing Swedish multi-stakeholder initiatives across agricultural, forestry, and urban contexts. The objective is to assess how these collaborations align with the Living Lab concept, and to identify their potential contributions to the Mission Soil goals for soil health.

Using a criteria-based qualitative analysis, the report evaluates how these initiatives operate as real-life platforms for soil health innovation. The case studies have been developed at different time, ranging from well-established initiatives to more recent ones, reflecting the temporal evolution of the approaches considered in the three cases.

The findings indicated that all three cases demonstrate strong alignment with key Living Lab principles, such as fostering cross-sector collaboration, engaging end-users, and innovation in real-life settings. The cases showed contributions to environmental and social outcomes, including improved biodiversity and soil health, and increased public awareness. Each initiative displayed development of practical tools, co-created knowledge, and tested solutions tailored to local needs that support regional development. While approaches and context vary, the challenges are similar around a long-term financial stability.

Overall, the report highlights how existing efforts in Sweden can contribute to Mission Soil agenda for soil-focused Living Labs across Europe, thereby supporting sustainable land management and innovation ecosystems.

For researchers, these three case studies underscore the role of applied, interdisciplinary research in promoting soil health in real-world setting. Policymakers can draw lessons on mobilizing frameworks that support regional collaboration, participatory methods, co-innovation processes, and scaling pathways.

Keywords:

Soil health, Living Labs, Existing initiatives, Multi actor collaboration, Swedish context.

1. Introduction

Soils health has received growing attention across Europe due to their critical role in supporting societal well-being, ecosystem functioning, and climate change mitigation. Yet, soils are considered to be at risk, globally and in Europe. Latest estimate suggests 60-70% of soils in the EU are considered unhealthy based on the soil degradation indicators [1]. This highlights the urgent need to restore and manage soil health to achieve multiple environmental, social, and economic benefits.

In response, the European Commission launched the *Mission Soil* initiative, which aims to establish 100 Living Labs and Lighthouses across Europe by 2030 to address agricultural, urban and natural /forest / grassland soil health issues (European Commission, A Soil Deal for Europe [2]). However, the application of Living Labs and Lighthouses as mechanisms for promoting soil health remains relatively new approach within research, policy, and practice.

At the same time, many existing initiatives and actor in various networks, in agriculture, forestry, and urban development, are already engaging in collaborative efforts to improve interconnected environmental and societal issues, including soil health. These initiatives often take the form of co-creation platforms that bring together stakeholders with diverse knowledge to address complex problems and facilitate mutual learning. Nevertheless, the concept of a "Living Lab" is defined with varied definitions and frameworks. This raises a key consideration: to what extent can existing initiatives be considered as Living Labs, and how might they contribute to the goals of the *Mission Soil* Agenda?

This report explores these questions in the Swedish context by analysing three ongoing multi-actor initiatives in agricultural, forestry/nature restoration and urban context that promote sustainability, including soil health. Using the agreed *Mission Soil* Living Lab criteria [3], we explore potential opportunities to contribute to the goal of establishing 100 Living Labs by 2030. Here we aim to clarify the Living Lab concept for Swedish context and illustrate how already existing partnerships and co-creation platforms already addressing soil health meet the established criteria.

2. Background concepts and definitions

2.1. What is a Living Lab?

Multiple definitions of "Living Labs" exist in the literature, reflecting a growing number of examples emerging globally across various sectors. In this report, we focus specifically on Living Labs related to soil health, land, and natural resource management, using agriculture, forestry and urban collaborations as examples.

The European Network of Living Labs (ENoLL) defines Living Labs (LL) as:

> "*open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end-users at the centre of the innovation process*." [4]

According to the EU Soil Deal for Europe**,** Living Labs are described as

> "*real-life testing environments where new approaches to soil management are developed and tested with the active involvement of stakeholders, including farmers, researchers, and local communities*". [2]

The definitions state that the LL should be based on the three core principles: **c**o creation, users-centred innovation and in reality (place-based). In the European Network of Agroecology Living Labs, the LL is defined it as_transdisciplinary approaches which involve farmers, scientists and other interested partners in the co-design, monitoring and evaluation of new and existing agricultural practices and technologies on working landscapes to improve their effectiveness and early adoption [5]. Despite differing emphases, these three definitions share a common vision: a Living Lab is a place where the actors, including the (beneficiaries), actively participate in learning, testing and developing both existing and new approaches and practices for soil management or a related common problem /issue within real-life settings.

In research, stakeholders and beneficiaries, including farmers, has along history of being involved at different level and stages of the research and innovation processes, together with researchers. Industry, farmers, advisors and other key stakeholders (beneficiaries, actors) participated in research through surveys, workshops and participatory tools [6]. There are typologies and framework that provides a categorisation of participation in research process, often ranging from limited / no participation of intended end beneficiaries to research -to-research actions (often in basic research) to research-and- non academic -actor co-creation and learning actions [7]. According to study conducted by Smith and Veisi (2023) [8], while participatory farming research (PFR) is widely promoted, its implementation varies significantly across projects. The participation of stakeholders vary according to the goals of the project, the stakeholders involved and the expected outcomes. Socio-economic aspects have explicitly or implicitly been taken into account in agriculture and soil science research. Studies have focused on socio-technical systems, socio-ecological systems, resilience studies, and the application of various participatory tools to include stakeholders' needs and perspectives effectively [9].

According to the EU Soil Deal for Europe, each LL consists of multiple sites. Some of the sites are classified as "lighthouses", which is defined as :

> "*places for demonstration of solutions, training and communication that are exemplary in their performance in terms of soil health improvement*." [2] .

These lighthouses are local sites (one farm, one forest exploitation, one industrial site, one urban city green area, etc.) that can be included in a living lab area or be situated outside a living lab area" [2].

Multiple ways to describe collaborative research and innovation systems with multi-actor approaches

The three core principles of co-creation, multi stakeholder and place-based research and innovation identified in the living lab approach, can be recognised in several existing theories of complex systems processes for addressing environmental-social economic and technical challenges. Here we highlight three common approaches of the "Soft systems methodology", "Socio-ecological systems approach" and the "innovation platform" approach.

- **Soft systems methodology (SSM)?**

The soft systems methodology is a method for system of learning that relies on the collaboration between individuals when analysing problems and solutions in business applications, originating from P Checkland [10].
SSM supports the exploration and deeper understanding of a problem situation by evaluating the challenge beyond its predefined characteristics. By integrating perspective of multiple stakeholders, this approach enable collaboration and joint problem-solving can help professionals in management to improve decision-making processes.
The following steps outline each phase of SSM implementation:

1. Identify the challenging situation
2. Communicate about the problem situation
3. Establish root definitions for the system
4. Create a model to represent the concept
5. Compare conceptualizations to real-world models
6. Evaluate possible improvements
7. Create an action plan

The soft systems methodology is a systems thinking approach, and applicable to the often complex issue of soil health with multiple actors. Different studies involved this methodology in land and soil management [11].

- **Socio-ecological system approaches**

Resilience of a social-ecological system refers to its capacity to develop and sustain human well-being in various contexts while facing changes, both graduate and sudden, but also through adapting or transforming in response to these changes. Resilience of social-ecological systems is commonly defined as the system's capacity to cope with shocks and absorb disturbance by adapting and re-organizing while maintaining the system's same structure, function, feedbacks, and identity. To build resilience in a socio-ecological systems therefore requires the joint understanding, negotiation and action by multiple actors to resolve a complex SES systems issue, often place -based. Therefore, the SES approach for building resilience bears many similarities to the core principles of LL approach advocated by *Mission Soil* [12,13].

- **Innovation Platforms**

Innovation Platforms in agricultural research for development stems from the idea that agricultural and natural resource issues, often land based or defined in a given geographical area, can be addressed with suitable jointly understood problem definitions and shared action [14]. Often a solution is coupled to the development or introduction of new technology, new business (incentive) model or value chain connectivity, or behavioural change, which is informed by research activities. These changes are often informed by new knowledge co-learning and co-creation across multiple actors in order to enable change.

3. Methodology and materials

In this study we illustrate that the core principles the Living Labs for soil health adopted by the Mission Soil may already be in progress in Sweden. We selected three initiatives, where the concept of LL is less commonly used, but where there exists an agreed approach among different actors in research and innovation actors, public and private sector to negotiate and co-create solutions for continuous mutual beneficial improved soil and land management. This study employed a qualitative, criteria-based analysis to evaluate collaborative projects, in agricultural, forestry/nature restoration and urban context, for their potential alignment with the *Mission Soil* goals, with a specific focus on their capacity to contribute to the goal of establishing 100 Living Labs by 2030 for soil health.

Projects were selected based on their relevance to sustainable soil management, regional agricultural and environmental development, and multi-actor engagement.

The analysis was based on the PREPSOIL Taxonomy of Mission Soil Living Labs (LLs) and Lighthouses (LHs), developed within the framework of the Horizon Europe project Preparing for the Soil Deal for Europe (PREPSOIL), which provides a tool to identify and classify initiatives aligned with LL and LH principles for soil health (Figure 1) [15].

Data sources included project documentation, reports, projects website and publications. Supplementary interviews and feedback from the projects' leaders were incorporated to capture stakeholder perspectives to our analysis.

Each case study was systematically evaluated against the listed criteria (Figure 1). For each criterion, a short comment was provided to assess alignment with the PREPSOIL taxonomy, identify missing elements, and highlight strengths or weaknesses in the project's approach. For each case study, key aspects such as multi-stakeholder partnerships, co-creation processes, user-centred approaches, real-world implementation, funding sources, and achieved results and impacts were examined to capture the project's components and to gain deeper insight into its implementation.

In line with the scope of this report, the assessment was aimed to illustrate an existing cases that align with the Living Lab concept in order to foster the Living Lab establishment in line with the *Mission Soil* goals.

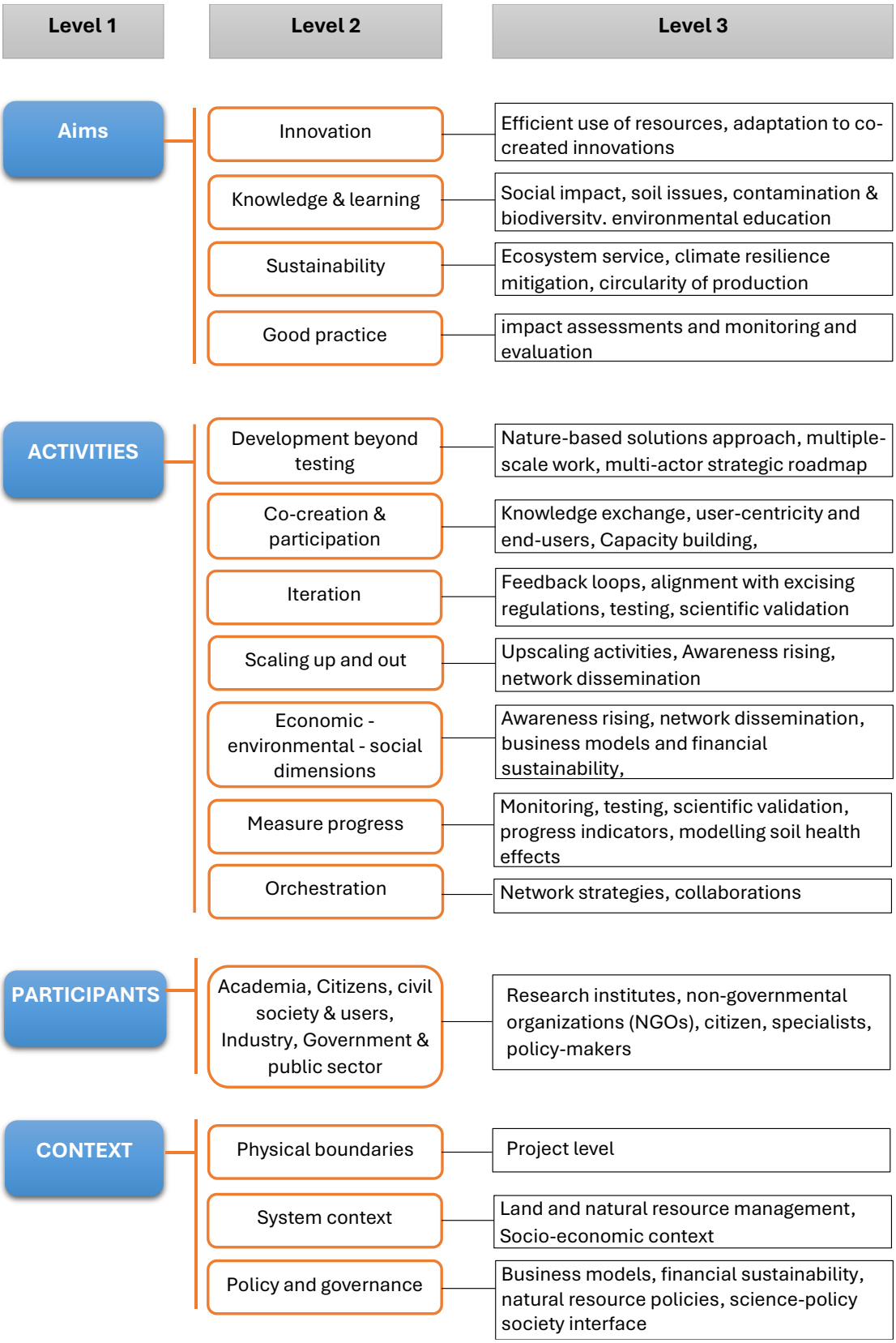

Figure 1. The PREPSOIL Taxonomy of Mission Soil Living Labs (LLs) and Lighthouses (LHs) [15].

4. Analysis of existing Swedish collaborations through a Living Labs lens

4.1. The collaborative project SLU - Västra Götalandsregionen

4.1.1. Västra Götalandsregionen presentation

The County of Västra Götaland, located in southwestern Sweden, covers a total area of 23,942 km² (Figure 2). It is one of the most populous counties of Sweden, with approximately, 1,767,000 habitants, after Stockholm region. Västra Götaland is also a key region for Swedish agriculture, known for its intensive cereal production and diverse forms of animal husbandry [16].

Sweden's national food strategy includes targets for increased food production, higher growth rates and new jobs, increased organic production, and alignment environmental goals [17]. As a part of national goal, Swedish counties are required by law to have a regional development strategy. In Västra Götaland County, this responsibility lies with the Västra Götaland Region [18]. Within the region's strategic framework, Västra Götaland 2020: the strategy for growth and development in Västra Götaland 2014-2020, the region aims to further strengthen the county as attractive, responsible and internationally competitive knowledge region. The strategy outlines four main areas: leading knowledge region, a region for everyone, a region where we take global responsibilities and a region that is visible and engaging. The collaboration project between the Regional Development Committee (Regionala utvecklingsnämnden, RUN), now called Environment and Regional Development Committee (Miljö- och regionutvecklingsnämnden, MRU), in the Region of Västra Götaland (VGR) and the Swedish University of Agricultural Sciences (SLU) represents a longstanding initiative aimed at fostering sustainable and resilient agriculture in the region.

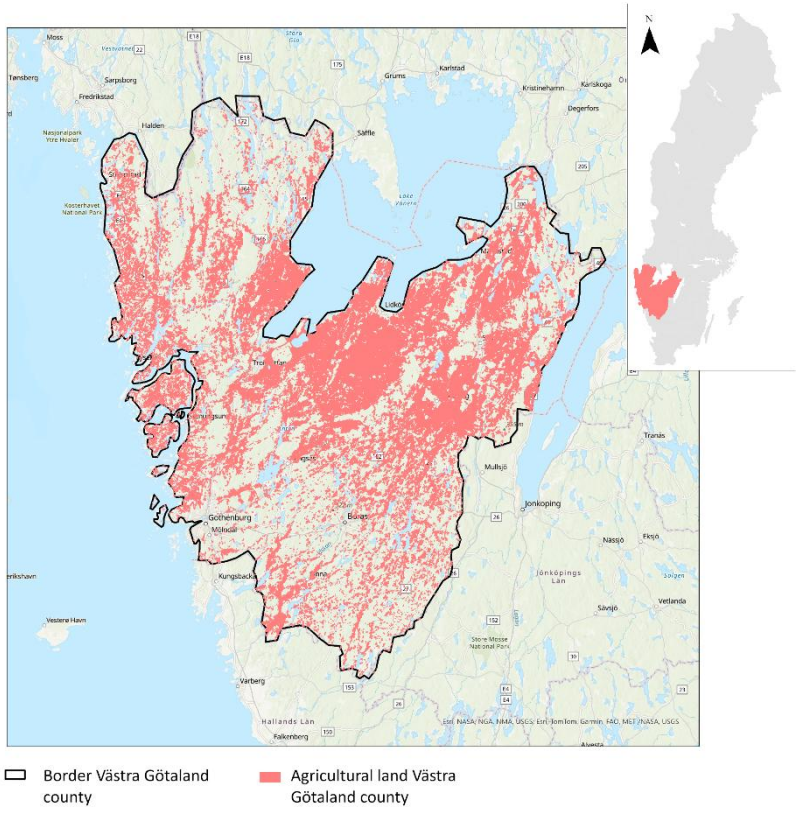

Figure 2. Geographical boundaries of Västra Götaland and the spatial distribution of agricultural land.

4.1.2. Regional collaboration and multi-stakeholder partnerships for sustainable development

Toward the goal sustainable regional development, Västra Götalandsregionen (VGR) acknowledges the value of broad collaboration across sectors. By engaging diverse stakeholders with varying expertise, roles, and resources, this inclusive approach captures the region's strategy and vision, titled "Together we make the transition.", as stated:

> "*We all have different responsibilities, resources and knowledge, and the strategy is the platform for our collaboration to transition to a sustainable Västra Götaland and for a strong implementation.*" [19].

The role of research was also recognized in this initiative of VGR and SLU as key for regional development and innovation. Together, the parties are cost sharing SEK 50 million in the initiative phase 4. Maria Knutson Wedel, Vice-Chancellor of the Swedish University of Agricultural Sciences (SLU), remarked:

> "*The collaboration between the Region of Västra Götaland and SLU is an excellent example of how research and regional collaboration can together contribute to solutions within some of society's most complex challenges. Through this initiative, we strengthen the agricultural sector with more knowledge and new solutions within, among other things, increased resilience, reduced climate impact and strengthened profitability"* [20].

Within this collaborative framework, the VGR project illustrates how co-creation and innovation can be embedded in the development and implementation of sustainable agricultural practices. The project has progressed through three phases since 2014 and Phase 4 started in 2024 (Figure 3).

Since 2014, each phase has strategically invested in three key research areas: livestock production, precision agriculture, and capacity building for advisory services. Throughout the four phases, the VGR–SLU collaboration has consistently supported initiatives within these areas to address both immediate agricultural needs and long-term sustainability goals. In the area of livestock production, efforts have focused on developing more competitive and climate-resilient systems, such as circular models for beef and lamb that promote biodiversity and enhance feed efficiency. Precision agriculture in soil and crop management initiatives have aimed to optimize resource use, reduce emissions and costs, and advance technologies that facilitate practical implementation on farms. Meanwhile, investments in capacity building have

strengthened the agricultural knowledge and innovation system, and fostered collaboration across sectors. These strategic directions have been supported by multi-actor partnerships and farmer involvement over time, demonstrating an evolving and consistent vision for sustainable agriculture in Västra Götaland.

The collaboration of VGR And SLU have evolved over time since its start in 2014. Regarding precision agriculture for soil and crop management, in Phase 1, SLU led this phase. The primary focus was to establish a foundation for cooperation among various stakeholders from different sectors and create the initial technical infrastructure with sensors and farm equipment packages for research. Phase 2 marked a shift toward more research, including the involvement of three PhD students who put into use the established infrastructure in phase 1, along active stakeholders' engagement and introducing participatory methods in testing new technologies. Stakeholders began to play a more active role in identifying needs and testing solutions through collaboration between research with advisors, industry and technology developers, mainly through the development of the Laboratory for smart agriculture decision support system (LADS) platform which helped to strengthen the work with digital support systems [21]. By Phase 3, the project had matured into a more multi-stakeholder environment. Farmers, industry and technologies developers, researchers, and advisory organizations collaborated to test and develop innovations together. There were experiments that were conducted not only at research stations but also on farms, where farmers, together with advisors, actively participated in testing tools, such zero plots and experiments on nitrogen utilization with different fertilisation strategies. In order to foster precision agriculture implementation, more participatory research was also conducted to identify the farmers and advisors needs and challenges to use precision agriculture technologies by analysing the socio-technical systems. These activities ensured that research becoming increasingly embedded in real-life agricultural settings. Over time, the project has increasingly emphasized innovation and environmental sustainability, aligning with regional and global climate goals. During the third phase, the project has also expanded to include international collaboration. As part of the European Joint Programme (EJP) SOIL [22], the VGR initiative was integrated into the PRAC2LIV project [23]. This project, which was running from 2022 to 2024, focused on fostering soil management practices and uptake and developing decision support tools through Living Labs in the European Union. Additionally, it examined how decision-support tools are used on farms and identified key knowledge gaps between tool developers and farmers. Additionally, the VGR initiative was included in the ProbeField project (2021–2024) [24], which focused on in-field monitoring techniques for carbon stocks and soil fertility. Now entering Phase 4 titled "Crop nutrition, precision agriculture and soil health" (2025-2027), the project continues focusing research into practical solutions, but with a more pronounced focus on climate adaptation, promoting biodiversity, and supporting long-term soil health.

For livestock production and climate resilience, SLU research station and commercial farms have been both used for research. This enabled to create a competitive research environment where results were effectively communicated to farmers and other stakeholders. Beef and lamb research in Skara also has a long-term collaboration with Agroväst Livsmedel that is founded as a private, non-profit company, owned by the non-profit association "Livsmedel i Väst". Agroväst provides services primarily based on projects and it works through a variety of agricultural development programs and initiatives. Collaboration with Agroväst also took place within the milk program and other time-limited projects. Similar collaborations have been established in the areas of precision agriculture, competency development, and innovation, engaging various stakeholders including industries, agricultural enterprises, farmers, and advisors. This approach ensures that the outcomes are both practical and scalable.

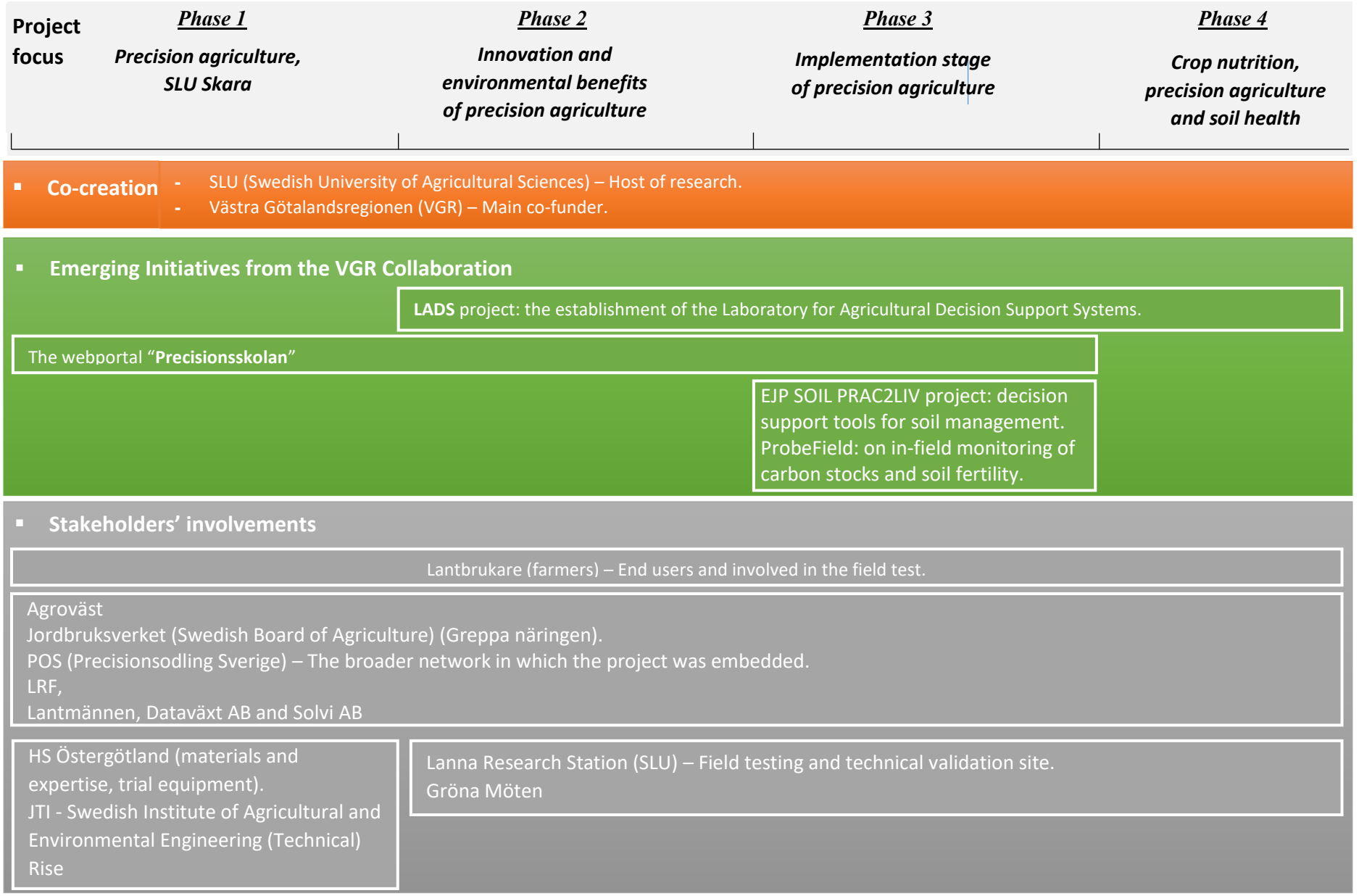

Figure 3. The collaborative VGR-SLU project phases, stakeholder involvement, and emerging initiatives over time.

4.1.3. Regional funding conditions and multi-actor commitments

Since its launch in 2014, the project has increasingly emphasized the integration of research, practical tools, and stakeholder participation. As the project recently started the Phase 4 (2023–2027), it continues to prioritize the co-development of practical tools, increased stakeholder collaboration, and broader implementation of sustainable agricultural systems across the region of Västra Götaland.

According to the funding guidelines:

> "*You can apply for support for innovative and concrete projects that promote sustainable regional development and contribute to solving current societal challenges in Västra Götaland. The projects must be based on broad collaboration between actors, preferably in different sectors, and be conducted and add value in all or large parts of Västra Götaland. Funding is always required from more than Region Västra Götaland (VGR)"* [25].

In line with these requirement, co-funding is mandatory, and all partners must enter into a formal collaboration agreement approved by VGR before the project begins. This reinforces the commitment, a collective ownership and shared accountability among partners.

The openness of the project and its network of stakeholders has also driven the emergence of additional initiatives made possible through the established collaboration and connections within the network. Originating within the VGR–SLU project (RUN 2018-00141), additional funding was allocated to establish the Laboratory for Agricultural Decision Support Systems (LADS) at SLU [21], supported byLantmännen Research Foundation, Dataväxt AB, and a second VGR grant (RUN 2021-00020). It focuses on the design and application of decision-support tools aimed at improving sustainable soil nutrient management and enhance productivity within Swedish agriculture. The cumulative upscaling of support from a broad range of funders over the years highlights the critical role of VGR in enabling applied research development and innovation.

4.1.4. Activities and achieved results

The collaborative partnership between VGR and SLU, 2014 – 2025, has targeted various objectives and outcomes, which were established in accordance with the local needs identified during each phase of the initiative (phases 1 to 3). The overarching aim has been to advance sustainable agriculture in Västra Götaland through a concentrated focus on three strategic areas:

- For livestock production and climate resilience, the focus during the years 2014-2017 was on sustainable production and consumption of livestock products, during the years 2018-2020 on competitive and climate-adapted production and during the years 2021-2024 on achieving application of new research findings. The research conducted aimed to enhance the competitiveness and sustainability of livestock farming, with a focus on beef and lamb production, by prioritizing preparedness and the conservation of biodiversity, improving feed efficiency, minimizing climate impact, and refining resilient pasture-based systems.

- In the area of precision agriculture for sustainable soil and crop management, the initial phase has successfully achieved several objectives, including the establishment of the Laboratory for Agricultural Decision Support Systems (LADS) at SLU Skara, the enhancement of research efforts in precision agriculture, building the technical infrastructure for research, and the initiation of partnerships with key industry stakeholders. These accomplishments have laid a solid foundation for the project's sustainability in this

field. The subsequent phase facilitated the scaling and integration of LADS activities, the development and implementation of advanced digital decision-support systems in collaboration with Dataväxt AB and Solvi AB, and the expansion of collaborations with farmers and other relevant stakeholders, while also demonstrating the advantages of these innovations through local field trials. In the third phase, the project has made significant contributions to the enhancement of decision-support tools and effectively addressing the barriers to the implementation of precision agriculture practices. These continuous efforts reflect a strong commitment to innovation and user-centered development in advancing precision agriculture.

- For competence development and innovation, this area has concentrated on establishing a collaborative foundation among various stakeholders, including municipalities, academic institutions, and the business sector, to facilitate knowledge exchange, to enhance the adaptability of existing stakeholders, encourage cross-sector collaboration, and to build new skills necessary for sustainable food production.

The VGR project is in alignment with various European policies, including the EU Soil Strategy for 2030, the Farm to Fork Strategy, and the European Green Deal. Through VGR 1, SLU was able to host the 19th international nitrogen workshop in June 2016. Between, 2022 and 2024, the collaboration with the European project "EJP Soil", such as PRAC2LIV and ProbeField projects, aimed to enhance soil sustainability and health in Sweden and Europe. This partnership facilitated the exchange of knowledge, the development of innovative solutions, and fostering network that are consistent with the EU's environmental and agricultural policies. Such collaborative initiatives underscore the importance of cross-national partnerships in achieving European environmental objectives, particularly in relation to soil health and sustainable agriculture. The EJP Soil project highlights the openness of the region and its stakeholders, as well as their commitment to contributing to broader changes and impacts in agriculture and soil health.

Finally, the collaboration with different stakeholders, including tools developers and end-user, for example in the Laboratory for smart agriculture decision support system (LADS),facilitated further impact of innovations from research to application.

The webportal "Precisionsskolan" was developed during the first phase of the project, VGR1, in collaboration with Agrovästand used in the teaching of agronomist and agrotechnicians. It is further developed in VGR 3 and 4.

An SLU researcher collecting soil samples for biodiversity study as part of VGR project.

Photo by Bo Stenberg

4.1.5. Assessment with the PREPSOIl Living lab taxonomy of Living lab

In this section, we apply the PERPOSIL taxonomy of Mission Soil Living Labs to assess whether a partnership such as VGR–SLU could be considered a Living Lab within the context of initiatives like *Mission Soil*. As illustrated in Table 1, the VGR partnership demonstrates key characteristics of a Living Lab, particularly through its activities related to soil nutrient management and precision agriculture.

Table 1. The alignment of the collaborative project VRG-SLU with the PREPSOIl taxonomy of Living lab.

Level 1	***Level 2***	***Level 3***
Aims	Innovation	The innovation is based on collaboration between research and the tools' developers. User-centricity is also key as described in the project application and calls.
	Knowledge & learning	The project has developed an online platform called 'Precision School' to support knowledge sharing, dissemination, and wider outreach
	Sustainability	The three research areas were defined to address sustainability by capturing different dimensions of agricultural development. The project offers a certain level of full lifecycle support (from design to commercialization) for tools and innovations, supported by active industry involvement, including partners such as AgroVäst.
	Good practice	The project includes experimental and demonstration sites, such as the Lanna Experimental Farm, used for field trials and monitoring in precision agriculture. Besides, each project phase was built on previous results, allowing continuous evaluation and adaptation of activities.
Activities	Development beyond testing	The project offers tools and services to different actors, farmers and advisors and policy-makers, for better soil management through data driven precision agriculture. These tools can support living labs to foster soil health.
	Co-creation & participation	Collaborations and co-creation are at the core of the VGR-SLU project, aimed at establishing shared values and goals to address regional needs. Furthermore, collaboration can be further enhanced among the three research axes.
	Iteration	The development of innovative decision-support tools is led by researchers and experts and involves farmers and end-users to ensure user-driven innovation.
	Scaling up and out	The project involved advisors for consultation and some farmers for field experiments. The VGR project has a focus on fostering agriculture innovation through regional research collaboration. While it participates in European initiatives, broader international outreach may be limited by financial constraints. To support knowledge sharing, the project developed the 'Precision School' online platform.

	Economic - environmental - social dimensions	The project engages several key stakeholders (SLU, VGR, private companies, farmers) in agriculture sector. The project depends on research funding and not on business model.
	Measure progress	The test-beds are available and used in the project for testing innovations.
	Orchestration	SLU and the involved stakeholders have a strong base of expertise in project operations and activities. And have implement in spin off projects. In the project call and application, a collaboration agreement needs to be signed and approved by VGR before the project begins, to ensure a commitment to collaboration and an open process.
Participants	Academia, Citizens, civil society & users, Industry, Government & public sector	The project engages several key stakeholders (SLU, VGR, private companies, advisors, farmers).
Context	Physical boundaries	The activities are carried out at the project level in real agricultural settings, including both on-station and on-farm research, one of the key strengths of the initiative.
	System context	The VGR-SLU project focuses on nutrient and soil management within precision agriculture, targeting dominant crop production systems at both regional and national levels in Sweden, while taking into account the broader socio-economic context.
	Policy and governance	The project involves strong partnerships with the government represented by the region Board (VGR) and academia (SLU). The maturity of these partnerships and with stakeholders have the potential for improvement. The VGR project is a collaborative innovation initiative that is build based on project call. A governance model is still lacking.

4.2. Vindel catchment river project

4.2.1. The Vindel river project presentation

Sweden has a long history of productive forest management, today covering 70% of the country. The soils are naturally highly acid and nutrient poor, and an important source for the carbon storage in this land-use systems. From the 1850s onwards, as part of the industrialisation, the northern forests and rivers of Sweden were subject to massive changes. Forestry was successively changed to forest production with active outtake and management. Subsequently, rivers were engineered to transport timber. To facilitate log transport, rapids were removed, river bends were straightened, and wooden flooring was installed on riverbeds. An extensive drainage network was created, and thousands of small dams were built to raise water levels during spring log drives. While these structures served their purpose in the past, many now remain as obsolete barriers that negatively impact river health and both aquatic and land base ecosystem services [26].

The Vindel river catchment and its tributaries were important routes for timber transport in northern Sweden, up until 1976 (Figure 4). To ease the movement of logs downstream, wooden dams were constructed, side streams were cut off and tributaries were straightened and cleared. These changes significantly affected the river ecosystem and populations of wild fish, mammals, mussels and other species of aquatic and riparian habitats. The changes therefore negatively impact the favourable conservation status of species and habitats within the Vindel river Natura 2000 network site. Actions to restore the tributaries of the Vindel river to a more natural state were considered a priority by the Swedish environmental protection agency, the Västerbotten county administrative board, and the EU under the habitats directive and the Water Framework Directive (WFD) [27].

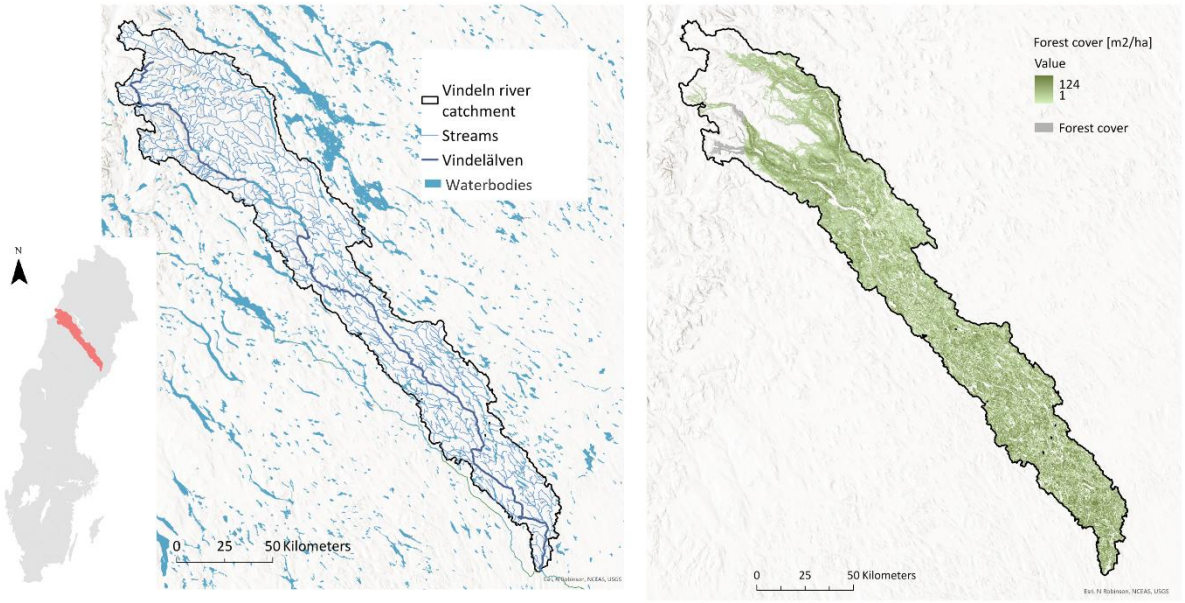

Figure 4. Geographic location and river network of the Vindel River catchment.

During the project period, restoration work was carried out on parts of 26 of the Vindel River tributaries from Sorsele municipality upstream to Umeå municipality. These tributaries have been greatly affected by fragmentation, channelization and flood control after timber-floating. Over the last year a couple of rapids in the main channel of the Vindel River have been restored.

The Vindel River catchment in Swedish Lapland is undergoing significant ecological restoration through the rewilding Sweden initiative. With support from the open rivers programme, a series of activities have been undertaken to improve habitat connectivity and restore natural river processes.

Recognizing the ecological value of the river and the need for restoration, the Vindel River LIFE Project was initiated in 2010, co-financed by the EU LIFE+ Programme and coordinated by Umeå University (Figure 5). This initiative built upon the experience and institutional collaboration developed through the earlier project *Ekologisk restaurering i Vindelälven och Piteälven* (EVP – Ecological Restoration in the Vindel and Pite Rivers), carried out between 2002 and 2005 [28]. The general objective of the Vindel River Life project was to achieve a 'good status' for the waters of the Vindel river with reference to the water framework directive, and 'good conservation status' for the species in the project area under the habitats directive. The aim was to reduce the negative impacts of fragmentation and channelization caused by timber-floating infrastructure in tributaries of the Vindel river system. The work was focused on a number of river stretches, altogether spanning just over 44 km, with the aim of removing

73% of the obstructions to natural river flow, placing large boulders and fallen trees in the water to simulate natural conditions and to reconnect streams to the tributaries to open up breeding areas for migrating fish [26, 27]. From a soil and land management, these strategies for water ways and biodiversity implicates the soil health through the re-established large areas of re-wetting, first and foremost implication soil carbon balances.

	1990	2000 2005	2010 2015	2024
Significant modifications to the Vindel River	**Some restoration efforts** began,	**Ecological restauration of the Vindel and Pite Rivers (EVP) project**	**Vindel River LIFE Project:**	**Ongoing Restoration**
for timber transport (construction of dams and channels	such as the partial removal of dams and reopening of certain channels.	The establishment of the partnership and the co-development of restoration methods	Comprehensive restoration of several tributaries in the Vindel River catchment, including the removal of dams, modification of channels, and creation of spawning grounds to improve biodiversity.	Removal of small dams by Rewilding Sweden to restore river connectivity and improve aquatic habitats over 84 km.

Figure 5. Chronological Progression of Restoration Activities in the Vindel River Project (1990–2024)**.**

4.2.2. The Vindel restauration project approach and multi-stakeholder partnerships for sustainable development

Actions to restore the tributaries of the Vindel River to a more natural state are considered a priority by the Swedish Environmental Protection Agency, the Västerbotten County Administrative Board, and the EU under the Habitats Directive and the Water Framework Directive (WFD) [27]. The Vindel river life project restored streams in 26 tributaries of the Vindel river catchment, all in the Natura 2000 network. Tributaries were restored by either using demonstration methods (10 sites), where innovative techniques or existing best-practice methods were demonstrated. The project team succeeded in removing at least 73% of the former timber-floating infrastructure in the project areas (certain constructions with high cultural and historical value were left for educational purposes). The area was also characterized by spring floods, so the restoration work included clearing trees in areas designated to become floodplains.

Additionally, the project involved also social aspects. They organised a range of dissemination, awareness-raising and networking activities, actively involving local stakeholders and the public.

The Vindel River LIFE project was funded by the project participants [26]:

- Umeå University,
- The Swedish University of Agricultural Sciences,
- The Vindel River Fishery Advisory Board (FAB)
- The Swedish agency for Marine And Water Management,
- EU,
- The County Administrative Board of Västerbotten
- The municipalities of Arjeplog, Sorsele, Lycksele, Vännäs, Vindeln and Umeå.

This partnership reflects the project's integrated approach to ecological restoration. Due to the strong network and cooperation between partners representing the main involved sectors (Umea University, Vindel river Fishery Advisory Board (FAB), the Swedish university of agricultural sciences, and the Swedish Agency for Marine And Water Management), the project successfully integrated scientific research and practical restoration work. The project implementation included meetings with local residents and fishing management organizations to discuss challenges and share information, as they are the potential direct beneficiaries of the project. Here, the Vindel River Fishery Advisory Board (FAB) played a major role in the project's technical coordination and stakeholder engagement. As a key partner, FAB provided expert guidance, supported efforts to engage with stakeholders, including research, landowners and local communities, to support the project's objectives.

4.2.3. Activities and achieved results

The project's work showed a clear socio-economic benefits in the project area. The restoration work of the Vindel river not only contributed to environmental improvement but also positively impacted the local economy by supporting sectors such as ecotourism and fishing..

The removed dams have improved the connectivity of waterways. This enhances the ecological health of the Ume River system. As a result, more salmon are migrating up the Vindel river today than at any other time since the national monitoring programme started. Restoring river flow dynamics and increasing connectivity between streams in the Vindel river catchment contributed to the restoration of 288 km of river. By removing dams, the natural connection between the river and its floodplains was restored. The restoration works has also led to the regeneration of riparian areas, with increased vegetation and biodiversity. In total, the project generated more than 4 000 ha of new areas accessible for fish reproduction. However, it may take many years for the ecosystem to fully recover. Artificial barriers pose a major threat to aquatic biodiversity. Dams fragment habitats, disrupt sediment and nutrient distribution within the catchment, and concentrate pollutants. Removing these barriers in the Vindel catchment helped to restore natural river dynamics, improved water quality, and reconnected aquatic ecosystems. Beyond dam removal, Rewilding Sweden is also restoring drained wetlands and degraded forests in the watershed. These efforts not only enhance biodiversity but also support migration routes in landscapes affected by commercial forestry. A field officer with Rewilding Sweden, Isak Edström, explained:

> "*By removing them, we are aiding fish migration and allowing natural flow patterns to resume, benefiting the entire ecosystem*".

Before and after reopening the Vindel river's side channels. *Photo provided by FAB.*

The Vindel River area has experienced a decrease in the human population over several decades. However, the restoration work has enhanced the ecosystem and landscape, making the region more attractive and providing new opportunities for employment in tourism companies offering fishing activities, which has encouraged people to stay. A study at one of the restored sites by the project revealed that the fish population increased from about 7 individuals per 100 m^2 in 2010 (before restoration) to around 32 individuals per 100 m^2 in 2015. Furthermore, new spawning grounds were well used by fish, with good embryo survival rates. Fishing is prohibited in Beukabäcken as it is an important nursing area. However, the fishing management organisation in nearby Gargån reported increased sales of fishing licenses from 76 000 sek in 2010 to 151 000 SEK in 2015; with a much higher increase in fishing license sales predicted in the near future.

Rivers provide essential ecological and societal benefits, yet climate change and human infrastructure continue to threaten their health. The Vindel River restauration works aimed to restore biodiversity and ecological connectivity andcontributed to the goals of the European Biodiversity Strategy.

In addition, beyond the Open Rivers Programme, financial support for these barrier removal efforts has also been provided by Rewilding Europe, demonstrating a growing commitment to enhance ecological resilience in the face of climate change. Good ecological status was reported in the demonstration sites, and most of the best-practice restoration sites have good or moderate ecological status. Beyond their ecological function, these sites were a key outcome of the Vindel River LIFE project and continue to serve as demonstration areas to this day, supporting research, knowledge sharing, and stakeholder learning, particularly among landowners and other organizations from other regions [29]. In policy terms, the project helped achieve good water status, with reference to the water framework directive. The project improved conditions in two habitat types listed in the habitats directive and improving the conservation status for several species [27].

4.2.4. Vindel restauration project assessment with the PREPSOIl taxonomy of Living lab: Potential initiative for Living Labs for forestry

In this section, we apply the PERPSOIL taxonomy of Mission Soil Living Labs to assess whether a partnership formed through the Vindel restauration project could be considered a Living Lab within the context of initiatives like Mission Soil. As shown in Table 2, the project partnership demonstrates key characteristics of a Living Lab, particularly in its ecosystem restoration activities, collaborative approach, and real-world application involving landowners. While, the initiative and the engagement of stakeholders were principally motivated by water management and biodiversity restauration, he measures implemented at a broader scale also indirectly contribute to improvements in soil and land health.

Table 2. The alignment of Vindel restauration project with the PREPSOIl taxonomy of Living lab.

Level 1	*Level 2*	*Level 3*
Aims	Innovation	The project had a user-centric approach by involving local communities and landowners.
	Knowledge & learning	The project implementation included consultation with local residents and fishing management organizations to discuss challenges and share information.
	Sustainability	The project mainly focused on the ecological restoration of the catchment and long-term monitoring and management. The project promotes supported biodiversity and ecosystem resilience.
	Good practice	Demonstration sites were established to test restoration methods and continue to serve as monitoring and demonstration of innovation.
Activities	Development beyond testing	The project goes beyond testing by actively implementing restoration measures, making it an action-oriented initiative focused on real-world ecological improvements.
	Co-creation & participation	The Vindel Restoration Project involved various actors like Rewilding Sweden, the local community, and government agencies, that are actively involved in the project implementation.
	Iteration	The landowners were involved in the process. The methods and tools for the restauration works were presented and introduced to the beneficiaries, rather than being user-driven innovation
	Scaling up and out	The demonstration sites support scaling up and replication of the restauration practices in other parts of Sweden. The project aligns with European water management policies and contributes to the European Biodiversity Strategy. The Vindel project has also international network through partnerships with Rewilding Europe.
	Economic - environmental - social dimensions	The project involved a wide range of actors including landowners, associations, research bodies, government agencies, and environmental organizations. Awareness rising activities helped to support restauration works. The project relies on external funding, both national and European, and not on business model.
	Measure progress	The project employed environmental monitoring tools and demonstration sites, measuring progress through biodiversity and economic indicators.
	Orchestration	The project involved stakeholders with a strong base of expertise in project operations and activities. Training was also provided for the new staff.

		The project has shown commitment to openness, through meetings and workshops involving various actors and by continually sharing information.
Participants	Academia, Citizens, civil society & users, Industry, Government & public sector	The project has demonstrated openness to various partners, including government and environmental agencies and research.
Context	Physical boundaries	The project operated at the catchment scale.
	System context	The Vindel project focused on land-water system that actively engages the local community, supports local fishery activities, and integrated local values and norms through workshops. Soil and land management was indirectly affected locally due to restauration efforts
	Policy and governance	The project has established strong partnerships among the various actors, which have been recognized as key to its success. The project is a collaborative action-oriented project led by experts in the field with defined roles and responsibilities.

4.3. The Swedish Soil Health Living Lab in urban Swedish context

4.3.1. The Swedish Soil Health Living Lab presentation

The Swedish Soil Health Living Lab (SE LL) is located in the Mälardalen region, which includes the NetZero city of Stockholm and the Greater Stockholm area, as well as Uppsala. SE LL aims to address two urban challenges: restoring contaminated soils and enhancing the city's green-blue infrastructure.

In this region, urban soil contamination comes from historical activities such as fire extinguishing foam, ash from district heating, air pollution from waste incineration, and the use of plastics and manure in urban farming. These activities have led to soils polluted with heavy metals, Polycyclic Aromatic Hydrocarbons (PAHs), and Per- and Polyfluoroalkyl Substances (PFAS), making them unable to support important ecosystem services like clean water filtration, urban farming, or biodiversity. This contamination accumulates in the environment and in human bodies, potentially causing health problems and risks for local communities.

The second major objective of SE LL involves the proactive development of climate-resilient, green and blue urban areas. The Mälardalen region is highly urbanised and experiences heat-island effects caused by hard surfaces. Permeable surfaces and more vegetation are needed to reduce this problem. This SE Living Lab initiative aligns with Uppsala Municipality's plans for major expansion, including the development of new residential areas for 60,000 to 100,000 people, as well as new infrastructure such as a tram or railway station. This expansion presents major challenges: preserving green spaces and biodiversity in Uppsala, protecting existing city trees during construction, preventing soil sealing and compaction, and maintaining and improving the city's blue-green infrastructure.

SE LL will be established in 2025 as a collaboration between different actors to work together and design solution. This project includes eleven experimental sites, both in Stockholm and Uppsala, as shown in Figure 6 and Table 3.

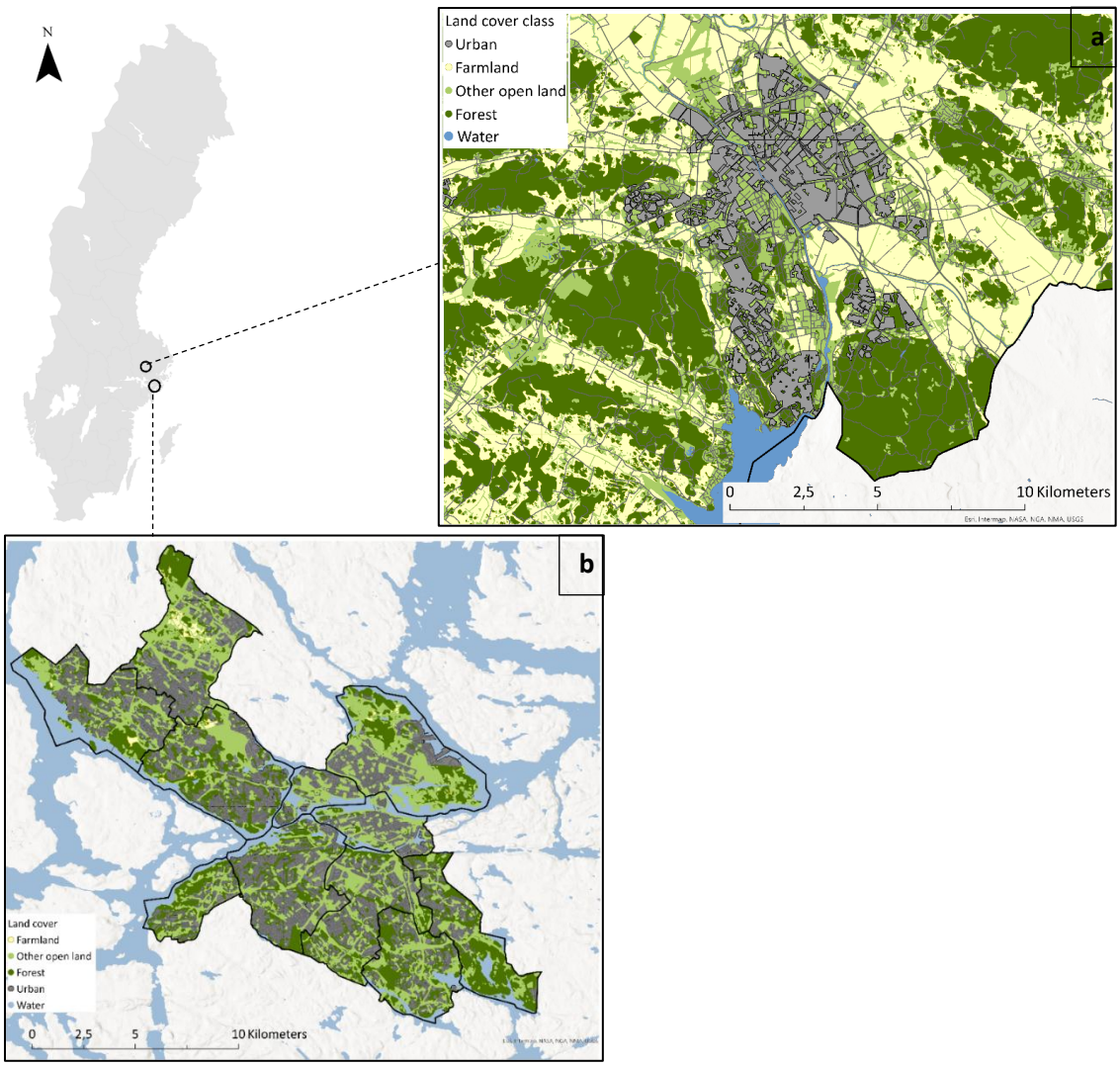

Figure 6. The location of the experimental sites (a) Uppsala and (b) Stockholm.

Table 3. The experimental sites and their soil-related challenges.

City	***Sites***	***Soil related challenges***
Stockholm	Barkarby	Clean PFAS contamination of soils
	Björkängsskolan	Pollution by heavy metals, PAH and dioxins.
	Jakobsbergstippen	Pollution by heavy metals, PAH and dioxins.
	Tullgårdsskolan	Soil sealing
	Eriksdalsskolan	Soil sealing
Uppsala	Fyrislund	Pollution by PFAS
	Ekebydalen	Contamination by PFAS, heavy metals and microplastics.
	Ultuna täppförening	Contamination by PFAS, heavy metals and microplastics.
	Ulls väg	
	Green and Yellow zone of Uppsala	Soil sealing that stops the soil gas exchange and water infiltration and thus reduces the health of urban trees.
	Kunskapsparken	Low sustainability of constructed urban soils resulting in low quality green cover and low biodiversity

4.3.2. Co-creation and multi-stakeholder partnerships for sustainable development

The Swedish Soil Health Living Lab (SE LL) adopts a collaborative approach, aiming to tackle urban soil health issues in the Mälardalen region, particularly in Stockholm and Uppsala cities. This project is led by the Research Institutes of Sweden (RISE) and involves multiple stakeholders collaboration, including academia, municipalities, industry and civil societies to ensure the real-world testing of innovative practices.

Academia and research institutions involved are the Swedish University of Agricultural Sciences (SLU), Research Institute of Sweden (RISE) and Linköping University (LiU). These actors, provide scientific knowledge, design solutions, and supervise monitoring activities and experiments. Public administrations, including the municipalities of Stockholm (MoS) and Uppsala (MoU), as well as the Swedish Environmental Protection Agency (SEPA), contribute with urban sites, regulatory support, and local expertise. Civil society organizations (ULT) and small- and medium-sized enterprises (ETPC, MYMI, AKAH, STOCKH, SISAB, ALSCAN) bring in practical perspectives, citizen engagement, and technical solutions for implementation. This broad stakeholder involvement allows for the integration of local knowledge, policy frameworks, and scientific research, making the SE LL a unique platform for testing and refining soil health interventions in urban environments, while also advancing education and knowledge-building through the active involvement of academia and research institution.

4.3.3. Funding and multi-actor involvement

The project's funding structure includes a combination of direct financial support and in-kind contributions from various stakeholders. The total funding allocated to the Swedish Soil Health Living Lab (SE LL) is approximately 1.5 million euros for three years. The municipalities of Stockholm (MoS) and Uppsala (MoU) provide resources such as access to experimental sites and local expertise, while academia (RISE, SLU, LiU) and small- and medium-sized enterprises "SMEs" (ETPC, MYMI, AKAH, STOCKH, SISAB, ALSCAN) offer technical knowledge and innovative solutions. In addition, the SE LL is collaborating and open to other on-going projects, including the EU Horizon Europe project *Innovative CO-creation Soil HEalth Living Labs* (iCOSHELLs) [30]. This partnership is grounded on shared objectives and common focus on developing practical interventions to improve soil health. These funding contributions and collaborations enable the SE LL to create and develop good environment for testing and improving soil management practices according to local soil issues and challenges in each city.

4.3.4. Expected activities and impact

The SE LL is currently in an ongoing phase of testing and development. It focuses on several key actions: gentle soil remediation through fungal-based and phytoremediation techniques, strategies to address soil sealing and compaction, and innovative amendments such as biochar and compost to improve soil health. These interventions will be tested across 11 sites in Stockholm and Uppsala, each addressing specific soil health challenges like PFAS contamination, heavy metals, soil sealing, and biodiversity loss. The expected outcomes include healthier urban soils capable of supporting ecosystem services such as water infiltration, food production in urban farming, and enhanced biodiversity. Moreover, these actions are designed to improve urban climate adaptation, reduce pollution exposure risks, and foster community engagement around soil health issues, contributing to broader urban sustainability goals.

Soil literacy activities will also include public events, trainings for students and practitioners and site visits. SLU offers educational programs for landscape architects (MSc), landscape engineers (BSc), and a MSc in environmental and water engineering, all focusing on urban planning, ecosystem services, and soil health. These courses address key topics, including soil

health, blue-green infrastructure, and urban biodiversity, to develop the skills and expertise required to meet the future demands of sustainable urban development.

4.3.5. Project assessment with the PREPSOIl taxonomy of Mission Soil Living Labs

In this section, we apply the PERPSOIL taxonomy of Mission Soil Living Labs to explore the Swedish Soil Health Living Lab (SE LL), that focuses on urban soil challenges. As presented in Table 4, the SE LL exhibits alignment with PERPSOIL taxonomy as emerging LL in areas such as stakeholder involvement and co-creation, soil literacy, education, and practical implementation on-site.

Table 4. The alignment of SE LL with the PREPSOIl taxonomy of Living lab.

Level 1	*Level 2*	*Level 3*
Aims	Innovation	SE LL focus on co-created innovations, on testing and demonstration. Yet, not enough information about long-term implementation or scaling
	Knowledge & learning	Soil literacy activities include public events, trainings for students and practitioners
	Sustainability	SE LL operates within a urban context, addressing both social and environmental sustainability by tackling soil health issues in Uppsala and Stockholm for blue-green cities.
	Good practice	The designed solutions are guided by scientific supervisors who lead the monitoring activities.
Activities	Development beyond testing	Provides test sites, solutions for soil remediation, and public engagement opportunities and education
	Co-creation & participation	Co-creation is central here, involving academia, municipalities, SMEs, and civil society
	Iteration	SE LL contributes to the municipality's goals by promoting environmental sustainability by engaging local community, practitioners and students and enhancing the city's blue-green infrastructure.
	Scaling up and out	Upscaling activities details not available.
	Economic - environmental - social dimensions	The SE LL focuses on addressing soil health through a research-funded project involving multiple actors and promotes awareness by mobilizing the local community and education practitioners and students.
	Measure progress	Test sites were provided by municipalities.
	Orchestration	Collaboration is established between actors with different contribution and with ongoing project, iCOSHELLs project regarding soil health..
Participants	Academia, Citizens, civil society & users, Industry, Government & public sector	SE LL involves a wide range of actors from academia, municipalities, small and medium-sized enterprises, and civil society in innovation and testing
Context	Physical boundaries	The project operates at municipality level.

System context	Urban system
Policy and governance	The SE LL lacks a clearly defined governance or business model; however, coordination is supported by RISE (Research Institutes of Sweden), which brings expertise in managing cross-sector collaboration and innovation processes.

5. Conclusion

This report aimed to explore the collaborative efforts to contribute to soil health improvement directly or indirectly in a Swedish context. The three case studies presented in this report reveals a diversity of collaborative initiatives through specific approaches in agriculture, forestry, and urban context. Each initiative demonstrated a diverse and inclusive partnerships and adaptable governance arrangements. For the agricultural and forestry cases, the partnerships had been operating for 15 years or more and had evolved and been strengthened over time. These initiatives go beyond traditional research models and used participatory experimentation and multi-actor learning in real-world setting. These projects showed how different models can achieve similar goals of sustainable soil management. However, they relied on research funding, with financial sustainability and business model still in need of development forward..

Another core aspect of the three case studies was the openness of the innovation initiatives examined. Projects demonstrated openness not only between the initial partners but also the potential to incorporate new partners and ideas. This openness resulted in evidence that facilitated knowledge diffusion and enhances the relevance of the solutions developed for a broader range of beneficiaries (i.e. scaling).

The focus on real-life application adapted to the local context played an important role in engaging diverse local actors and fostering the co-creation process, ultimately leading to reliable and relevant outcomes. Field experiments and community-based ecological restoration projects demonstrate a strong commitment to practical, real-world settings, which enhances both societal acceptance and the applicability of results. The studied initiatives highlighted that workshops, demonstration trials and educational activities, were essential for enabling co-learning and encourage active participation of end-users.

Finally, while financial sustainability and upscaling mechanisms remain key challenges requiring further development, the cases show promising pathways for maintaining and extending the results beyond the initial project phases. We conclude that there are likely many initiatives and collaborations that could contribute to building soil health through LL approaches in line with Mission Soil objectives. Openness to broader network can further contribute to national and European goals, including Mission Soil efforts for soil health across different regions and sectors.

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