ICOSHELLs

D2.3 – LL IMPLEMENTATION DESIGN & SITE SELECTION REPORT

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In a nutshell

Soil is essential for life on Earth, yet 60%-70% of EU soils are unhealthy due to pollution, urbanisation, and intensive agriculture - issues made worse by climate change. This soil degradation leads to significant economic, social, and environmental challenges, including reduced land productivity and biodiversity loss.

The iCOSHELLs project supports the EU Mission 'A Soil Deal for Europe,' aiming to restore healthy soils by 2030. Specifically, iCOSHELLs focuses on three key objectives: **reducing soil pollution and promoting restoration, improving soil structure and biodiversity**, and **increasing soil literacy among society**.

To achieve these goals, iCOSHELLs leverages **six Living Labs (LLs)** located in the **Basque Country, Bulgaria, Greece, Italy, Spain, and Sweden**. These Living Labs bring together diverse local stakeholders to co-design and test practical strategies for soil health improvement.

The project employs a systematic approach that strengthens stakeholder capacities, bridges scientific research with practical solutions, enhances understanding of soil indicators, and replicates effective recovery methods. Its ultimate purpose is to develop and validate scalable solutions that can be applied across Europe.

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List of Abbreviations

Abbreviation	Full Term
LL	Living Lab
SWE LL	Swedish Soil Health Living Lab
SES LL	Southeastern Spain Soil Health Living Lab
ITA LL	Italian Soil Health Living Lab
BUV LL	Bulgarian Viticultural Soil Health Living Lab
Greek LL	Greek Mine Soil Health Living Lab
Basque LL	Basque Soil Health Living Lab
MSO	Mission Soil Objective
WP	Work Package
WP2	Work Package 2: Living Lab Implementation
WP3	Work Package 3: Monitoring & Evaluation Framework.
WP4	Work Package 4: Cascade Funding.
WP5	Work Package 5: Communication, Dissemination, and Scaling
WP6	Work Package 6: Lessons Learned and Integration
WP8	Work Package 8: Project Management
CEC	Cation Exchange Capacity
GHG	Greenhouse Gas

Executive Summary

This report, D2.3 – Living Labs Implementation Design & Site Selection Report, presents the first iteration of implementation planning under Work Package 2 (WP2) of the iCOSHELLs project. It provides a harmonised yet context-sensitive overview of how six regional Soil Health Living Labs (LLs) have translated co-created priorities into concrete experimental designs and site-level deployment plans. This deliverable marks a critical operational milestone in establishing the iCOSHELLs network as a pan-European platform for soil health innovation.

The primary purpose of D2.3 is to document how experimental sites were selected, how prototype testing will be implemented, and how soil health indicators will be monitored in accordance with the project's objectives and the EU Mission "A Soil Deal for Europe." Each LL has selected a minimum of ten test sites, using a structured, stakeholder-led process rooted in WP1 co-creation activities. These sites span diverse land-use types — from arable–livestock systems and vineyards to urban green spaces and post-mining landscapes — and address a wide range of regional soil health challenges, including erosion, compaction, nutrient imbalances, low organic matter, and contamination.

Experimental designs across the Living Labs are tailored to site conditions but unified by common principles: use of control treatments, 2–8 experimental treatments per site, 3–6 replications, and consistent monitoring of a core set of soil health indicators as defined in D3.1. This methodological harmonisation ensures data comparability across highly diverse contexts while enabling locally relevant adaptations. In addition to soil intervention prototypes, several LLs are also testing monitoring and decision-support tools, as well as soil literacy and behavioural engagement approaches linked to these test sites.

The report highlights variations in implementation models — for example, land access through FSTP-supported farms (SWE), partner-operated sites (SES), municipal land (Basque), and post-industrial terrains (Greek LL) — which reflect regional governance realities and offer complementary insights for scaling. Stakeholder engagement processes and governance structures that underpin these activities are led under WP1 and are therefore not detailed here but closely inform the site and prototype choices reported.

Importantly, this deliverable does not include the development, refinement, or evaluation of prototypes, which will be reported separately in D2.6–D2.8. Likewise, while co-creation processes are referenced to contextualise implementation, the documentation and analysis of stakeholder mapping and governance fall under WP1 and its associated deliverables.

Integration with other work packages is a core function of this report. D2.3 provides the experimental foundation for WP3 (Monitoring and Evaluation), contributes to the outreach and policy relevance goals of WP5, and ensures that all data collection is aligned with the Data Management Plan (D8.2) developed under WP8.

This first iteration will be followed by D2.4 and D2.5, which will update and expand on site selection, design refinements, and risk mitigation in response to early implementation feedback and the upcoming Open Call for new LL sites. Together, these reports ensure that iCOSHELLs Living Labs remain scientifically robust, socially grounded, and policy-relevant throughout their evolution.

1. Introduction

This deliverable presents the first iteration of the Living Labs (LLs) Implementation Design and Site Selection Report (D2.3), produced under Task 2.3 of Work Package 2 (WP2) of the iCOSHELLs project. The purpose of this report is to document the initial design of experiments and the selection of suitable implementation sites for each LL. This foundational step is critical to ensure that the interventions developed through co-creation processes are tested under real-world conditions that reflect regional soil challenges, stakeholder needs, and operational feasibility. The report also provides a baseline for comparison with future iterations (D2.4 and D2.5), which will capture progressive refinements and adaptations as the project evolves.

In the iCOSHELLs framework, each Living Lab is not a single site, but a network of at least 10 distinct experimental sites embedded within real agricultural, peri-urban, or degraded land contexts. These LLs are designed as open innovation ecosystems, where scientists, land managers, farmers, and other stakeholders co-create, implement, and evaluate prototypes for improving soil health. WP2 plays a central role in translating these co-created ideas into tangible experiments, by supporting the operationalisation, implementation, and iterative refinement of interventions across the LLs. The current report builds directly on the stakeholder mapping and co-creation activities undertaken in WP1 and aligns closely with the soil health indicator framework established in WP3.

The methodology applied by all LLs follows a harmonised yet flexible approach to ensure comparability while respecting local diversity. Site selection processes were guided by shared criteria, supported by standard templates, and informed by both technical assessments and stakeholder input. The experimental designs include defined treatments, reference conditions, monitoring protocols, and risk mitigation strategies to ensure scientific rigour and practical relevance. Each site will monitor a core set of standard soil health indicators defined in D3.1, with additional site-specific parameters as needed.

This report is structured to provide a common methodological foundation followed by detailed accounts from each LL. It describes the process used to identify and evaluate experimental sites, outlines the experimental design strategies, and presents the main risk categories and mitigation plans identified so far. Together, these elements form the operational backbone of the iCOSHELLs Living Lab approach.

The work presented here also contributes to the broader objectives of the EU Mission “A Soil Deal for Europe,” which has highlighted that an estimated 60–70% of soils in the EU are currently unhealthy. By grounding experimentation in co-designed, regionally adapted Living Labs, iCOSHELLs aims to develop actionable solutions for soil health improvement and feed reliable data into the EU Soil Observatory and forthcoming EU Soil Monitoring Law.

2. Material and Methods

This section outlines the methodology applied by iCOSHELLs Living Labs (LLs) to identify, evaluate, and select field sites for implementation, and to develop preliminary experimental designs tailored to local contexts. The approach was guided by the co-creation processes initiated in WP1, technical considerations from soil experts, and the overarching objectives of WP2.

2.1 Co-creation Process and Stakeholder Involvement

The implementation design of each LL is fundamentally grounded in a structured co-creation process, as outlined in WP1 of the iCOSHELLs project. This process ensures that the interventions tested in each LL reflect real-world soil health challenges identified by local stakeholders and are embedded in the socio-ecological contexts of their respective regions.

Each LL initiated its co-creation process by engaging a diverse group of stakeholders (including farmers, landowners, municipalities, advisors, researchers, and NGOs) through the activities defined under Task 1.1 (stakeholder mapping and recruitment) and Task 1.3 (regional co-creation meetings). At least two stakeholder workshops were conducted during this period (M1–M9) to:

- Identify and prioritize key soil health problems,
- Define regional objectives and constraints,
- Explore potential solutions to these challenges,
- Set the direction for experimental interventions to be implemented under WP2.

The co-creation process was facilitated by the LL Leads and often supported by CSCP and national WP1 teams. A key output of this process was the identification of the "problem–solution pair" for each LL: a defined challenge (e.g., erosion, compaction, contamination) and a corresponding prototype or practice to be tested (e.g., cover crops, compost amendments, biochar, vegetation strips).

This participatory approach is not only essential to ensuring local relevance and stakeholder ownership but also aligns with the broader aims of the EU Mission "A Soil Deal for Europe," which emphasizes open innovation and multi-actor engagement in soil health transitions.

The experimental design and site selection activities documented in this deliverable are therefore not top-down technical decisions, but rather the direct outcome of co-defined priorities and dialogues with local actors. This principle of embedded co-creation will continue to guide subsequent iterations of experimental refinement, evaluation, and scaling, in close collaboration with stakeholders and in synergy with WP3.

2.2 Prototype Typology and Selection

The co-creation process in each Living Lab served as the foundation for identifying soil-related challenges and selecting potential solutions to be tested. These co-created solutions are initially referred to as prototypes, which form the basis of the Living Lab experimentation and learning cycles. As prototypes, after testing, are deemed successful in improving soil health, it is then called a solution.

iCOSHELLs recognizes that addressing soil health challenges are multi-dimensional. As a result, the project tests three broad categories of prototypes, reflecting different pathways to improve soil health directly or indirectly:

- **Soil Intervention Prototypes**: Active interventions implemented on soils with the explicit purpose of improving soil health. They are tested through structured experimental designs under real-life conditions.
- **Monitoring & Decision-Support Prototypes**: tools and methods for assessing soil health and supporting management decisions, ranging from indicator monitoring to digital platforms and decision-support systems.
- **Soil Literacy Prototypes**: Initiatives designed to enhance soil health indirectly by fostering soil literacy, community involvement, and behavioural change, often through participatory and awareness-raising processes.
- **Solution**: A prototype is considered successful when it demonstrates the ability to improve soil functions under real-life conditions, foster soil literacy and behavioural change, and provide reliable, actionable data to guide soil management and policy.

While prototypes are broadly defined as direct soil health, educational/social engagement, or monitoring, their design and implementation within iCOSHELLs also reflect different functional domains. These domains represent the practical orientation of prototypes, highlighting the types of interventions, engagement mechanisms, or monitoring approaches they involve.

It is important to note that prototypes often bridge more than one functional aspect. For instance, educational or social engagement activities can also be direct interventions when they involve collective action, and monitoring prototypes may overlap with soil management when tools are applied in practice. Such overlaps reflect the integrated and co-created nature of prototypes developed in Living Labs.

The following matrix (Table 1) illustrates how prototypes can be positioned within these functional categories, ranging from agronomic and fertilization-based interventions to digital, technological, and management-based solutions, as well as their links to awareness, engagement, and monitoring tools.

Table 1. Prototype functional categories within iCOSHELLs. The matrix presents the main functions in which prototypes fulfil (columns) and relevant sub-categories, reflecting their integrated nature and potential to combine direct interventions, educational and social engagement, and monitoring functions.

Prototype Functional Categories

Soil Intervention Prototypes (direct)	Monitoring & Decision-Support Prototypes (indirect)	Soil Literacy Prototypes (indirect)
Agronomic Crop rotations Intercropping Companion planting **Fertilisation-based** Replacing conventional fertilisers with bio-based fertilisers (BBF) Nitrification inhibitors Application method **Soil Amendments** Organic mulching Biochar Compost Gypsum or lime Green manure Vermicompost **Nature-based** Cover crops Infield biodiversity strips Hedgerows or windbreaks Native vegetation buffer zones **Management-based** Tillage practices Crop residue management Irrigation systems Plant protection Irrigation scheduling Changing livestock grazing rotations	**Soil Condition (In-situ sensors)** IoT soil sensors (moisture, EC/pH, nutrient sensors) Standalone in-field devises Portable kits (soil or nutrient testers) **Bio-indicator tools** eDNA monitoring Acoustic sensors for soil fauna Enzymatic activity Nematode community analysis **Environmental & Landscape (remote sensing)** Weather stations Drone-based NDVI or multispectral imagery Satellite images-based indexes Thermal imaging **Data integration platforms** Apps for planning (farm or field level) Digital dashboards integrating soil sensor data into management tools, AI-assisted management Digital twins for simulation tools	**Awareness & outreach** Social media campaigns Storytelling installations Soil health festivals Installations to promote soil awareness (Murals or art) **Behavioural engagement** Workshops / Seminars Urban soil stewards Adopt-a-plot initiatives **Community-led Action** Community composting hugs Community erosion control projects Community restoration projects **Education & training** Curriculum-linked soil literacy initiatives University soil health modules Train-the-trainer programmes **Participatory monitoring & co-design** Citizen (non-expert) data gathering / reporting Cooperative soil sampling groups Citizen soil condition mapping

This categorisation provides a structured way to understand the diversity of prototypes developed within LLs, and supports the identification of synergies, complementarities, and potential gaps across the project portfolio.

Each LL selects one or more prototypes, depending on regional needs, stakeholder capacity, and experimental feasibility. This typology also informs the methodological approach in subsequent sections: site selection (2.3), experimental design (2.4), and monitoring (2.5) are adapted to suit the characteristics of the prototypes tested.

2.3 Site Identification and Selection

Each iCOSHELLs Living Lab (LL) consists of a network of at least 10 physical soil test sites, selected through a structured, stakeholder-led process grounded in WP1 co-creation activities. These test sites represent real-life agricultural, peri-urban, or degraded land settings within each regional context and form the backbone for testing both direct soil health and monitoring prototypes. Educational and social engagement prototypes are primarily connected to these test sites, but may also involve complementary implementation settings such as schools, municipal areas, or community venues. The goal of the site selection process was to ensure that the chosen locations are representative of regional soil health challenges and provide real-world conditions suitable for testing, demonstrating, and evaluating co-created prototypes.

2.3.1 Site Identification Process

Site identification was carried out through an iterative process combining:

- Stakeholder engagement, as facilitated in WP1 (Tasks 1.1 and 1.3), where local actors contributed insights on soil challenges, community needs, and potential test or implementation sites.
- Field-based reconnaissance and validation, led by the LL Office and technical teams, including site visits and preliminary assessments to confirm suitability for soil interventions and monitoring prototypes, as well as institutional discussions where educational and social engagement prototypes required complementary implementation settings.
- Strategic alignment with co-created objectives, ensuring that selected sites or settings were logistically feasible for repeated monitoring, stakeholder engagement activities, or prototype demonstrations.

In all LLs, the identification process began with a larger pool of candidate sites. From these, at least 10 physical soil test sites were selected as the core experimental backbone, while additional settings could be included to support the implementation of educational and social engagement prototypes. Final selection was guided by stakeholder willingness, contextual suitability, and evaluation against agreed criteria.

2.3.2 Selection Criteria

To guide selection and ensure consistency across LLs, the following selection criteria were applied when identifying test sites for prototypes:

- Relevance to prioritized soil health challenges – each LL was required to select at least 10 physical soil test sites where recognized soil health problems (e.g., compaction, erosion, fertility loss, contamination) could be addressed through direct interventions and monitored over time.
- Contextual conditions – for direct soil health and monitoring prototypes, this refers to soil and environmental factors (soil type, texture class, slope and drainage, climate zone, and land use history); for educational/social prototypes, proximity and accessibility to communities were considered to ensure a link between engagement activities and the soil test sites; for monitoring prototypes, suitability of the test sites for deploying and validating tools was emphasized.
- Operational feasibility – including accessibility of sites, long-term commitment of landowners or farmers, and compatibility with the interventions and monitoring systems to be implemented.
- Representativeness and diversity – the set of ≥10 soil test sites per LL was selected to collectively represent a diversity of regional environmental and management conditions. Educational and monitoring prototypes were connected to these sites, with the option to include complementary locations only when they directly reinforced the core soil-based experimentation.

2.3.3 Site Documentation and Field Verification

All ≥10 required soil test sites in each LL were visited by technical teams between Months 3 and 8. Preliminary visual assessments and initial soil sampling were conducted to confirm site suitability to test soil health and monitoring prototypes, or to launch engagement activities, and to establish the Baseline Soil Health Indicators established in D3.1.

Each LL has compiled a description of their selected sites, including:

- A summary table of key attributes across all ≥10 sites
- A brief narrative of how the site set reflects regional diversity and co-creation priorities
- Maps, if available, and GPS coordinates showing site distribution

Educational and social engagement prototypes were primarily connected to these soil test sites, and in some cases complemented by additional venues (e.g., schools, municipal spaces, or community areas) to strengthen outreach and participation. Where such complementary venues were included, they were documented in relation to their linkages with the core soil test sites.

This first iteration of this D2.3 report presents the outcome of this process for each LL and establishes a foundation for subsequent refinement in Deliverables D2.4 and D2.5.

2.4 Experimental Design Approach

The experimental design approach in iCOSHELLs was developed to accommodate the three main prototype types: direct soil health interventions, monitoring prototypes, and educational/social engagement prototypes. All LLs are anchored in a minimum of 10 physical soil test sites, which form the backbone for testing direct interventions and validating monitoring prototypes. Educational and social engagement prototypes are primarily linked to these soil test sites but may also extend to complementary community or institutional venues when appropriate.

Direct soil health prototypes follow field-experimental designs with treatments, controls, replication, and structured monitoring of soil health indicators. Monitoring prototypes are validated at the same soil test sites, either in parallel with interventions or through comparative testing against reference methods, with emphasis on accuracy, reliability, and usability. Educational and social engagement prototypes are implemented in structured cycles connected to the soil test sites, and evaluated through metrics such as participation, knowledge gains, behavioural shifts, or community ownership, with additional venues used only when they reinforce the link to the core soil test sites.

While prototype ideas and problem definitions were co-created with stakeholders, the detailed experimental and implementation designs were developed by LL researchers and experts to ensure scientific validity, feasibility, and comparability across sites. All test sites are required to monitor the standard set of core soil health indicators defined in WP3 (D3.1), ensuring consistency across the LL network. In addition, site-specific functional indicators may be included depending on the prototype being tested, such as crop performance metrics, water quality parameters, biodiversity and biological activity measures, or other variables needed to assess impacts and effectiveness.

2.4.1 Experimental Setup

The experimental setup in each LL is structured around a common set of principles to ensure scientific robustness and comparability across sites. For direct soil health prototypes, these principles include:

- Use of replicated test sites across multiple locations per LL to reflect environmental heterogeneity and stakeholder diversity.
- Comparison of prototypes (e.g., compost application, cover cropping, reduced tillage) against reference or control conditions.

- Monitoring of soil health indicators at each test site, including, at a minimum, the core baseline indicators defined in WP3 (D3.1). LLs may also include supplementary indicators relevant to the specific soil challenge or expected effects of the prototype.
- Use of a Design of Experiments (DoE) appropriate to local contexts and expected impact of the prototype being tested, with guidance from LL technical teams and soil experts.
    - Which prototypes will be tested (treatments)
    - What they will be compared against (controls)
    - How many replicates (depending on expected variation)
    - Randomisation of treatment and control plots
    - Which variables will be measured (only Core soil health indicators or other indicators)
    - Over what period
- Documentation of experimental metadata, including treatment timing, application rates, and site-specific conditions.

The level of experimental formalisation varies depending on LL capacity and local context. LLs could initiate small-scale plot trials with defined controls and replications, while others could integrate the intervention directly into operational farm systems with before–after or paired comparisons.

For monitoring prototypes, the setup involves deploying and validating tools at the same soil test sites, either in parallel with interventions or in dedicated test plots. Designs emphasise replication where feasible, calibration against reference methods, and the collection of data on accuracy, reliability, and usability to ensure the tools are both scientifically valid and practically relevant.

For educational and social engagement prototypes, the setup is structured around cycles of activities connected to the soil test sites, complemented where necessary by community or institutional venues. Design elements include the number and type of activities, target stakeholder groups, participant reach, and timing of engagement. Evaluation methods, such as pre/post surveys, participation metrics, or qualitative feedback, are used to capture impacts on soil literacy, awareness, and behavioural change.

2.4.2 Data Management

All primary data generated from the prototypes are collected by each LL using harmonised protocols and templates to ensure consistency and comparability across sites. For Field Intervention Prototypes, this includes soil health indicators, treatment performance data, and management metadata such as application rates and timing. For Monitoring Prototypes, this includes tool outputs, calibration data against reference methods, and records of usability or reliability. For Soil Literacy Prototypes, this includes participation metrics, survey results, qualitative feedback, and documentation of engagement processes.

Where applicable, supplementary metadata such as land use history, weather conditions, or management practices are also recorded. All datasets are stored in the project's shared repository in alignment with the Data Management Plan (D8.2), ensuring adherence to FAIR principles and enabling long-term accessibility via the EU Soil Observatory.

2.4.3 Iterations

As this is the first iteration, prototype designs remain at an early stage of implementation and will be progressively refined through stakeholder feedback, technical review, and iterative learning during the second and third reporting cycles (D2.4 and D2.5).

For Field Intervention Prototypes, iterations may involve adjusting treatments, replication levels, or monitoring protocols in response to observed performance. For Monitoring Prototypes, refinement will focus on tool calibration, integration with soil health indicators, and simplification for end-user uptake. For Soil Literacy Prototypes, iteration involves adapting engagement methods, communication formats, and evaluation strategies to improve effectiveness and reach.

Flexibility has been maintained to allow for seasonal constraints, local adaptation, and the evolution of co-created priorities, while ensuring that all refinements remain scientifically valid and comparable across LLs.

2.5 Risk Identification and Mitigation Planning

he implementation of prototypes across diverse LL settings involves a range of potential risks associated with site-specific challenges, whether field interventions, monitoring activities, or soil literacy initiatives. The objective of this planning phase is to anticipate obstacles early, safeguard stakeholder engagement, and ensure smooth and adaptive implementation of the experiments throughout the project's lifecycle.

Common risk categories assessed in each LL include:

- Environmental and climatic risks: Extreme weather, drought, flooding, or erosion affecting field trials.
- Site-specific limitations: Poor access, difficult terrain, or degraded soils unsuited to intervention.
- Stakeholder and social risks: Withdrawal of landowners or farmers, lack of long-term commitment.
- Logistical and operational risks: Equipment failure, delays in prototype delivery, or lack of field staff.
- Data and monitoring risks: Inconsistencies in sampling or loss of data due to technical error or poor documentation.
- Monitoring-specific risks: failure of new tools, lack of calibration data, or poor usability for end-users.
- Educational and social risks: declining participation, low engagement, or limited continuity of community or institutional involvement.

For each identified risk, LLs were required to propose mitigation or contingency measures. These include, for example:

- Selecting backup sites in case of access loss or severe degradation.
- Using redundant measurement protocols or sensors for key indicators.
- Ensuring clear stakeholder agreements or memoranda of understanding (MoU) to secure long-term participation.
- Adjusting the timing or layout of experiments to reduce climate exposure (e.g., avoid known flood periods).
- Coordinating with local partners for logistics support and troubleshooting.
- Validating monitoring prototypes in parallel with established methods to ensure data reliability and planning fallback use of reference indicators if new tools fail.
- Embedding educational activities in schools, advisory services, or municipal programmes to safeguard continuity and ownership.

By recognising risks across all prototype types—field, monitoring, and literacy—the framework safeguards both technical robustness and social legitimacy throughout the project lifecycle. Where risks cannot be fully mitigated, LLs are encouraged to adopt contingency plans such as identifying backup sites and broadening the stakeholder base. This layered approach keeps LLs resilient, transparent, and adaptive to local realities. Embedding risk monitoring into the design phase aligns iCOSHELLs with best practices in Living Lab governance (e.g. NATI00NS, PREPSOIL, SOILL-Startup), making risk management not only a protective measure but also a proactive tool for resilience, iterative learning, and stakeholder trust—essential for delivering outcomes that inform both science and policy.

2.6 Iterative Co-creation and Prototype Refinement

The identification of prototypes in each Living Lab (LL) was grounded in the iterative co-creation process established under WP1, where stakeholders and experts jointly defined regionally specific soil health challenges and identified potential solutions. Based on these priorities, researchers and technical teams have translated the concepts into implementable designs that can be scientifically validated.

As the LLs progress, all prototypes will be revisited and refined through iterative learning cycles. For Field Intervention Prototypes, refinement involves adjusting treatments, replication, or management practices in response to field performance and monitoring data. For Monitoring Prototypes, refinement focuses on tool calibration, integration with soil health indicators, and end-user usability. For Soil Literacy Prototypes, refinement involves adapting engagement methods, communication formats, and evaluation strategies to strengthen effectiveness and reach.

This iterative approach ensures that prototypes remain context-relevant, adaptable, and scalable, supporting the mission objective of developing actionable and socially grounded practices for soil health improvement.

3. Living Lab Profiles

3.1 Basque Urban Soils LL (Spain)

The Basque Soil Health Living Lab is situated within the **Urdaibai Biosphere Reserve** in the Basque Country, Spain. It is a diverse landscape where cultural heritage, protected nature, and increasing urbanisation intersects. The LL is led by **GAIA Innovation Cluster**, the **University of the Basque Country (UPV/EHU)**, and several local municipalities, with additional support from environmental NGOs and community groups. The Basque LL addresses the challenge of soil degradation in peri-urban and public spaces, aiming to enhance soil health, biodiversity, and community well-being.

3.1.1 Co-creation and stakeholder involvement

The LL addresses the challenge of restoring and sustainably managing urban and peri-urban soils in a protected natural environment. The co-creation process began with two participatory workshops in June 2025 involving 51 stakeholders, including citizens, researchers, municipal representatives, industry actors, and NGOs. Gender distribution was 42% male and 58% female, with participants spanning age groups, mainly 18–34 (25%) and 35–54 (25%).

The first workshop focused on mapping degraded soils, defining site objectives, giving basic training in community led composting. The second workshops transitioned towards identifying nature-based, technological and educational prototypes to address soil compaction, biodiversity loss, and low community awareness of soil functions. Community schools and local NGOs were instrumental in shaping governance structures and ensuring inclusive participation throughout the co-creation process. These sessions established a shared governance model for site management. and draft soil health monitoring protocols adapted to urban conditions.

Ideas that emerged during the co-creation workshop were both classic intervention prototypes, combinations of intervention-based prototypes and educational/social engagement activities, and even combinations of monitoring and social engagement:

Soil Intervention Prototypes
- **Agronomic –** Deep rooted cover crops
- **Nature-based –** Establishment of pollinator-friendly green infrastructure

Monitoring & Decision-Support Prototypes
- **Digital / technological -** Acoustic sensing of soil life

Soil Literacy Prototypes
- **Social Engagement –** Citizen led compost production and application

3.1.2 Site Selection

Sites were selected to include degraded areas, community gardens, and urban green spaces that suffer from soil compaction, depleted organic matter, and reduced biodiversity. Site selection was guided by three criteria: (i) potential for urban regeneration, (ii) demonstrated community interest and willingness to engage, and (iii) opportunities to enhance biodiversity in alignment with the conservation goals of the Urdaibai Reserve.

Ten test sites were selected on municipal property in collaboration with the Forua municipality and local community stakeholders. All sites are in peri-urban zones with easy public access and strong potential for educational, recreational, and restoration use. The selection focused on areas with varying degrees of historical degradation and land-use legacy. Five sites are located where houses once stood but have since been demolished; they lie adjacent to an abandoned lot and opposite an industrial facility. One site was formerly part of a railway corridor, now decommissioned, and four sites are situated within a former landfill area that has been converted into a public park. This diversity ensures the Living Lab can test interventions across a gradient of disturbance and restoration potential. The sites are situated on Arenosols and Albeluvisols, with soils characterised by low organic matter content, heavy compaction, light to medium clay textures, and limited vegetation cover. Slopes range from gently to moderately sloping (2–15%), and the total area across all sites is approximately 8 hectares.

Site contracts are secured through the municipal partnership, and sites are embedded in local planning strategies to ensure long-term viability.

3.1.3 Experimental Design Approach

The experimental programme is structured around nature-based and circular solutions. A split-plot design was used, with the main plots assigned to different treatment types (e.g., control and alternative practices), and sub-plots receiving varying application rates or management intensities. This allows assessment of both treatment and dose effects under field conditions. Experimental designs use split-plot layouts, allowing comparison of amendment types, application rates, and treatment combinations.

All treatments will be tested at each site with a minimum of three replicates according to:

- Main plots
  - Control – no intervention or current park management.
  - Treatments
    - Compost addition
    - Deep rooted cover crop establishment
    - Establishment of pollinator-friendly green infrastructure
- Sub-plots
  - Application rates
  - Treatment combinations

3.1.4 Monitoring Indicators

A comprehensive monitoring framework is in place, covering the standard baseline soil monitoring indicators determined in D3.1 plus additional functional indicators to follow the effects of the various treatments. Baseline sampling has occurred on all sites, but results are still pending:

- **Physical indicators**: soil bulk density, particle size distribution, water-holding capacity
- **Chemical indicators**: pH, electrical conductivity, macronutrient availability (N, P, K, Ca, Mg, S), total nitrogen, CEC, heavy metals
- **Biological indicators**: microbial biodiversity, microbial respiration, soil organic matter content,

In addition to the baseline indicators, the Basque LL is also monitoring additional **specific indicators** to follow impact of the prototype treatments. These are more site-specific depending on the treatments being tested and the location of the test site and include.

- Nutrient balances, pollinator habitat provision, community use, and soil literacy indicators, acoustic sensing of soil life, eDNA-based monitoring

3.1.5 Risk Identification and Mitigation

Key risks for the Basque LL include competing urban development pressures and shifting municipal priorities, which may jeopardise access to pilot sites. To mitigate these, agreements are being negotiated with municipalities, and alternative plots within the biosphere reserve have been identified as contingency options. Loss of municipal access due to political changes or urban development plans. To mitigate these, the LL has secured site agreements with the municipality and embedded activities within school programmes and local NGO networks.

Technical risks include failure or data loss from monitoring prototypes; redundancies in monitoring (e.g., acoustic + eDNA) and involvement of university labs for data processing help reduce these risks.

Another potential risk is waning or insufficient community engagement, particularly due to the reliance on volunteers. Mitigation measures include integrating Living Lab activities into school curricula and NGO programmes to strengthen long-term participation, local ownership, and continuity., and variability in citizen participation

All identified risks are tracked in the LL risk log, with updates coordinated under WP2.

3.1.6 Summary

The Basque LL exemplifies the role of peri-urban soils in advancing the Soil Mission's objectives of improving biodiversity, promoting circular solutions (composting), and increasing societal soil literacy. By integrating arts, education, and nature-based restoration, it creates a unique experimental setting for demonstrating how community-driven soil health solutions can deliver tangible environmental and social outcomes.

3.2 Bulgarian Viticultural Soil Health LL (BUV LL)

The Bulgarian Viticultural Soil Health Living Lab (BUV LL) is anchored in the **Yuzhen tsentralen (BG42)** wine-producing region and coordinated by the **Agricultural University of Plovdiv (AUP)**, with the support of wine producers, cooperatives, policymakers, and academic partners. The LL targets key challenges facing vineyard soils in the region, including erosion, nutrient depletion, soil compaction, and biodiversity loss. These are exacerbated by Bulgaria's continental climate, with hot summers, cold winters, and increasing climatic variability.

3.2.1 Co-creation and stakeholder involvement

The co-creation process was launched with a structured workshop held on 10 February 2025 in Plovdiv. The session brought together 32 stakeholders, including 10 land managers, 8 researchers, 2 industry representatives, 5 policymakers, and 7 citizen/community participants, ensuring balanced input from across the viticultural value chain. The workshop focused on aligning monitoring methodologies, selecting experimental sites, establishing soil sampling and monitoring strategies, and securing contracts with participating vineyard owners. The demographic spread included mostly 18–54-year-olds (34% aged 18–34, 59% aged 35–54) and showed good gender balance (53% male, 47% female). The participatory process reinforced shared responsibility for implementation and co-learning.

Main issues identified for the vineyard soils were erosion, especially on sloping fields, nutrient imbalances, compaction, and biodiversity decline. These challenges are exacerbated by Bulgaria's continental climate, characterised by hot, dry summers and cold winters.

Prototypes of interest for testing emerged from co-creation workshops and interviews and address both soil health and climate resilience:

Soil Intervention Prototypes

- **Agronomic –** Cover cropping (grassed vine inter-rows)
- **Fertilization-based –** Replacing mineral fertilizers with bio-based fertilizers
- **Management-based –** Conservation tillage, Plant protection (bio vs chemical), Precision irrigation

Monitoring & Decision-Support Prototypes

- **Soil Condition –** soil sensors for irrigation control

3.2.2 Site Selection

Ten vineyard test sites were selected to test prototypes across several municipalities: Chernogorovo, Brestovitsa, Yagodovo, Rogosh, Skutare, Bresnik, Govedare, and Perushtitsa. These sites were chosen to represent Bulgaria's main viticultural landscapes and to reflect diversity in slope (from nearly level to strongly sloping), soil type (mostly sandy to loamy), management practices, and degradation severity. This diversity ensures both scientific control and sector-wide representativeness. All sites are managed by landowners participating directly in the project. The selection criteria included:

- Relevance to representative vineyard soil degradation
- Stakeholder willingness and engagement
- Accessibility for monitoring and outreach

The ten test sites have a total area of 17.5 hectares and range in size from 0.4 – 4.5 ha. Half of the sites have medium clay contents (25-40%), three heavy clays (>40%), one very heavy clay (>60%), and one light clay (<25%). Sites lie on slopes ranging from nearly level (0–2%) to strongly sloping (15–30%) which have increasing susceptibility to erosion and runoff. Eight of the sites are under conventional management practices and two sites are under organic management.

The test sites are irrigated primarily via drip or micro-irrigation, using groundwater, and fertilisers are applied in split doses using liquid injection.

3.2.3 Experimental Design Approach

The experimental design is structured around paired comparisons and matched field designs. Each site tests 8 prototype treatments (including control) in six replicated blocks. This design supports robust comparison of soil management practices under real-world vineyard conditions.

Solutions under evaluation include cover cropping, organic amendments, precision irrigation management, and soil structure conservation practices. Advanced digital soil sensors and meteorological stations are used for continuous monitoring of soil moisture, EC, pH, NPK, carbon, and vineyard microclimate (temperature, humidity, precipitation). These sensor data are validated against conventional soil sampling and laboratory analyses.

Treatments include:

- **Control** – Current grower practice (tillage, fertilisation, irrigation)
- **Treatments (prototypes)**:
  - Grassed vine inter-rows (cover crops)
  - Reduced tillage

- Organic vs. mineral fertilisers
- Bio-based vs. chemical plant protection
- Irrigated vs. non-irrigated soil zones
- Use of precision irrigation system controlled by soil sensors
- Soil structure conservation practices

3.2.4 Monitoring Indicators

Baseline soil sampling was completed in April 2025 and covers:

- **Physical indicators:** bulk density, water-holding capacity, aggregate stability.
- **Chemical indicators:** soil pH, electrical conductivity, macronutrient availability (N, P, K), CEC.
- **Biological indicators:** soil organic matter content, microbial biodiversity, microbial respiration.

Additional **specific indicators** followed include:

- Nutrient balances, vineyard microclimate (temperature, humidity), and digital sensor data (soil moisture, EC, carbon).

The first co-creation session, held on 10 February 2025 in Plovdiv, gathered 32 participants: 10 land managers, 8 researchers, 2 industry representatives, 5 policymakers, and 7 citizen/community representatives. The session focused on establishing a unified methodology for soil monitoring and vineyard management experiments. Demographic data show inclusivity across age groups (18–34 = 34%, 35–54 = 59%, 55–69 = 6%) and a balanced gender representation (47% male, 53% female). These dynamics reinforce the participatory governance model underpinning the LL.

3.2.5 Risk Identification and Mitigation

Risks for the BUV LL include climate variability (droughts and extreme rainfall), shifting market demand for wine, and policy uncertainties affecting vineyard management. Mitigation strategies focus on crop diversification, adaptive irrigation scheduling, and strengthening farmer–researcher networks to support resilience planning.

3.2.6 Summary

In summary, the BUV LL represents a systematic, stakeholder-driven approach to restoring and sustaining soil health in viticulture. By combining experimental rigour, diverse site selection, and inclusive governance, it creates a strong platform for delivering Mission Soil objectives, particularly those related to erosion prevention, soil organic carbon conservation, and biodiversity enhancement.

3.3 Greek Mine Soil Health LL

The Greek Mine Soil Health Living Lab is in **Western Macedonia**, a region undergoing major socioeconomic transitions as lignite mining is phased out. Coordinated by the **Cluster of Bioeconomy and Environment of Western Macedonia (CluBE)**, with **DIADYMA S.A., the University of Thessaly, and Generation A.G.** as partners, the LL focuses on transforming heavily degraded post-mining soils into multifunctional landscapes.

3.3.1 Co-creation and stakeholder involvement

The LL focuses on abandoned lignite mine lands, where soils are heavily degraded both structurally and chemically. The co-creation process began in June 2025 with a workshop involving 32 stakeholders, including landowners, researchers, municipal and regional authorities, industry representatives, and citizens. The session presented baseline soil analyses from previous studies and identified priority areas including remediation of heavy metal contamination (Cr, Ni), structural improvement of mine soils coupled with poor soil aggregation, low organic matter, and limited water-holding capacity and in some areas moderate slopes that increase erosion risks. Participants spanned ages 18–69 with balanced gender representation. There was also focus on developing ideas for potential post-mining land uses.

The workshop generated problem–solution pairs focused on phytoremediation and soil amendment practices, complemented by monitoring and literacy prototypes to increase transparency and trust.

Soil Intervention Prototypes
- **Soil amendments –** Compost
- **Agronomic –** Cover crops
- **Nature-based –** Phytoremediation (fast growing trees, aromatic plants for essential oils)

Monitoring & Decision-Support Prototypes
- **Bioindicator –** Biomass uptake of heavy metals

Soil Literacy Prototypes
- **Education & Training –** Soil days in schools
- **Awareness & Outreach –** Public events

3.3.2 Site Selection

Ten experimental sites have been secured within abandoned lignite fields in Western Macedonia. These sites represent Technosols and Regosols with sandy loam to loam textures, low soil organic matter, and moderate slopes prone to erosion. Sites were chosen to cover:

- Areas with severe contamination and urgent remediation needs.
- Areas with potential for productive reuse (e.g., biomass cultivation).
- Accessibility for field experimentation and monitoring.

All sites are under formal agreement with regional stakeholders, ensuring continuity and access.

3.3.3 Experimental Design Approach

The experimental design applies a replicated block structure across the mine soil test sites. Treatments are compared against untreated reference plots, with at least three replicates per treatment where site conditions allow. Plot layout is adapted to local heterogeneity, and randomisation is used to minimise bias.

Treatments include:
- **Control** – No treatment
- **Treatments** (Soil Intervention Prototypes):
  - Not determined yet

Monitoring prototypes include indicator testing to assess the effectiveness of phytoremediation. Heavy metal concentrations (e.g. Cr, Ni) are measured in the leaves, stems, and roots of trees, cover crops, and aromatic plants established at the mine test sites. Sampling is carried out in parallel with soil monitoring at defined intervals, and biomass yields are recorded to enable calculation of total contaminant uptake. By combining tissue concentrations with biomass production, the design allows evaluation of contaminant removal efficiency and comparison of performance across treatments and over time.

Soil Literacy Prototypes follow a structured implementation cycle linked to the test sites. Engagement activities will be evaluated using harmonised templates to track participation, knowledge gain, and stakeholder feedback.

3.3.4 Monitoring Indicators

Baseline soil sampling covers:

- **Physical indicators**: soil bulk density, particle size distribution, water-holding capacity
- **Chemical indicators**: pH, electrical conductivity, macronutrient availability (N, P, K, Ca, Mg, S), total nitrogen, CEC, heavy metals
- **Biological indicators**: microbial biodiversity, microbial respiration, soil organic matter content,

Specific Indicators include

- *aggregate stability, heavy metal uptake in plant biomass*

These indicators will allow the LL to track both contaminant reduction and improvements in soil functionality.

3.3.5 Risk Identification and Mitigation

Key risks identified for the Greek LL include:

- **Environmental:** persistence of heavy metal contamination, drought, erosion.
- **Institutional:** unclear policies on land reuse and tenure.
- **Social:** sustaining engagement in degraded landscapes.
- **Operational:** lack of irrigation infrastructure and potential crop failure.

Mitigation strategies include small-scale piloting before scaling, formal agreements with regional authorities, adaptive crop selection, and targeted outreach via schools and NGOs to strengthen long-term participation.

3.3.6 Summary

The Greek Mine Soil Health LL pioneers the restoration of post-mining landscapes by combining phytoremediation, soil amendments, and community engagement. Its work directly supports Soil Mission objectives to reduce pollution, restore soil functions, and strengthen soil literacy, while generating transferable lessons for other post-industrial regions in Europe.

3.4 Italian Soil Health LL (ITA LL)

The Italian Soil Health Living Lab is in Northern Italy, primarily in **Lombardy, Veneto, and Trentino-Alto Adige**. The LL focuses on intensively managed agricultural soils under vineyards, orchards, horticultural rotations, rice systema and adjacent wetlands. Coordinated by **ISINNOVA** in collaboration with regional cooperatives, municipalities, and research partners, the LL addresses key soil health challenges with high external inputs, frequent tillage, and monocropping. Baseline conditions in the region highlight critical issues including nutrient surpluses from mineral fertilisation, compaction from heavy machinery use, and declining soil organic carbon. These challenges are compounded by erosion and nutrient leaching risks due to soil types ranging from loamy sands and silty loamy to clay-rich paddy soils on gently sloping terrain.

3.4.1 Co-creation and stakeholder involvement

The Italian LL has engaged regional cooperatives, farmer groups, and policymakers through workshops and training sessions. The co-creation process identified priority soil health challenges: compaction, erosion, carbon decline, and nutrient imbalances. Based on these, stakeholders and researchers agreed on the following prototypes:

Soil Intervention Prototypes

- **Soil amendments –** Compost & digestate amendments, liming
- **Agronomic –** Cover crops
- **Fertilisation-based –** Partially replacing mineral fertilisers with BBFs

- **Management-based –** Reduced tillage

Monitoring & Decision-Support Prototypes

- **Soil Condition –** soil sensors for moisture and temperature
- **Digital platforms –** Nutrient balance modelling to guide adaptive fertiliser strategies

Soil Literacy Prototypes

- **Awareness and outreach –** Public campaigns and newsletters on sustainable soil management
- **Education and training –** Farmer training workshops on reduced tillage and soil amendment use
- **Community action –** Cooperative driven compost distribution networks

3.4.2 Site Selection

Ten test sites have been secured across the three regions, covering vineyards, orchards, rice paddies, and wetland soils. Site selection was based on:

- Relevance to priority soil challenges (compaction, nutrient surpluses, SOC decline).
- Soil diversity (loamy sands, loams, clay-rich rice soils).
- Operational feasibility and farmer commitment.
- Representation of intensive cropping systems at regional scale.

3.4.3 Experimental Design Approach

The experimental design follows primarily replicated block designs with at least three replicates (blocks). Treatments are compared against untreated reference plots and randomly applied where feasible. Plot size is adapted to crop and management system. Trials run across three cropping cycles (2024–2027), ensuring robust temporal comparisons.

Treatments include:

- **Control** – No treatment, reference management
- **Treatments (Soil Intervention Prototypes)**:
  - Cover crops
  - Compost
  - Digestate
  - Liming
  - Replacement of mineral fertilisers with BBFs
  - Reduced tillage

For Monitoring & Decision-Support Prototypes, nutrient balance modelling is integrated with the field trials, while soil conditions sensors are installed in selected sites for management-based decisions.

Soil Literacy Prototypes are implemented through a cycle of training sessions, demonstrations, and advisory workshops. Evaluation relies on participation metrics, surveys, and feedback forms to assess knowledge gains and behavioural shifts.

3.4.4 Monitoring Indicators

All sites monitor the baseline soil sampling covers:

- **Physical indicators**: soil bulk density, particle size distribution, water-holding capacity
- **Chemical indicators**: pH, electrical conductivity, macronutrient availability (N, P, K, Ca, Mg, S), total nitrogen, CEC, heavy metals
- **Biological indicators**: microbial biodiversity, microbial respiration, soil organic matter content,

Specific Indicators include

- nutrient balance modelling, aggregate stability

3.4.5 Risk Identification and Mitigation

Key risks identified for the ITA LL include:

- **Market risks:** fluctuations in crop and fertiliser prices may limit adoption. Mitigation: promote cost-neutral strategies through cooperative purchasing and advisory support.
- **Pest and disease pressures:** may increase under diversified cropping. Mitigation: adaptive pest monitoring and integration of resistant varieties.
- **Operational risks:** variability in farmer engagement. Mitigation: strong cooperative involvement, training, and field demonstrations.

Mitigation strategies include promoting cost-neutral strategies through cooperative purchasing and advisory support. Use of adaptive pest monitoring and integration of resistant varieties and the involvement of strong cooperatives that offer trainings and field demonstrations.

3.4.6 Summary

The Italian LL represents a coordinated multi-regional effort to co-develop sustainable practices for intensively managed soils. Through replicated trials, indicator testing, and farmer-led literacy initiatives, it generates robust evidence on how soil health can be restored under high-input systems. The LL contributes to Mission Soil goals by demonstrating pathways to conserve carbon, prevent erosion, and improve biodiversity in productive agricultural landscapes.

3.5 Southeastern Spain LL (SES LL)

The Southeastern Spain Living Lab is in the **Campo de Cartagena (Murcia) and Almería regions**, two **semi-arid zones** of high agricultural productivity and environmental vulnerability. Coordinated by **CETENMA**, with partners including **CEBAS, IMIDA**, and **FUNCA**, the main objectives of SES LL is to address deteriorating soil health under severe water constraints and nutrient stress.

3.5.1 Co-creation and stakeholder involvement

The co-creation process leading to the SES LL implementation plan was initiated in May 2025 and involved three structured sessions with a broad range of stakeholders. These included farmers, researchers, industry actors, and local policy representatives. These sessions introduced the LL's scope and co-developed strategies for optimising fertigation and regenerative practices, laying the foundation for shared governance of the experimental sites.

Production in the SES LL regularly faces pressure from drought and extreme weather events, projected to intensify under climate change and salinity escalation. The main soil health problems identified were soil erosion, declining fertility, and pollution related to intensive horticultural practices.

Mitigation strategies under consideration include testing drought-resilient crops, upgrading irrigation infrastructure with precision sensors, and applying adaptive fertigation strategies to balance crop needs with aquifer protection. Stakeholders jointly identified key intervention areas, leading to the selection of multiple prototypes for improving soil health in both conventional and organic systems. One proposed prototype involved replacing conventional fertilizers entirely with bio-based fertilizers (BBFs). However, due to concerns about potential nutrient limitations and yields reductions during the transition period, an alternative prototype was introduced that combines conventional fertilizers with BBFs to ensure agronomic performance while moving towards more sustainable nutrient sources.

A range of direct Soil Intervention Prototypes were chosen to test:

Soil Intervention Prototypes

- **Agronomic –** Crop rotations
- **Fertilization-based –** Replacing all or part of conventional fertilizers with biobased fertilizers
- **Soil amendments -** Mulching
- **Nature-based -** Continuous vegetation cover, establishment of native vegetation along borders
- **Management-based (technology) –** Drip irrigation
- **Integrated (Management (practice), soil amendment, nature based) –** Biosolarisation

Monitoring & Decision-Support Prototypes

- **Soil Condition –**soil moisture sensors for steering irrigation

3.5.2 Site Selection

Site selection was driven by environmental urgency and representativeness. Pilot plots were chosen in Nitrate Vulnerable Zones (NVZs) under irrigation communities where nutrient leaching and salinity directly contribute to the lagoon's decline. Additional plots were selected in other critical areas outside NVZs, including sites affected by specific pest pressures and high salinity irrigation water. This ensures both scientific control and high policy relevance, as results are intended to inform regional restoration strategies such as those for Mar Menor.

A total of 10 experimental sites are being established, three in Almeria and seven in Murcia. The landowners are partners in the project except for one site which is from outside the project. The total experimental area of the LL is just over 32 hectares, but test sites range in size from 30 m^2 to 9.7 hectares. The test sites are situated mainly on Regosols and Calcisols, with half of them on nearly level fields and the other half on gently sloping (2–5%) fields which increases the risk of runoff threatening the downstream Mar Menor Lagoon, which suffers eutrophication from agricultural runoff.

Five of the sites are arable farming systems and the other five have permanent crops (citrus). Four of the sites are conventional cropping systems, one is conventional mixed crop and livestock, and the remaining five are organic mixed crop and livestock farms. Seven of the sites use conventional tillage and three use reduced tillage techniques.

3.5.3 Experimental Design Approach

Most of the experimental approaches for the selected sites are randomized block designs. One site is using a randomized controlled trial, and one site is using a split-plot design. Treatments range from 2 to 4 per site plus control, with a minimum of three blocks or replicates each. Examples of treatments include:

- Control – conventional cropping, fertiliser, irrigation and pest management.
- Treatments
  - Mulching
  - Crop rotations
  - Continuous cover
  - Establish native vegetation
  - Replacing all conventional fertilisers with biobased fertilisers
  - Replacing part of conventional fertilisers with biobased fertilisers
  - Biosolarisation
  - Soil/irrigation sensors
  - Drip irrigation

3.5.4 Monitoring Indicators

A comprehensive monitoring framework is in place, covering the standard baseline soil monitoring indicators determined in D3.1 plus additional functional indicators to follow the effects of the various treatments. Baseline sampling has occurred on all sites, but results are still pending:

- **Physical indicators**: soil bulk density, particle size distribution, , water-holding capacity
- **Chemical indicators**: pH, electrical conductivity, macronutrient availability (N, P, K, Ca, Mg, S), total nitrogen, CEC, heavy metals
- **Biological indicators**: microbial biodiversity, microbial respiration, soil organic matter content,

In addition to the baseline indicators, the SES LL is also monitoring additional specific indicators to monitor impact of the treatments. These are more site-specific depending on the treatments being tested.

- **Specific indicators**: fertiliser input analysis, irrigation water quality, crop productivity, and nutrient balances, nematode incidence

3.5.5 Risk Identification and Mitigation

The SES Living Lab identified risks across five categories during the planning of its experimental activities. Key environmental risks include heatwaves, drought, and salinity, which may affect prototype performance, particularly for cover crops and biosolarisation. Flexible timing of interventions, adaptive fertigation, and sensor-guided irrigation are planned to mitigate these risks.

Site-specific variability—especially in greenhouse management—is addressed through harmonised protocols and detailed baseline characterisation. To reduce social risks, including inconsistent participation from landowners, most test sites are operated by project partners, with agreements in place and regular engagement ensured.

Operational risks such as delays in sourcing mulch or bio-based fertilisers are mitigated via early procurement and reliance on local suppliers. Standardised monitoring templates and coordinator training help minimise data inconsistencies. In addition, treatment-specific risks (e.g. nutrient limitations or increased pest pressure) are addressed through ongoing performance monitoring and tailored adjustments.

All risks and responses are tracked in a shared risk log to enable iterative refinement throughout the LL implementation process.

3.5.6 Summary

In summary, the SES LL provides a critical testbed for demonstrating soil restoration strategies under semi-arid and high-pressure conditions. By integrating advanced fertigation, regenerative practices, and co-created governance mechanisms directly supports the Soil Mission objectives of improving soil structure, reducing nutrient pollution, and conserving scarce water resources while protecting the sensitive Mar Menor ecosystem.

3.6 Swedish Soil Health LL (SWE LL)

The Swedish Soil Health Living Lab is primarily in central and southern Sweden, anchored in **mixed livestock–arable farming systems**. Coordinated by **RISE Research Institutes of Sweden** in partnership with **Hushållningssällskapet (HS Konsult)**, the **Swedish Veterinary Institute (SVA), Odling i Balans,** the **Federation of Swedish Farmers (LRF),** and the **Swedish University of Agricultural Sciences (SLU)**, the LL addresses soil health challenges linked to intensive livestock production, including soil compaction, poor aggregation, biodiversity decline, and phosphorus surpluses.

3.6.1 Co-creation and stakeholder involvement

The first co-creation workshop (April 2025) engaged 27 participants, including land managers, researchers, advisors, and community members, with a broad age distribution (18–69 years) and gender balance (67% male, 33% female). Discussions centred on identifying priorities with farm-level needs, particularly around manure redistribution logistics and the practicalities of implementing reduced tillage under Swedish climatic conditions. Follow up co-creation workshops were held in June and early July.

A range of direct Soil Intervention Prototypes were chosen to test:

Soil Intervention Prototypes

- **Soil amendments –** Biochar, gypsum, effective microorganisms
- **Fertilisation-based –** Use of urine fertilisers instead of conventional mineral fertilisers
- **Nature-based –** Cover crops
- **Agronomic –** Crop rotations
- **Management-based –** Manure redistribution between animal-dense and crop-dominant farms, reduced tillage, deep tillage

Monitoring & Decision-Support Prototypes

- **Soil Condition –**soil moisture and temperature sensors
- **Data Integration –** Nutrient balance accounting

3.6.2 Site Selection

Fifteen farms were secured for the Swedish LL, representing both livestock-dense regions (southern and central Sweden) and crop-dominant farms (central regions). Selection was guided by:

- Relevance to regional soil health challenges (compaction, nutrient surpluses, carbon decline).
- Coverage of soil diversity (light sandy soils to heavy clays).
- Feasibility of conducting replicated experiments.
- Commitment of participating farmers to long-term collaboration.

Test sites cover a mix of light sandy soils and heavier clay-rich soils, mainly with little or no sloping (0–2%, nearly level) and a few with gently sloping (2–5%) conditions. These soils exhibit variable clay contents from <15% (light sands) to >40% (heavier clays), creating diverse soil management challenges, particularly in relation to soil compaction which is a major issue for soil health in Swedish agricultural soils.

3.6.3 Experimental Design Approach

Experimental trials apply a mix of replicated block and split-plot designs, with three to four replicates (blocks) per treatment depending on site conditions. Farmer-standard practice serves as the reference control. Treatments and controls are randomised where feasible, with plot sizes adapted to crop and management systems.

- Control – conventional cropping, fertiliser, and pest management.
- Treatments
  - Biochar amendments
  - Cover crops
  - Improved crop rotations
  - Replacing conventional fertilisers with urine fertilisers
  - Replacing part of conventional fertilisers with biobased fertilisers

Monitoring & Decision-Support Prototypes are implemented in parallel with interventions, focusing on field-level nutrient balances. Nutrient balance accounting is applied primarily at plot level across the relevant test sites. The approach involves systematic recording of all nutrient inputs (fertilisers, manures, bio-based amendments) and outputs (harvested biomass, leaching estimates, gaseous losses where available), with a particular emphasis on phosphorus. Data are collected annually using harmonised farm diaries, advisory records, and direct measurements of soil and crop nutrient contents.

The experimental design uses nutrient balances to compare prototype interventions (e.g. manure redistribution, soil amendments, fertilizer replacement) against control practices. Effectiveness is assessed by:

- **Reduction of P surpluses** in nutrient balance sheets relative to baseline and controls.
- **Improved nutrient use efficiency** (ratio of outputs to inputs).
- **Alignment with environmental targets**, such as lowering surplus below regionally accepted thresholds.

Evaluation of the prototype itself focuses on usability and robustness: whether the balance methodology is feasible for farmers to implement with available data, whether results are comparable across farms and regions, and whether outcomes are sufficiently clear to inform decision-making. Feedback from farmers, cooperatives, and advisors is integrated into the evaluation cycle to refine the accounting approach and its integration into advisory systems.

3.6.4 Monitoring Indicators

A comprehensive monitoring framework is in place, covering the standard baseline soil monitoring indicators determined in D3.1 plus additional functional indicators to follow the effects of the various treatments. Baseline sampling has occurred on all sites, but results are still pending:

- **Physical indicators**: soil bulk density, particle size distribution, , water-holding capacity
- **Chemical indicators**: pH, electrical conductivity, macronutrient availability (N, P, K, Ca, Mg, S), total nitrogen, CEC, heavy metals
- **Biological indicators**: microbial biodiversity, microbial respiration, soil organic matter content,

In addition to the baseline indicators, the SES LL is also monitoring additional specific indicators to monitor impact of the treatments. These are more site-specific depending on the treatments being tested.

- **Specific indicators**: Nutrient balance accounting.

3.6.5 Risk Identification and Mitigation

The Swedish LL faces several potential risks. A key social risk is declining farmer participation over the project's duration, which is being mitigated through long-term contracts with participating farms and by embedding monitoring within advisory services to ensure continuity. Environmental risks are linked to climate extremes, with southern sites exposed to recurrent droughts and central and northern sites vulnerable to flooding; these risks are addressed through adaptive cropping plans and tailored water management strategies. Operational risks also arise from the logistical complexity of manure redistribution across regions, which are mitigated through cooperative coordination and careful redistribution planning adapted to regional conditions.

3.6.6 Summary

The Swedish Soil Health LL integrates diverse farming systems, soil types, and experimental approaches at national scale. By combining field interventions, nutrient redistribution, GHG monitoring, and farmer-led knowledge exchange, it delivers robust evidence for restoring soil structure, reducing surpluses, and enhancing resilience. Its multi-actor design and scale make it a cornerstone of iCOSHELLs, directly contributing to the Soil Mission objectives of carbon conservation, erosion prevention, biodiversity improvement, and nutrient balance.

4. Cross-LL Site Selection and Design Synthesis

4.1 Overview of Site Selection Patters

The six iCOSHELLs Living Labs (LLs) have collectively identified and secured over 65 soil test sites across diverse agroecosystems, including mixed arable–livestock systems, vineyards, urban green spaces, post-mining areas, and intensive horticultural zones. Site selection processes were grounded in stakeholder co-creation (WP1) and aligned with shared criteria to ensure relevance, feasibility, and experimental comparability.

All LLs applied the following core selection principles:

- *Relevance to co-identified soil challenges (e.g., compaction, nutrient surplus, erosion)*
- *Representation of regional environmental and management diversity*
- *Operational feasibility (e.g., site access, long-term collaboration)*
- *Stakeholder ownership and willingness to engage*

While the co-creation approach was consistent, each LL adapted the selection to local contexts, land tenure models, and logistical constraints. Table 4.1 provides a synthesis of site selection across LLs.

Table 4.1. Overview of Site Selection Characteristics by Living Lab

LL	# Sites	Dominant Land Use	Key Soil Types	Main Soil Challenges
SWE	15	Mixed arable–livestock	Sandy, clay	Compaction, nutrient surpluses, carbon loss
BUV	10	Vineyards	Sandy loam, clay	Erosion, nutrient depletion, compaction
Greek	10	Post-mining Technosols	Sandy loam, Regosols	Contamination (Cr/Ni), poor aggregation
ITA	10	Orchards, vineyards, rice	Loam, silty clay	SOC loss, nutrient imbalance, compaction
SES	10	Arable and citrus systems	Regosols, Calcisols	Fertility loss, salinity, erosion
Basque	10	Urban/peri-urban green	Arenosols, Albeluvisols	Compaction, low biodiversity, community use

4.2 Overview of Experimental Designs

Experimental design strategies across LLs were developed to ensure scientific validity while remaining adaptable to field constraints and stakeholder capacity. Most LLs employ replicated block designs with 2–8 treatments and 3–6 replicates, enabling meaningful statistical comparisons across management strategies. Split-plot and paired comparison designs are used where space or logistics limit full randomisation.

All test sites are implementing the core set of soil health indicators defined in D3.1, ensuring consistency in physical, chemical, and biological monitoring. Where relevant, additional functional indicators (e.g., nutrient balances, pollutant uptake, biodiversity measures) have been added based on the prototype goals.

Table 4.2. Summary of Experimental Design Elements by Living Lab

LL	Design Type	# Treatments	Replicates	Additional Indicators
SWE	Block & split-plot	4–6	3–4	Nutrient balances (P-focused), GHGs
BUV	Replicated block	6–8	3–6	Digital sensor calibration, irrigation data
Greek	Replicated block	3–5	3	Phytoremediation biomass analysis
ITA	Replicated block	3–6	3–5	Nutrient modelling, aggregate stability
SES	Split-block & RCT	2–4	3	Irrigation quality, nematode presence
Basque	Split-plot, small scale	3–4	3	eDNA, acoustic soil life monitoring

These variations reflect both the heterogeneity of site conditions and the flexibility of the iCOSHELLs approach, while the harmonised monitoring framework ensures a strong foundation for future cross-site comparisons.

4.3 Commonalities and Key Variations

All iCOSHELLs Living Labs follow a shared methodological approach grounded in stakeholder co-creation, site-level experimentation, harmonised indicator monitoring (as defined in D3.1), and early-stage risk planning. However, notable contextual variations exist in how the LLs operationalise these principles—particularly regarding land access models, stakeholder engagement strategies, and the settings used for educational and literacy prototypes.

At the same me, several notable variations emerged:

- **Land access models**: the Swedish LL (SWE) engages a network of privately operated farms distributed across southern and central Sweden. These farms are not project beneficiaries but participate through cascade funding (FSTP), which provides financial compensation and technical support for prototype implementation. This model offers flexibility and maintains independence for the farmers while securing long-term commitment through formal agreements. In contrast, the Southeastern Spain LL (SES) primarily conducts its experimental activities on farms that are formal partners in the project consortium. This allows for close alignment between research design and day-to-day operations, reducing administrative barriers and facilitating rapid implementation. The Greek LL represents a different model entirely, operating on abandoned mining lands in Western Macedonia. These degraded post-industrial sites are accessed through partnerships with regional authorities and local stakeholders. While the absence of private landowners simplifies access in some respects, these sites present unique challenges related to soil contamination, land tenure complexity, and long-term reuse planning. The Basque LL, meanwhile, implements its activities on municipally owned plots located in urban and peri-urban zones. This approach enables strong integration with public engagement strategies and ensures high visibility for soil restoration activities in areas under direct local governance.
- **Engagement strategies**: Engagement and governance strategies also vary across the LLs, shaped by their stakeholder ecosystems and institutional settings. In SWE, implementation is embedded within the national agricultural advisory system, with project staff and extension agents supporting farmers through continuous engagement, technical assistance, and shared learning platforms. This model supports robust implementation across a dispersed network of commercial farms. In contrast, the Basque and Greek LLs rely heavily on municipalities, civil society organisations, and community groups to co-design and manage interventions. Their focus is on fostering collective ownership, building capacity through participatory processes, and ensuring continuity via integration into existing educational or environmental programmes. The BUV, SES, and ITA LLs are more strongly oriented toward farm-level actors and cooperatives, using participatory workshops, pilot demonstrations, and farmer-led experimentation to ensure the practical relevance of prototypes and facilitate adoption.
- **Complementary venues** for soil literacy prototypes differ: In the Basque and Italian LLs, activities are often embedded in schools, public buildings, or municipal spaces, enabling engagement with a wide

cross-section of the public, including students, educators, and residents. The Swedish LL situates its educational activities more within the advisory and professional farming context, using field visits, training sessions, and data-sharing platforms to raise awareness among farmers and consultants. In Greece and Spain, educational activities are closely linked to community initiatives and NGOs, focusing on building soil literacy in relation to land restoration, environmental justice, and sustainable farming transitions. While the settings differ, all LLs ensure that these activities remain connected to the core experimental sites, creating a feedback loop between field-based interventions and public-facing engagement.

These variations in land access, governance, and engagement are not inconsistencies but rather strengths of the Living Lab model. They reflect the diverse institutional, social, and biophysical conditions in which soil health solutions must ultimately be applied. By accommodating this diversity within a harmonised methodological framework, iCOSHELLs ensures that the knowledge generated is both locally grounded and transferable across regions, a critical prerequisite for scaling innovation in line with the Soil Mission's objectives.

5. Integration with Other Work Packages

This first iteration of the LLs Implementation Design and Site Selection Report (D2.3) forms a foundational output of WP2 and supports the operationalisation of the iCOSHELLs Living Labs across six European regions. While D2.3 is focused specifically on experimental site selection and implementation design, it is structurally interconnected with several other Work Packages that address co-creation, monitoring, scaling, and prototype refinement.

The co-creation processes and stakeholder engagement activities that underpin prototype selection and site identification are led under WP1 (Living Lab Co-Creation and Governance). In particular, Tasks 1.1–1.3 handle stakeholder mapping, motivation analysis, and the facilitation of regional co-creation workshops. While this report references those processes as context for how experimental sites and challenges were identified, the full documentation and analysis of stakeholder participation will be delivered in WP1 outputs (not within D2.3). This ensures that responsibilities for social mapping, stakeholder typologies, and governance structures remain clearly within WP1.

Similarly, while D2.3 describes which types of prototypes are being implemented at the selected sites, it does not include development or refinement logic for these prototypes. Those processes are handled in a separate set of WP2 deliverables: D2.6–D2.8 (Prototype Development and Refinement Reports). That series will provide detailed accounts of how prototypes were co-created, adjusted through stakeholder feedback and technical validation, and iteratively refined during implementation. This separation ensures that D2.3 remains focused solely on physical deployment and experimental setup, without overlapping with the innovation and usability aspects addressed in D2.6.

The indicators used to monitor soil health and prototype performance are defined under WP3 (Monitoring and Evaluation). D3.1 sets out the core and optional soil health indicators that all Living Labs are required to implement, and WP3 will lead the ongoing data collection, harmonisation, and cross-site evaluation of prototype impacts. The experimental designs and site-level metadata captured in D2.3 provide the operational backbone for this monitoring work, ensuring data quality and comparability across sites.

Finally, WP5 (Communication, Scaling, and Policy Uptake) will draw upon the design logic, regional diversity, and implementation models presented here to support outreach, stakeholder engagement, and policy dialogue. The testbed diversity established in D2.3, from urban soils to post-mining lands to intensive farms — will enable WP5 to tailor communication strategies and demonstrate the adaptability of soil health solutions across Europe.

All data and metadata associated with site selection, implementation, and monitoring setup are stored in the internal WP2 repository and will be made accessible to relevant WPs according to the principles outlined in the

Data Management Plan (D8.2). Future iterations of this deliverable (D2.4 and D2.5) will build upon this initial implementation framework, incorporating additional sites from the Open Call and updates to experimental designs based on early results and stakeholder feedback.

In this way, D2.3 plays a central coordinating role within WP2 and across iCOSHELLs, serving as the structural and methodological foundation for subsequent monitoring, refinement, and scaling efforts.

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