iCOSHELLs

D7.6 PRACTICE ABSTRACTS – BATCH1

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Disclaimer

iCOSHELLs 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.

Executive Summary

Purpose: The first batch of Practice Abstracts (PAs) developed by iCOSHELLs' partners collects good practices and solutions developed and tested within the project. These summaries aim to boost knowledge exchange and share innovative solutions across the EU. The PAs will be published in the EU CAP Network repository, for this purpose, they have been developed following the EIP-AGRI common format.

Intended Audience: The purpose of this deliverable is to share knowledge in an accessible way with farmers, rural communities, advisers, land managers and other end users. The PAs will be shared via the iCOSHELLs website and social media channels as a project deliverable, but also as self-standing documents to reach a wider audience. Their publication in the EU CAP Network repository will enhance the exchange with other Horizon Europe-funded projects and strengthen interaction with Operational Groups.

Main Activities: The first batch gathers 12 Practice Abstracts describing diverse innovative solutions for soil health protection and improvement. These practices range from technical solutions addressing soil issues such as drought and compaction, to the development of collaboration methodologies to support farmers, as well as the use of bio-based solutions and non-mineral fertilizers. The practices reflect experiences and solutions tested across iCOSHELLs Living Labs in Sweden, Spain, Bulgaria, Greece and Italy.

All practices are described by multiple project partners, who provide their contact details to facilitate direct exchange with practitioners interested in learning more about these innovations.

Key Results, Findings or Highlights: The 12 PAs highlight innovative and context-specific approaches to improving soil health, combining technical, biological, and collaborative solutions. Together, they illustrate the added value of the Living Lab approach in developing practices that are both practical and adaptable.

Conclusion: iCOSHELLs project is still at an early stage of implementation (M18), and some tests and results are therefore preliminary. Further testing will be carried out and additional solutions will be developed throughout the project, allowing confirmation and consolidation of these initial findings. This new and validated information will be collected in a second batch under **D5.1 – Tool: Practice Abstracts to support replication - Batch 2** (M48).

By supporting soil health and sustainable land management, the proposed practices contribute to the objectives of the EU Soil Mission and the Common Agricultural Policy.

1. Introduction

1.1. Structure and purpose

The deliverable introduces the first batch of Practice Abstracts developed within the iCOSHELLs project. The PAs collect concrete practices tested in real conditions in the project's Living Labs and present them as short, practical summaries adapted to end-users.

The PAs are designed following the EIP-AGRI format to ensure clarity and accessibility for a wide audience. All Practice Abstract share a common structure based on three main sections: **Challenge, Our Solution and Recommendations.**

Each PA contains a maximum of 2,000 characters and presents one prototype or operational lesson that has been tested or applied in practice. The objective is not to describe project structures or research activities but clearly explain:

- the problem that practitioners faced in the agricultural activities,
- the solution tested by the project partners in real conditions, and
- practical recommendations to replicate the practices or to adapt them to a different environment.

The abstracts are written in simple and non-technical language to ensure accessibility for farmers, advisers, land managers, rural communities, and other relevant end users. While most practices were developed within the Living Labs, they are transferable and do not require a Living Lab setting to be replicated or adapted.

1.2. Development process of the PAs

The Practice Abstract template and guidance were developed collaboratively by G!E and IFAU to ensure clarity, consistency and alignment with the EIP-AGRI common format. Clear instructions were provided to project partners to focus on practical implementation, concrete actions, and added value for end users, avoiding general descriptions of organisations or lists of services.

The scope and structure were further refined in consultation with the scientific coordinator from RISE to ensure that all PAs clearly described a tested solution and its practical relevance.

A total of 14 Practice Abstracts were submitted by project partners. These were collected by G!E and reviewed by IFAU from an expert perspective to ensure quality, clarity, and practical focus. Following this review process, 12 Practice Abstracts were selected for inclusion in this first batch in order to avoid overlaps and ensure coherence. Additional ideas and practices will be further developed and considered for inclusion in Batch 2 at the end of the project.

The next section presents each of the 12 Practice Abstracts in a concise text format for easy reading. Full self-standing versions of each abstract, following the one-page template, are provided in Annex I. These self-standing documents are ready to be shared with farmers, advisers, land managers, and other end users.

2. Practice Abstracts

PA#1 - How intercropping with grass can save vines from drought? by AUP

Challenge

In Plovdiv region, in the heart of Bulgaria, the Bulgarian Viticulture Soil Health Living Lab (BUVLL) is located. It is connected to the Agricultural University of Plovdiv (AUP). The region is known for its vineyards, grape and wine production. The sector is strategic for the country with more than 340 wineries nation-wide.

During the last five or six years, the severe impact of rising temperatures and long periods of drought hit hard the grape and wine producers. There were warm spells as early as February, which trigger fruit trees and vines to flower too soon. Then colder weather returns, and the flowers fail to develop.

When drought hits later in spring, irrigation offers only temporary relief. The additional soil watering by drip irrigation did not help, as the soil dries out within few hours. Microorganisms and earthworms die quickly, and without them the soil can no longer hold minerals or feed the vines properly.

Our Solution

One solution now being tested is relatively simple: grow grass between the vines. When it’s cut, the grass remains on the ground, creating a protective layer that keeps soil cooler and prevents moisture loss. It can be combined with a digital monitoring system that constantly tracks climate conditions and suggest working solutions.

Ten vineyards, including the university’s own experimental site, are part of the study. Farmers are not just observers but co-creators. Recently, the AUP research team explained to farmers how soil microorganisms can indicate what the soil needs and which solutions can be implemented, such as grassing. This can be described as a new way of “listening” to the soil, based on so-called metagenomic analysis of active soil microorganisms.

The idea of grassing soil is not new. It was first observed in orchards in Belgium fifteen years ago and was later transferred to vineyards and orchards in Bulgaria.

Recommendations

The BUVLL leaders, co-creators and all the soil health stakeholders in the region got together and discussed possible solution to climate impact. Grassing should be done with very precise machines, in a precise time and by using new grass-legume mixtures adapted to dry conditions. The information from digital sources is fast and accessible and would give a hand to farmers when applying the solutions.

PA#2 - GREENNOMED Living Lab services: from networking to real innovation by CETENMA

Challenge

How can we make sure that a Living Lab (LL) truly sparks those strategic actions that lead to large-scale adoption of innovative solutions?

At GREENNOMED LL we want to go beyond the concept of LL as a place for networking and driving R&D proposals. We work to be the physical and intellectual go-to place for stakeholders in need of technical support for complex challenge or fresh ideas and inspiration, helping Mediterranean farming and agroforestry become more resilient.

Our Solution

We provide access to the technical expertise and facilities of our leading partner, CETENMA, and its network of collaborators. First step? Listen to companies and organisations' needs and challenges. Then, offer a tailored set of services to develop and test new ideas and solutions. This customised support enables organisations to innovate from their respective starting points, regardless of size or experience, while establishing the Living Lab as a go-to hub for innovative initiatives. Services include:

- R&D planning and project support
- Evaluation of innovative solutions
- Soil health assessment - soil DNA extraction for metagenomics analysis, quantification of microbial groups via targeted qPCR analysis, chemical-physical analysis.
- Circular economy and resource efficiency action plans.
- Consultancy services on how to successfully kick-off and manage an impactful living lab.
- Funding opportunities scouting - inclusion in regional, national, and European R&D&i projects.
- Access to a wide range of innovative solutions currently under testing, through engagement with multiple initiatives and fellow Living Labs

Recommendations

Do you want to replicate GREENNOMED LL's approach?

- Include partners with strong technical background in the LL management structure.
- Map constantly real local challenges and stakeholders' needs, by keeping a close and frequent dialogue with them.
- Approach the innovation process from stakeholders' starting point and offering clear pathways that include R&D services, access to funding, grants, partnerships, and scaling opportunities.

PA#3 - Development of sustainable fertigation protocols by CEBAS-CSIC

Challenge

One of the major problems facing intensive agriculture in arid or semi-arid regions is the excessive use of mineral fertilizers (mainly nitrogen), which, when not applied correctly, end up affecting the quality of groundwater bodies. In this regard, a key challenge for most farmers in maintaining their agricultural production while respecting the environment is optimising the use of fertilizers and improved irrigation practices, in turn, resulting in improved soil health.

Our Solution

The solution that we propose is the use of new organic fertilizers that allow plant growth without causing nitrogen accumulation in the agricultural systems. In addition to using new fertilizers, we also propose improving water use efficiency through the use of soil moisture sensors, which will facilitate the development of sustainable fertigation protocols. These action protocols are being tested in the Campo de Cartagena (Southeast of Spain) on melon and broccoli crops. So far, farmers have managed to maintain high levels of production and crop quality while reducing the inputs of mineral fertilizers, improving water management and maintaining the functionality of the soils.

Recommendations

The development of sustainable fertigation protocols based on the use of new fertilizers and the control of irrigation management is a strategy that should be supported at the political level and applied routinely in all areas with intensive irrigation systems in order to improve the sustainability and socio-economic impact of these production systems.

PA#4 - Practical assessment for soil health solutions through set of indicators and common monitoring methodology in Living Labs by CETENMA

Challenge

Farmers, landowners and Living Labs often struggle to understand whether new soil practices or innovations are really resolving specific soil and agricultural challenges while not affecting negatively soil health. There are many existing indicators as “wish-lists”, making difficult to understand which monitoring set to pick. Most of the indicators are hard to measure, expensive, time consuming and, in some cases, overlapping with each other, lacking practical thresholds, or not comparable across sites or either too general or too specific. Depending on the indicator selected, it might be assessing the solution's performance but ignoring the impact on soil health.

This creates uncertainty when testing new solutions, slows down adoption, and limits the ability to demonstrate the full range of benefits for soil functions and ecosystem services, especially when sample resources are limited and consistent analytical methods are required to compare results across sites.

Our Solution

CETENMA together with iCOSHELLs consortium, developed a practical approach that is time and resource saving, and based on a set of general soil health indicators that any Living Lab can use to monitor soil changes over time. Alongside, **soil-specific indicators** tailored to assess solution performances in each LL were proposed. This combined approach not only enables Living Labs to monitor the performance of new practices while ensuring that no negative effects are impacting soil health but also produces reliable datasets that will support the ongoing development of iCOSHELLs predictive model.

The general indicators set covers physical, chemical and biological soil properties, offering a balanced picture and monitoring of soil condition, to make results comparable over time and across LLs. These general indicators include key parameters such as bulk density, pH, nutrients, organic carbon, microbial biodiversity and respiration; all selected for their relevance and contribution to soil health.

The approach also proposes a common soil sampling protocol and standard laboratory procedures, to help ensure that data collected across different regions, soils and sampling campaigns can be analysed and compared in a consistent way.

Recommendations

- Combine the set of general soil health indicators with your Living Lab specific challenge to capture local impact on soil health and solution performance, respectively.
- Use the proposed common sampling and analysis methods to ensure consistent data across sites.
- Establish a baseline reference before testing innovations to monitor soil health.
- Share data across sites and LLs to help build stronger evidence and improve future soil health prediction models.
- Soil characterization needs expert interpretation and evaluation.

PA#5 - Can we use remote sensing data to manage crops more efficiently? by UPM

Challenge

Which field is performing the best, is it the one that produce the most, is it the one that has the highest soil organic matter, more balanced ph, the one that handles the best climate extreme events (more common every year…) It is hard to pick based on one single metric, like production, a particular soil property, biological biodiversity, etc. In our project we are doing laboratory analysis of soil physical, chemical, and biological properties to evaluate how the different prototypes each Living Lab is implementing produces the best results and comparing those results with remote sensing data.

Our Solution

Remote sensing provides cost-effective monitoring compared to laboratory measurements. Platforms such as Copernicus Browser offer pre-calculated vegetation indices (e.g., NDVI) that allow temporal and spatial comparison between plots and across years. We assess whether vegetation indices can reflect laboratory-observed improvements across crop types, plot sizes, and varying soil exposure.

Recommendations

Based on the combined analysis of laboratory soil measurements and remote sensing indicators, we recommend integrating remote sensing tools as a strategic component of field performance assessment. Rather than relying exclusively on yield data or individual laboratory parameters, vegetation indices (e.g., NDVI) can serve as an early warning system, detecting deviations in plant health or soil moisture dynamics before they become visible in production outcomes.

In addition, we encourage the promotion of knowledge-sharing initiatives among farmers and livestock associations to reduce the technical barrier associated with remote sensing data analysis. Collective data interpretation platforms or advisory services could distribute the workload and required expertise across networks of producers. Furthermore, institutional support through targeted training programs and capacity-building courses would facilitate the wider adoption of remote sensing tools, ensuring that technological innovation remains accessible and practical for end users.

PA#6 - Making soil restoration feasible in post-mining areas with limited resources by CluBE

Challenge

In the pilot sites of the Living Lab in Western Macedonia, post-mining areas are characterised by degraded soils resulting from legacy mining activities, combined with structural limitations such as a lack of irrigation networks, uneven terrain, and limited on-site infrastructure, including water supply and electricity networks. Although nature-based solutions are increasingly promoted for soil restoration, many of them implicitly assume stable water supply, regular maintenance and sufficient financial inputs. In reality, local authorities and land managers must operate under tight resource constraints. Designing restoration actions without fully considering these limitations can lead to project delays, increased costs or technical failure. The core challenge was therefore to identify restoration pathways that are not only environmentally sound, but also technically and economically feasible under dry, low-input conditions.

Our Solution

In the Greek Living Lab, a feasibility-first planning approach was adopted. Instead of selecting a predefined remediation technique, the design process began with an assessment of on-site constraints, including water availability, accessibility, required inputs and long-term management capacity. Restoration options were screened against these conditions before any technical prioritisation. Approaches demanding irrigation or intensive maintenance were excluded at an early stage. This structured screening redirected planning toward low-input, drought-adapted and scalable strategies compatible with Mediterranean post-mining environments. By placing feasibility at the centre of decision-making, the Living Lab reduced implementation risks and improved the realism of future pilot actions.

Recommendations

Post-mining soil restoration should begin with a structured feasibility assessment linked to real field conditions. Water availability, infrastructure, maintenance responsibility and budget limits must be clarified before selecting a technique. Screening and documenting excluded options strengthen transparency and reduces the likelihood of project failure. In dry regions with limited resources, climate-adapted and low-input approaches offer greater long-term sustainability than technically complex interventions.

PA#7 - Soil decompaction practices in an apple orchard by RUMA

Challenge

Apple orchards are subject to a persistent problem of soil compaction, which is caused by the continuous passage of heavy machinery throughout the growing season. The repeated disturbance caused by traffic results in the formation of dense, hardened soil layers, which has a detrimental effect on the soil's natural functions. Soil compaction is a process that can lead to a deterioration in the soil's structure, resulting in a reduction in water infiltration. This, in turn, can cause an increase in runoff of essential nutrients that are crucial for the growth and health of plants. Farmers encounter a frustrating cycle in which fertilisation becomes less effective than it should be. This is due to nutrients either running off before being absorbed or leaching through compacted layers without benefiting the trees. This phenomenon signifies a considerable deficit in valuable resources and inputs, thereby compromising the productivity and sustainability of the orchard. Consequently, practitioners are compelled to administer greater quantities of fertilisers to redress the losses, a practice that results in escalated costs and augmented environmental impact.

Our Solution

In order to address the issue of compaction, a practical intervention strategy was employed, which involved the implementation of a surface soil decompaction technique using a vertical ripper. This approach involves the mechanical disruption of the compacted upper soil layers (0-20 cm) with the objective of restoring optimal physical conditions for plant growth and nutrient retention. The period chosen for the intervention was autumn, after harvest. The practice was only adopted subsequent to a particularly rainy harvesting period, with the objective being to aerate the soil and restore its optimal condition and structure. The findings from the field application demonstrated quantifiable enhancements in pivotal soil physical properties, including augmented soil structure that facilitates enhanced root penetration, improved colour indicative of elevated organic matter integration and aeration, and considerably improved permeability that enables water and nutrients to traverse the soil profile more efficaciously. Conventional practices often neglect compaction until it becomes severe or rely solely on deep tillage, which can be disruptive and expensive. In contrast, this surface decompaction method offers a targeted, efficient way to restore soil health while maintaining the orchard structure and minimising disturbance to the established root systems. Furthermore, a shallow decompaction of the soil surface (0-10cm) was obtained in spring (one month before germination) through the use of a rotary harrow. This process was also undertaken in order to flatten the surface.

An additional experiment was conducted as part of this study, involving the application of fertilisers in the inter-row. The objective of this experiment was to enable apple roots to explore the soil in different directions and act as natural “decompactors”.

Recommendations

For practitioners considering the implementation of surface soil decompaction through vertical ripper or rotary harrow in their orchards, the temporal aspect is of critical importance in achieving optimal outcomes. It is imperative that the practice is carried out when the soil is dry, as working wet or moist soil can exacerbate compaction rather than alleviate it. This allows the loosened soil structure to receive and absorb water more effectively while preventing the reformed structure from being damaged by working saturated conditions. Farmers are advised to closely monitor weather forecasts and incorporate decompaction operations into their management calendars during periods of favourable weather conditions. It is imperative to refrain from operating heavy machinery in freshly “decompacted” areas until the soil has had sufficient time to settle and stabilise, as premature traffic will merely exacerbate the compaction problem and invalidate the objectives of the intervention.

PA#8 - Healthy soil, healthy food: sustainable rice cultivation strategies by UCSC

Challenge

Rice farmers in Europe, particularly in high-production areas like the Po valleys, are facing significant challenges due to soil degradation caused by intensive agricultural practices and climate change. These phenomena lead to a loss of biological fertility. For practitioners, the main difficulty is maintaining high productivity while ensuring the long-term sustainability of the soil resource and meeting the increasing demand for high-quality food products. Current methods often rely on an excessive use of fertilizers that risks harming the environment without providing real benefits to the crop's yield, nutritional, or structural value.

Our Solution

The project aims to bridge the gap between scientific research and practical application through a structured co-creation process. Moving beyond isolated laboratory tests, the core innovation for rice growers is the direct implementation of optimised agronomic practices within their own fields. This hands-on transition ensures that strategies —such as use of liming materials, cover crops, and high-quality compost— are not just theoretical concepts, but actively executed solutions tailored to real-world farming conditions. The project includes monitoring of rice yields and quality to ensure the purity and excellence of the final harvest. These integrated practices aim to restore soil health, improve nutrient cycles (C, N, K, and P), and enhance the natural resilience of the paddy fields.

Recommendations

To adapt these practices successfully, the most important lesson is patience, as structural improvements to soil health and organic matter could require a consistent commitment of several years to yield significant results. These methods are effective in regions with diverse climatic conditions. The farmers should take into consideration the proposed agronomic practices to naturally restore nutrient cycles. Throughout this transition, rice quality will be monitored to verify grain purity and ensure that sustainable management leads to a superior harvest. Finally, using a Living Lab framework is essential to ensure that these innovations are co-created with local stakeholders, making them both socially acceptable and economically viable for the farming community.

PA#9 - Use of organic soil amendments and reduction of inputs for sustainable agriculture and recovery of degraded soils by Fundación Grupo Cajamar

Challenge

In intensive agriculture in the Mediterranean region, one of the main problems is the poor soil quality due to over-fertilization, which affects the quality of the soil and the worsening of the quality of irrigation water due to environmental pollution.

Our Solution

The solution we propose is the development of new organic soil amendments from the waste generated by intensive horticulture. This involves using microorganisms to enhance compost, improving both its quality and effectiveness. Similarly, the method aims to reduce the use of nitrogen, phosphorus, and potassium fertilizer units by 20 to 30%. In addition to organic amendments, other types of bioproducts are being tested as substitutes for inorganic inputs. We have been working for several years at the Cajamar Las Palmerillas Experimental Station on different crops such as tomato, pepper, cucumber, and zucchini, where we have used soil amendments and subsequently, managed to produce 20% more in some cases by reducing the application of N, P, and K by 20%.

Recommendations

The use of these organic amendments, made from plant remains and known as compost, should be implemented regularly to avoid the significant problem of using manure transported from many kilometers away. Similarly, it would be important to teach farmers proper management of the biomass generated at the end of the growing season to maximise its value. All of this should be complemented by the use of microorganisms and other bioproducts to improve the quality of the compost produced.

PA#10 - Integrating soil microbiome genomics into holistic soil health assessment by UPM

Challenge

Soil health is more than pH, nutrients, or organic matter levels. These indicators are important, but they do not tell us whether the soil is biologically active and resilient.

Healthy soils depend on living organisms — bacteria and fungi — that help release nutrients, support plant growth, improve soil structure, and increase tolerance to drought or climate stress. However, this biological component is rarely included in routine assessments because it is more difficult to measure and interpret. As a result, soil management decisions are often based on incomplete information.

Our Solution

To better understand how management practices influence soil life, we use gene sequencing to analyze soil microbial communities in different Living Lab prototypes.

This allows us to:

- Identify the diversity of bacteria and fungi present in the soil
- Detect changes in microbial communities under different management systems
- Link soil biology with crop performance and resilience

Rather than replacing conventional soil analysis, microbial assessment adds a missing layer of information. It helps us understand why certain fields perform better over time — not only in terms of yield, but also in stability and resistance to stress.

Recommendations

Soil assessments should move beyond chemistry and include biological indicators where possible. While genomic tools may not yet be part of routine farm monitoring everywhere, they can support advisory services, Living Labs, and research–practice networks in identifying management strategies that strengthen soil life.

In practice, farmers and land managers can promote a healthy soil microbiome by:

- Reducing soil disturbance
- Increasing organic matter inputs
- Diversifying crop rotations
- Avoiding excessive chemical inputs

Supporting soil biology is not an abstract goal — it is a practical strategy to improve long-term productivity and climate resilience. When soil microorganisms thrive, nutrient cycling improves, soil structure stabilizes, and crops become more robust. Investing in soil life means investing in the sustainability of the entire production system.

PA#11 - The role of biochar in arable agriculture by RISE

Challenge

Many arable soils show signs of declining soil health, including compaction, low organic matter, acidification, and uneven nutrient distribution. In several Swedish cases, soil assessments also indicate low microbial activity, which affects soil structure, nutrient cycling, and long-term fertility. These constraints reduce nutrient-use efficiency, increase leaching risks, and make soils more vulnerable to drought, compaction, and weather variability. Acidification further limits crop choice and complicates soil management.

Our Solution

Within the Swedish Living Lab, biochar has been tested on one farm so far, and both field experience and existing studies suggest it can address several of these soil health challenges. Based on these results, testing will continue on additional farms.

In practice, biochar is applied to the topsoil or mixed with manure, compost, or digestate before spreading. This “charging” step improves nutrient retention and helps avoid temporary nitrogen immobilisation. Field observations show that results depend on matching the type of biochar to soil needs. Wood-derived biochar mainly contributes stable carbon and supports long-term soil structure, while biochar made from nutrient-rich residues (such as seed husks or hulls) can help supply phosphorus and potassium where deficiencies are identified.

Overall, biochar can improve aggregate stability, water retention, soil pH in acidic soils, and microbial habitat. Application rates typically range from 2 to 30 t/ha, depending on soil conditions and management goals.

Recommendations

Biochar application should be based on soil analysis to ensure it addresses actual constraints such as pH, nutrient status, organic matter, and biological activity. More consistent results are achieved when biochar is applied together with organic amendments, which support microbial activity and reduce nitrogen immobilisation. Farmers are advised to start with small-scale or strip trials before applying biochar across entire fields, as responses may vary. Certified biochar (e.g. under the European Biochar Certificate) should be used to ensure quality and safety. Biochar acts as a long-term soil amendment, and its benefits typically develop gradually over several seasons.

PA#12 - Subsoiling to fight deep soil compaction by RISE

Challenge

Compacted subsoil is a widespread, persistent problem that limits soil function in many production systems. Unlike surface compaction, which can be alleviated by reduced tillage, subsoil compaction occurs deeper, typically from repeated heavy machinery traffic or wet-field operations and can persist for decades.

For farmers, it restricts root growth, forcing shallow, weak root systems that reduce water and nutrient uptake. Crops become more vulnerable to drought and waterlogging, while reduced porosity limits drainage, infiltration, and soil oxygen, affecting microbial activity essential for nutrient cycling. Typical symptoms include patchy growth, standing water, and poor resilience to weather extremes. Over time, compaction degrades soil structure, lowers yields, and increases reliance on external inputs. Because natural recovery is slow, subsoil compaction represents a long-term barrier to soil health, productivity, and resilience.

Our Solution

Subsoiling uses deep shanks or tines to penetrate 30–50 cm below the plow layer, lifting and fracturing the soil without inverting it. This creates vertical and lateral fissures, restoring pore space and enabling deeper root growth. Modern implements may include winged shanks for enhanced lateral shattering or variable depth systems to match compaction profiles, improving efficiency.

Experiences from the Swedish Living Lab highlight that success depends on reaching the correct depth and operating in dry conditions to avoid smearing. Some farmers combine subsoiling with organic materials (e.g., straw pellets) added to the fractured layer to boost microbial activity and stabilise the loosened structure. Early evidence suggests this can enhance long-term soil resilience.

Subsoiling is promising but context-dependent: proper diagnosis of compaction depth, equipment selection, and favourable soil moisture are critical. When combined with biological inputs, it can significantly improve rooting depth, water availability, and overall soil health.

Recommendations

- Subsoiling works best in medium-textured soils (loams, clay loams) under dry conditions.
- In sandy soils, loosened layers may collapse quickly; in heavy clays, subsoiling only works when the subsoil is dry.
- To avoid rapid re-compaction, adopt controlled traffic, reduced axle loads, and other soil-preserving practices.
- Combine mechanical loosening with deep-rooted cover crops and careful field timing to maintain structure.
- Always verify compaction depth before subsoiling and operate under suitable moisture conditions.

Annex I – Self-standing Practice Abstracts

How intercropping with grass can save vines from drought?

iCOSHELLs project | Practice Abstracts | No. 01

Author:	**Vladislav Popov**
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Country/region:	Bulgaria/Plovdiv
Keywords:	Grass, vineyards, soil, microorganisms, precision

Challenge

In Plovdiv region, in the heart of Bulgaria, the Bulgarian Viticulture Soil Health Living Lab (BUVLL) is located. It is connected to the Agricultural University of Plovdiv (AUP). The region is known for its vineyards, grape and wine production. The sector is strategic for the country with more than 340 wineries nation-wide.

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Learn more about the project on our website
www.icoshells.eu

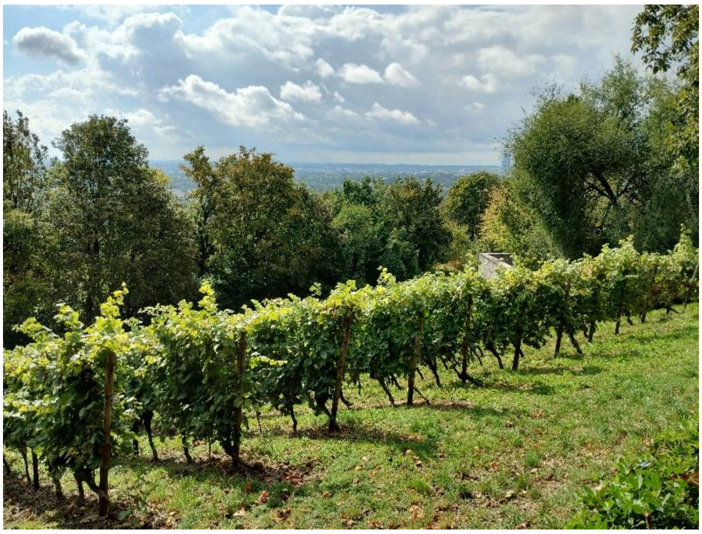
Funded by the European Union

Our Solution

One solution now being tested is relatively simple: grow grass between the vines. When it’s cut, the grass remains on the ground, creating a protective layer that keeps soil cooler and prevents moisture loss. It can be combined with a digital monitoring system that constantly tracks climate conditions and suggest working solutions.

Ten vineyards, including the university’s own experimental site, are part of the study. Farmers are not just observers but co-creators. Recently, the AUP research team explained to farmers how soil microorganisms can indicate what the soil needs and which solutions can be implemented, such as grassing. This can be described as a new way of “listening” to the soil, based on so-called metagenomic analysis of active soil microorganisms.

The idea of grassing soil is not new. It was first observed in orchards in Belgium fifteen years ago and was later transferred to vineyards and orchards in Bulgaria.



Recommendations

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GREENNOMED Living Lab services: from networking to real innovation

iCOSHELLs project | Practice Abstracts | No. 02

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Keywords:	Living lab, services, innovation

Challenge

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At GREENNOMED LL we want to go beyond the concept of LL as a place for networking and driving R&D proposals. We work to be the physical and intellectual go-to place for stakeholders in need of technical support for complex challenge or fresh ideas and inspiration, helping Mediterranean farming and agroforestry become more resilient.

Our Solution

We provide access to the technical expertise and facilities of our leading partner, CETENMA, and its network of collaborators. First step? Listen to companies and organisations' needs and challenges. Then, offer a tailored set of services to develop and test new ideas and solutions. This customised support enables organisations to innovate from their respective starting points, regardless of size or experience, while establishing the Living Lab as a go-to hub for innovative initiatives. Services include:

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- R&D planning and project support
- Evaluation of innovative solutions
- Soil health assessment - soil DNA extraction for metagenomics analysis, quantification of microbial groups via targeted qPCR analysis, chemical-physical analysis.
- Circular economy and resource efficiency action plans.
- Consultancy services on how to successfully kick-off and manage an impactful living lab.
- Funding opportunities scouting - inclusion in regional, national, and European R&D&i projects.
- Access to a wide range of innovative solutions currently under testing, through engagement with multiple initiatives and fellow Living Labs

Recommendations

Do you want to replicate GREENNOMED LL's approach?

- Include partners with strong technical background in the LL management structure.
- Map constantly real local challenges and stakeholders' needs, by keeping a close and frequent dialogue with them.
- Approach the innovation process from stakeholders' starting point and offering clear pathways that include R&D services, access to funding, grants, partnerships, and scaling opportunities.

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Development of sustainable fertigation protocols

iCOSHELLs project | Practice Abstracts | No. 03

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Keywords:	Soil health, fertilizers, irrigation, sustainability

Challenge

One of the major problems facing intensive agriculture in arid or semi-arid regions is the excessive use of mineral fertilizers (mainly nitrogen), which, when not applied correctly, end up affecting the quality of groundwater bodies. In this regard, a key challenge for most farmers in maintaining their agricultural production while respecting the environment is optimising the use of fertilizers and improved irrigation practices, in turn, resulting in improved soil health.

Our Solution

The solution that we propose is the use of new organic fertilizers that allow plant growth without causing nitrogen accumulation in the agricultural systems. In addition to using new fertilizers, we also propose improving water use efficiency through the use of soil moisture sensors, which will facilitate the development of sustainable

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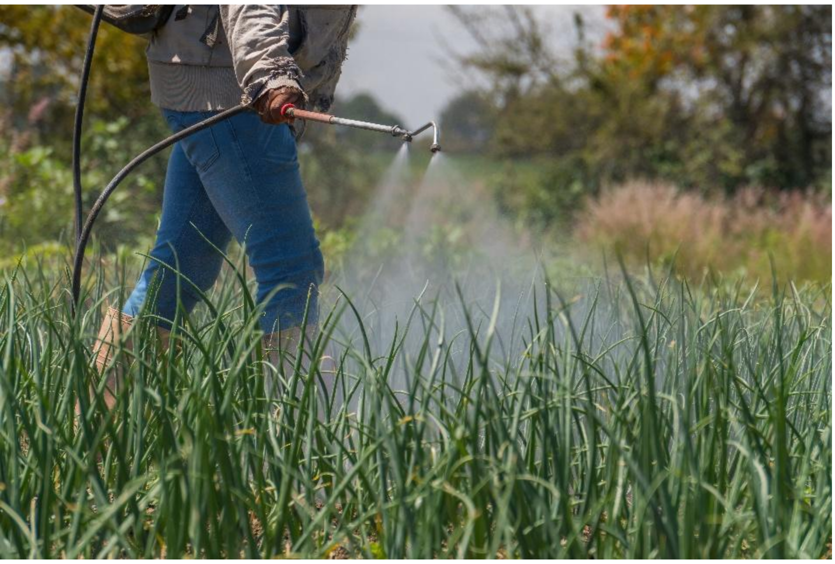
fertigation protocols. These action protocols are being tested in the Campo de Cartagena (Southeast of Spain) on melon and broccoli crops. So far, farmers have managed to maintain high levels of production and crop quality while reducing the inputs of mineral fertilizers, improving water management and maintaining the functionality of the soils.



Recommendations

The development of sustainable fertigation protocols based on the use of new fertilizers and the control of irrigation management is a strategy that should be supported at the political level and applied routinely in all areas with intensive irrigation systems in order to improve the sustainability and socio-economic impact of these production systems.

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Practical assessment for soil health solutions through indicators and common monitoring methodology in Living Labs

iCOSHELLs project | Practice Abstracts | No. 04

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Keywords:	Living lab, soil health, soil indicators

Challenge

Farmers, landowners and Living Labs often struggle to understand whether new soil practices or innovations are really resolving specific soil and agricultural challenges while not affecting negatively soil health. There are many existing indicators as “wish-lists”, making difficult to understand which monitoring set to pick. Most of the indicators are hard to measure, expensive, time consuming and, in some cases, overlapping with each other, lacking practical thresholds, or not comparable across sites or either too general or too specific. Depending on the indicator selected, it might be assessing the solution's performance but ignoring the impact on soil health.

This creates uncertainty when testing new solutions, slows down adoption, and limits the ability to demonstrate the full range of benefits for soil functions and ecosystem services, especially when

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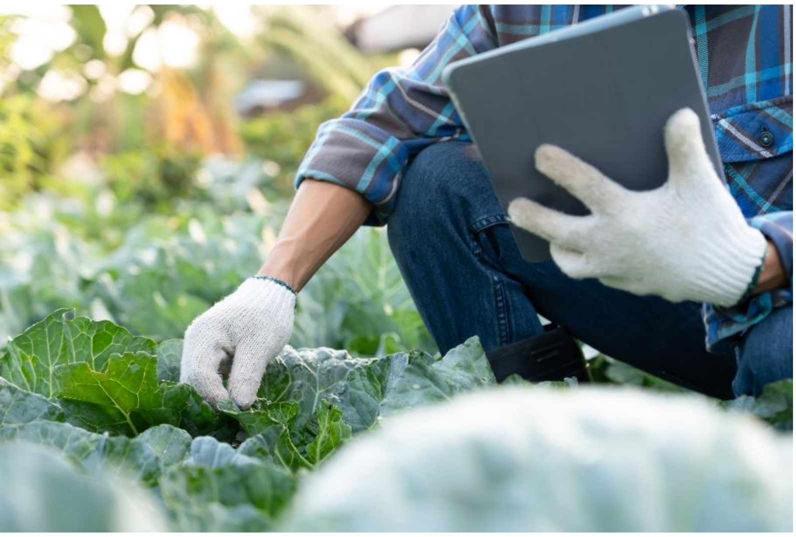
sample resources are limited and consistent analytical methods are required to compare results across sites.

Our Solution

CETENMA together with iCOSHELLs consortium, developed a practical approach that is time and resource saving, and based on a set of general soil health indicators that any Living Lab can use to monitor soil changes over time. Alongside, **soil-specific indicators** tailored to assess solution performances in each LL were proposed. This combined approach not only enables Living Labs to monitor the performance of new practices while ensuring that no negative effects are impacting soil health but also produces reliable datasets that will support the ongoing development of iCOSHELLs predictive model.

The general indicators set covers physical, chemical and biological soil properties, offering a balanced picture and monitoring of soil condition, to make results comparable over time and across LLs. These general indicators include key parameters such as bulk density, pH, nutrients, organic carbon, microbial biodiversity and respiration; all selected for their relevance and contribution to soil health.



The approach also proposes a common soil sampling protocol and standard laboratory procedures, to help ensure that data collected across different regions, soils and sampling campaigns can be analysed and compared in a consistent way.

Recommendations

- Combine the set of general soil health indicators with your Living Lab specific challenge to capture local impact on soil health and solution performance, respectively.
- Use the proposed common sampling and analysis methods to ensure consistent data across sites.
- Establish a baseline reference before testing innovations to monitor soil health.
- Share data across sites and LLs to help build stronger evidence and improve future soil health prediction models.
- Soil characterization needs expert interpretation and evaluation.

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Can we use remote sensing data to manage crops more efficiently?

iCOSHELLs project | Practice Abstracts | No. 05

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Keywords:	Remote sensing, vegetation index, soil monitoring

Challenge

Which field is performing the best, is it the one that produce the most, is it the one that has the highest soil organic matter, more balanced ph, the one that handles the best climate extreme events (more common every year...) It is hard to pick based on one single metric, like production, a particular soil property, biological biodiversity, etc. In our project we are doing laboratory analysis of soil physical, chemical, and biological properties to evaluate how the different prototypes each Living Lab is implementing produces the best results and comparing those results with remote sensing data.

Our Solution

Remote sensing provides cost-effective monitoring compared to laboratory measurements. Platforms such as Copernicus Browser offer pre-calculated vegetation indices (e.g., NDVI) that allow temporal and spatial comparison between plots and across years. We

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assess whether vegetation indices can reflect laboratory-observed improvements across crop types, plot sizes, and varying soil exposure.

Recommendations

Based on the combined analysis of laboratory soil measurements and remote sensing indicators, we recommend integrating remote sensing tools as a strategic component of field performance assessment. Rather than relying exclusively on yield data or individual laboratory parameters, vegetation indices (e.g., NDVI) can serve as an early warning system, detecting deviations in plant health or soil moisture dynamics before they become visible in production outcomes.

In addition, we encourage the promotion of knowledge-sharing initiatives among farmers and livestock associations to reduce the technical barrier associated with remote sensing data analysis. Collective data interpretation platforms or advisory services could distribute the workload and required expertise across networks of producers. Furthermore, institutional support through targeted training programs and capacity-building courses would facilitate the wider adoption of remote sensing tools, ensuring that technological innovation remains accessible and practical for end users.

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Making soil restoration feasible in post-mining areas with limited resources

iCOSHELLs project | Practice Abstracts | No. 06

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Keywords:	Post-mining areas, soil restoration, feasibility assessment, dry conditions, nature-based solutions

Challenge

In the pilot sites of the Living Lab in Western Macedonia, post-mining areas are characterised by degraded soils resulting from legacy mining activities, combined with structural limitations such as a lack of irrigation networks, uneven terrain, and limited on-site infrastructure, including water supply and electricity networks. Although nature-based solutions are increasingly promoted for soil restoration, many of them implicitly assume stable water supply, regular maintenance and sufficient financial inputs. In reality, local authorities and land managers must operate under tight resource constraints. Designing restoration actions without fully considering these limitations can lead to project delays, increased costs or technical failure. The core challenge was therefore to identify restoration pathways that are not only environmentally sound, but

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also technically and economically feasible under dry, low-input conditions.

Our Solution

In the Greek Living Lab, a feasibility-first planning approach was adopted. Instead of selecting a predefined remediation technique, the design process began with an assessment of on-site constraints, including water availability, accessibility, required inputs and long-term management capacity. Restoration options were screened against these conditions before any technical prioritisation. Approaches demanding irrigation or intensive maintenance were excluded at an early stage. This structured screening redirected planning toward low-input, drought-adapted and scalable strategies compatible with Mediterranean post-mining environments. By placing feasibility at the centre of decision-making, the Living Lab reduced implementation risks and improved the realism of future pilot actions.

Recommendations

Post-mining soil restoration should begin with a structured feasibility assessment linked to real field conditions. Water availability, infrastructure, maintenance responsibility and budget limits must be clarified before selecting a technique. Screening and documenting excluded options strengthen transparency and reduces the likelihood of project failure. In dry regions with limited resources, climate-adapted and low-input approaches offer greater long-term sustainability than technically complex interventions.

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Soil decompaction practices in an apple orchard

iCOSHELLs project | Practice Abstracts | No. 07

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Keywords:	Soil, compaction, run off, leaching, fertilization, loss

Challenge

Apple orchards are subject to a persistent problem of soil compaction, which is caused by the continuous passage of heavy machinery throughout the growing season. The repeated disturbance caused by traffic results in the formation of dense, hardened soil layers, which has a detrimental effect on the soil's natural functions. Soil compaction is a process that can lead to a deterioration in the soil's structure, resulting in a reduction in water infiltration. This, in turn, can cause an increase in runoff of essential nutrients that are crucial for the growth and health of plants. Farmers encounter a frustrating cycle in which fertilisation becomes less effective than it should be. This is due to nutrients either running off before being absorbed or leaching through compacted layers without benefiting the trees. This phenomenon signifies a considerable deficit in valuable resources and inputs, thereby compromising the productivity and sustainability of the orchard. Consequently, practitioners are compelled to administer greater quantities of fertilisers to redress the losses, a practice that results in escalated costs and augmented environmental impact

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Our Solution

In order to address the issue of compaction, a practical intervention strategy was employed, which involved the implementation of a surface soil decompaction technique using a vertical ripper. This approach involves the mechanical disruption of the compacted upper soil layers (0-20 cm) with the objective of restoring optimal physical conditions for plant growth and nutrient retention. The period chosen for the intervention was autumn, after harvest. The practice was only adopted subsequent to a particularly rainy harvesting period, with the objective being to aerate the soil and restore its optimal condition and structure. The findings from the field application demonstrated quantifiable enhancements in pivotal soil physical properties, including augmented soil structure that facilitates enhanced root penetration, improved colour indicative of elevated organic matter integration and aeration, and considerably improved permeability that enables water and nutrients to traverse the soil profile more efficaciously. Conventional practices often neglect compaction until it becomes severe or rely solely on deep tillage, which can be disruptive and expensive. In contrast, this surface decompaction method offers a targeted, efficient way to restore soil health while maintaining the orchard structure and minimising disturbance to the established root systems. Furthermore, a shallow decompaction of the soil surface (0-10cm) was obtained in spring (one month before germination) through the use of a rotary harrow. This process was also undertaken in order to flatten the surface.

An additional experiment was conducted as part of this study, involving the application of fertilisers in the inter-row. The objective of this experiment was to enable apple roots to explore the soil in different directions and act as natural “decompactors”.

Recommendations

For practitioners considering the implementation of surface soil decompaction through vertical ripper or rotary harrow in their orchards, the temporal aspect is of critical importance in achieving optimal outcomes. It is imperative that the practice is carried out when the soil is dry, as working wet or moist soil can exacerbate compaction rather than alleviate it. This allows the loosened soil structure to receive and absorb water more effectively while preventing the reformed structure from being damaged by working saturated conditions. Farmers are advised to closely monitor weather forecasts and incorporate decompaction operations into their management calendars during periods of favourable weather conditions. It is imperative to refrain from operating heavy machinery in freshly “decompacted” areas until the soil has had sufficient time to settle and stabilise, as premature traffic will merely exacerbate the compaction problem and invalidate the objectives of the intervention.

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Healthy soil, healthy food: sustainable rice cultivation strategies

iCOSHELLs project | Practice Abstracts | No. 08

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Keywords:	Sustainable agriculture, rice, healthy soil, healthy food

Challenge

Rice farmers in Europe, particularly in high-production areas like the Po valleys, are facing significant challenges due to soil degradation caused by intensive agricultural practices and climate change. These phenomena lead to a loss of biological fertility. For practitioners, the main difficulty is maintaining high productivity while ensuring the long-term sustainability of the soil resource and meeting the increasing demand for high-quality food products. Current methods often rely on an excessive use of fertilizers that risks harming the environment without providing real benefits to the crop's yield, nutritional, or structural value.

Our Solution

The project aims to bridge the gap between scientific research and practical application through a structured co-creation process. Moving beyond isolated laboratory tests, the core innovation for rice growers is the direct implementation of optimised agronomic practices within their own fields. This hands-on transition ensures

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that strategies —such as use of liming materials, cover crops, and high-quality compost— are not just theoretical concepts, but actively executed solutions tailored to real-world farming conditions. The project includes monitoring of rice yields and quality to ensure the purity and excellence of the final harvest. These integrated practices aim to restore soil health, improve nutrient cycles (C, N, K, and P), and enhance the natural resilience of the paddy fields.

Recommendations

To adapt these practices successfully, the most important lesson is patience, as structural improvements to soil health and organic matter could require a consistent commitment of several years to yield significant results. These methods are effective in regions with diverse climatic conditions. The farmers should take into consideration the proposed agronomic practices to naturally restore nutrient cycles. Throughout this transition, rice quality will be monitored to verify grain purity and ensure that sustainable management leads to a superior harvest. Finally, using a Living Lab framework is essential to ensure that these innovations are co-created with local stakeholders, making them both socially acceptable and economically viable for the farming community.

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Use of organic amendments and reduction of inputs for sustainable agriculture and recovery of degraded soils

iCOSHELLs project | Practice Abstracts | No. 9

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Keywords:	Degraded soil, organic amendments, agriculture

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Challenge

In intensive agriculture in the Mediterranean region, one of the main problems is the poor soil quality due to over-fertilization, which affects the quality of the soil and the worsening of the quality of irrigation water due to environmental pollution.

Our Solution

The solution we propose is the development of new organic soil amendments from the waste generated by intensive horticulture. This involves using microorganisms to enhance compost, improving both its quality and effectiveness. Similarly, the method aims to reduce the

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use of nitrogen, phosphorus, and potassium fertilizer units by 20 to 30%. In addition to organic amendments, other types of bioproducts are being tested as substitutes for inorganic inputs. We have been working for several years at the Cajamar Las Palmerillas Experimental Station on different crops such as tomato, pepper, cucumber, and zucchini, where we have used soil amendments and subsequently, managed to produce 20% more in some cases by reducing the application of N, P, and K by 20%.

Recommendations

The use of these organic amendments, made from plant remains and known as compost, should be implemented regularly to avoid the significant problem of using manure transported from many kilometers away. Similarly, it would be important to teach farmers proper management of the biomass generated at the end of the growing season to maximise its value. All of this should be complemented by the use of microorganisms and other bioproducts to improve the quality of the compost produced.

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Integrating soil microbiome genomics into holistic soil health assessment

iCOSHELLs project | Practice Abstracts | No. 10

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Keywords:	Soil health, microbiome, soil monitoring

Challenge

Soil health is more than pH, nutrients, or organic matter levels. These indicators are important, but they do not tell us whether the soil is biologically active and resilient.

Healthy soils depend on living organisms — bacteria and fungi — that help release nutrients, support plant growth, improve soil structure, and increase tolerance to drought or climate stress. However, this biological component is rarely included in routine assessments because it is more difficult to measure and interpret. As a result, soil management decisions are often based on incomplete information.

Our Solution

To better understand how management practices influence soil life, we use gene sequencing to analyse soil microbial communities in different Living Lab prototypes.

This allows us to:

- Identify the diversity of bacteria and fungi present in the soil

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- Detect changes in microbial communities under different management systems
- Link soil biology with crop performance and resilience

Rather than replacing conventional soil analysis, microbial assessment adds a missing layer of information. It helps us understand why certain fields perform better over time — not only in terms of yield, but also in stability and resistance to stress.

Recommendations

Soil assessments should move beyond chemistry and include biological indicators where possible. While genomic tools may not yet be part of routine farm monitoring everywhere, they can support advisory services, Living Labs, and research–practice networks in identifying management strategies that strengthen soil life.

In practice, farmers and land managers can promote a healthy soil microbiome by:

- Reducing soil disturbance
- Increasing organic matter inputs
- Diversifying crop rotations
- Avoiding excessive chemical inputs

Supporting soil biology is not an abstract goal — it is a practical strategy to improve long-term productivity and climate resilience. When soil microorganisms thrive, nutrient cycling improves, soil structure stabilizes, and crops become more robust. Investing in soil life means investing in the sustainability of the entire production system.

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The role of biochar in arable agriculture

iCOSHELLs project | Practice Abstracts | No. 11

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Keywords:	Biochar

Challenge

Many arable soils show signs of declining soil health, including compaction, low organic matter, acidification, and uneven nutrient distribution. In several Swedish cases, soil assessments also indicate low microbial activity, which affects soil structure, nutrient cycling, and long-term fertility. These constraints reduce nutrient-use efficiency, increase leaching risks, and make soils more vulnerable to drought, compaction, and weather variability. Acidification further limits crop choice and complicates soil management.

Our Solution

Within the Swedish Living Lab, biochar has been tested on one farm so far, and both field experience and existing studies suggest it can address several of these soil health challenges. Based on these results, testing will continue on additional farms.

In practice, biochar is applied to the topsoil or mixed with manure, compost, or digestate before spreading. This “charging” step improves nutrient retention and helps avoid temporary nitrogen immobilisation. Field observations show that results depend on matching the type of biochar to soil needs. Wood-derived biochar

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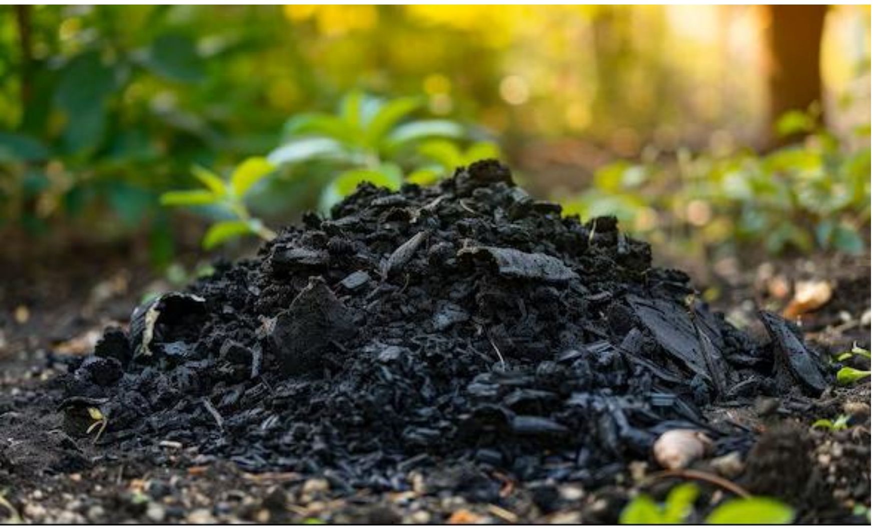
mainly contributes stable carbon and supports long-term soil structure, while biochar made from nutrient-rich residues (such as seed husks or hulls) can help supply phosphorus and potassium where deficiencies are identified.

Overall, biochar can improve aggregate stability, water retention, soil pH in acidic soils, and microbial habitat. Application rates typically range from 2 to 30 t/ha, depending on soil conditions and management goals.

Recommendations

Biochar application should be based on soil analysis to ensure it addresses actual constraints such as pH, nutrient status, organic matter, and biological activity. More consistent results are achieved when biochar is applied together with organic amendments, which support microbial activity and reduce nitrogen immobilisation. Farmers are advised to start with small-scale or strip trials before applying biochar across entire fields, as responses may vary. Certified biochar (e.g. under the European Biochar Certificate) should be used to ensure quality and safety. Biochar acts as a long-term soil amendment, and its benefits typically develop gradually over several seasons.



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Subsoiling to fight deep soil compaction

iCOSHELLs project | Practice Abstracts | No. 12

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Keywords:	Subsoiling, plough pan, soil compaction

Challenge

Compacted Compacted subsoil is a widespread, persistent problem that limits soil function in many production systems. Unlike surface compaction, which can be alleviated by reduced tillage, subsoil compaction occurs deeper, typically from repeated heavy machinery traffic or wet-field operations and can persist for decades.

For farmers, it restricts root growth, forcing shallow, weak root systems that reduce water and nutrient uptake. Crops become more vulnerable to drought and waterlogging, while reduced porosity limits drainage, infiltration, and soil oxygen, affecting microbial activity essential for nutrient cycling. Typical symptoms include patchy growth, standing water, and poor resilience to weather extremes. Over time, compaction degrades soil structure, lowers yields, and increases reliance on external inputs. Because natural recovery is slow, subsoil compaction represents a long-term barrier to soil health, productivity, and resilience.

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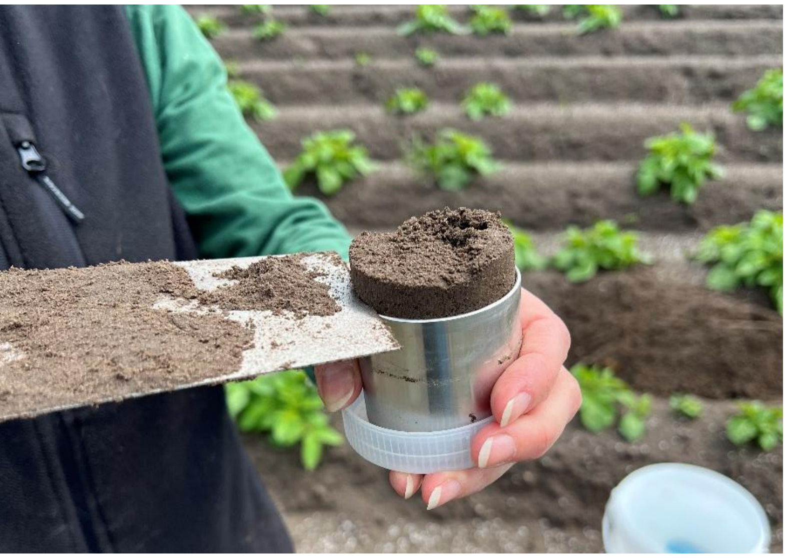
Our Solution

Compacted Subsoiling uses deep shanks or tines to penetrate 30–50 cm below the plow layer, lifting and fracturing the soil without inverting it. This creates vertical and lateral fissures, restoring pore space and enabling deeper root growth. Modern implements may include winged shanks for enhanced lateral shattering or variable depth systems to match compaction profiles, improving efficiency.

Experiences from the Swedish Living Lab highlight that success depends on reaching the correct depth and operating in dry conditions to avoid smearing. Some farmers combine subsoiling with organic materials (e.g., straw pellets) added to the fractured layer to boost microbial activity and stabilise the loosened structure. Early evidence suggests this can enhance long-term soil resilience.



Subsoiling is promising but context-dependent: proper diagnosis of compaction depth, equipment selection, and favourable soil moisture are critical. When combined with biological inputs, it can significantly improve rooting depth, water availability, and overall soil health.

Recommendations

- Subsoiling i Subsoiling works best in medium-textured soils (loams, clay loams) under dry conditions.
- In sandy soils, loosened layers may collapse quickly; in heavy clays, subsoiling only works when the subsoil is dry.
- To avoid rapid re-compaction, adopt controlled traffic, reduced axle loads, and other soil-preserving practices.
- Combine mechanical loosening with deep-rooted cover crops and careful field timing to maintain structure.
- Always verify compaction depth before subsoiling and operate under suitable moisture conditions.

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