SALAM-MED
Sustainable Approaches to Land and water Management in Mediterranean Drylands

Deliverable D4.4

Lessons learned and guidelines for upscaling Living Lab innovation processes in the MED area

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Disclaimer

Outline

This document presents the main results, insights, and practical recommendations derived from the implementation and evaluation of Living Lab (LL) activities across six Mediterranean countries within the SALAM-MED project. It begins by outlining the Monitoring and Evaluation (M&E) framework and methodology applied to assess the LL's processes, outcomes, and impacts. Subsequent sections provide an overview of each LL's context and innovations, detailed findings from the M&E process, and a comparative analysis highlighting commonalities and differences. The document then distils lessons learned and identifies strategic considerations for scaling the LL innovation approach in Mediterranean drylands. It concludes with final reflections and a set of recommendations for future LL initiatives.

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Executive Summary

This document presents the main results, insights, and practical recommendations from the implementation and evaluation of six Living Labs (LLs) across Mediterranean drylands within the SALAM-MED project. It synthesises lessons learned and identifies strategic recommendations for future LL initiatives.

The Monitoring and Evaluation (M&E) framework applied a formative, iterative approach based on efficacy, efficiency, and effectiveness criteria, integrating qualitative and quantitative data to assess LL processes, outcomes, and impacts. The LLs operated as open innovation social learning systems, combining scientific and local knowledge to co-create context-sensitive nature-based solutions (NBS) addressing land degradation, water scarcity, and socio-ecological resilience.

Each LL focused on site-specific innovations – from microbial technologies and adaptive grazing in Italy, sustainable olive farming in Greece, adaptive forest management in Spain, managed aquifer recharge in Tunisia, argan forest restoration in Morocco, to enhanced water harvesting and soil fertility in Egypt – alongside promoting active stakeholder engagement, particularly of women and youth, and sustainable business/livelihood opportunities.

Comparative analysis identified key success factors, including trust-building, adaptive facilitation, integration of traditional knowledge, and iterative co-design. Barriers encompassed resistance to change, resource intensity, technical challenges, and governance complexities. The LL approach transformed research practices toward participatory, reflexive, and transdisciplinary methods.

Lessons learned also emphasise the centrality of formative M&E as a learning tool, the need for context-sensitive and flexible LL design, and the critical role of facilitation skills. Scalability requires simultaneous attention to scaling out (geographic and social expansion), scaling up (institutional integration), and scaling deep (transformative cultural and relational change).

Recommendations include embedding structured formative M&E from project inception, investing in facilitation capacity, designing for multi-dimensional scalability, and fostering networks for knowledge exchange. Ultimately, LLs are dynamic social learning systems enabling sustainable socio-ecological transformations through inclusive co-creation, adaptive management, and knowledge integration.

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EU: European Union

LL: Living Labs

M&E: Monitoring and Evaluation

NBS: Bature-based Solutions

SHLLs: Soil Health Living Labs

List of Beneficiaries

Desertification Research Center, University of Sassari	NRD	Italy
Università degli studi di Firenze	UNIFI	Italy
CNR, Inst. for Sustainable Plant Protection	CNR-IPSP	Italy
Centre Int. Hautes Etudes Agronomiques Méditerranéennes	CIHEAM	France
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1 Introduction

Deliverable D4.4 "Lessons Learned and Guidelines for Upscaling Living Lab Innovation Processes in the MED Area" outlines the main results, insights, and practical recommendations derived from the implementation and evaluation of Living Lab (LL) activities conducted across six Mediterranean (MED) countries as part of the SALAM-MED project. The main objective of this document is to synthesise the lessons learned from these local experiences and develop a set of recommendations that can support the upscaling and adaptability of the Living Lab innovation model within and beyond the MED region.

The deliverable draws on the Monitoring and Evaluation (M&E) process applied throughout the project's LL implementation phase, which involved the systematic collection, analysis, and interpretation of qualitative and quantitative data concerning each LL's processes, outcomes, and impacts over time. The evaluation aimed to assess the contribution of LLs in addressing complex socio-ecological challenges related to land and water sustainability in MED drylands.

Living Labs can be understood as "open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end-users at the centre of the innovation process" (ENoLL, 2025). A range of different approaches and activities can be incorporated within the Living Lab commensurate with the levels of participation, skills and knowledge of those interested in co-creating the innovation. Living Labs have six common elements:

1. Active user involvement
2. Multi-stakeholder participation
3. Orchestration
4. Co-creation (bottom-up and top-down driven)
5. Real-life setting
6. Multi-method approach.

The element "orchestration" emphasises that Living Labs orchestrate the process of connecting stakeholders and managing the innovation process. This involves facilitation and coordination of collaborative efforts in relation to shared objectives.

The LL approach has gained recognition in the research and policy arenas relating to agricultural contexts in addressing sustainability challenges (Ceseracciu et al., 2023; Marselis et al., 2024; Potters et al., 2022; Trivellas et al., 2023). The MED region, with its diverse socio-ecological landscapes, water scarcity, desertification, and land degradation challenges, benefits from participatory open innovation processes that foster collaboration among a wide range of stakeholders, including local communities, researchers, policymakers, and private sector actors. The LL model aims to support adaptive, inclusive, and place-based innovations that are both evidence-based and context-sensitive.

This deliverable is organised as follows: Section 2 presents the M&E framework and methodology used throughout the SALAM-MED LLs; Section 3 provides an overview of each of the six LLs, located in Italy, Greece, Spain, Tunisia, Morocco, and Egypt; Section 4 details the key findings from the M&E process; Section 5 offers a comparative analysis that highlights commonalities and differences across the LLs; Section 6 distills the lessons learned and identifies strategic considerations for scaling up the LL approach in the MED context; Section 7 concludes with final reflections and actionable recommendations for policy, practice, and future research.

2 Monitoring and Evaluation Framework and Methodology

2.1 Conceptual framing of M&E

M&E is a common phrase and a widespread practice, but with considerable variation in design and implementation.

Monitoring is an intrinsic requirement for evaluation and usually describes a 'continuing function' (OECD, 2002; TAP, 2016), even if this is infrequent. Monitoring can be defined as the systematic process of observing, measuring and documenting ideas, events, activities and outcomes over time using criteria and indicators to provide information to stakeholders on the extent of progress and achievement of objectives to support decision-making (adapted from OECD, 2002; TAP, 2016; Vervoort & Campodonico, 2025).

It is generally considered good practice to involve stakeholders in the design and process of monitoring (and also evaluation) to promote ownership, build trust and ensure a range of experiences are represented in the indicators used and data collected (Amin et al., 2023; Serpe et al., 2022; TAP, 2016).

The concept of "value" is, quite literally, at the core of evaluation. It involves making a judgment about the activity in question against quantitative and/or qualitative criteria or standards, most often with reference to the importance, worth, usefulness, success or benefit of the activity in question. The intention is to develop insights into the current situation and the effects of any interventions, how resources have been used and whether a tool or intervention has achieved what it set out to do (TAP, 2016). Evaluation criteria can apply to inputs, processes, outputs, and outcomes over the short, medium and long term, depending on the chosen timeline (Kuchenmüller et al., 2022).

Both monitoring and evaluation can be formal and/or informal, criteria can be explicit or implicit, and both can be carried out continuously and/or at agreed time intervals. M&E can focus on different levels of activity as needed, using a range of supporting tools and techniques. However, the diversity of LL contexts, topics, aims and approaches gives rise to an equal diversity of approaches for evaluating LLs (Forbat et al., 2025). To address this, some efforts have focused on describing theories of change to provide structure to M&E, such as shown in Figure 1.

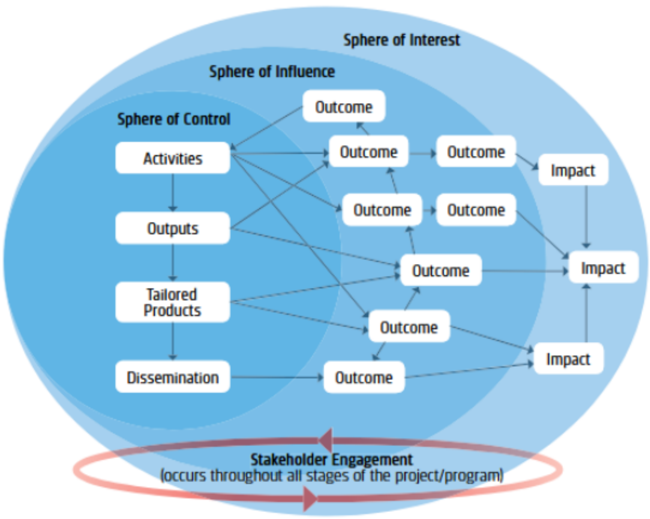

Figure 1 Theory of change based on spheres of control, influence and interest (Belcher & Claus, 2020)

The key aspect of Figure 1 is to note that the different LL activities occur within the sphere of control, whereas outcomes and impacts occur within the spheres of influence and interest, respectively, which are external to the LL boundary and progressively distant in terms of both control and time (see Forbat et al., 2025). This temporal aspect is particularly significant, as impacts may only arise for several years after a LL activity. In addition, Figure 1 illustrates that impacts cannot be assumed to be linear in origin – several outcome pathways may need to converge for impacts to occur. Adding to the complexity is the expectation of stakeholder engagement at all stages. Based on this theory of change, any M&E of LL should aim to encompass each sphere and stakeholder engagement processes, while acknowledging the substantial challenge of capturing the pathways and time differentials across each sphere.

To address some of these difficulties and challenges in relation to LL in agricultural contexts specifically, the SOILL Monitoring and Evaluation Guidelines outline a structured framework for Soil Health Living Labs (SHLLs) to monitor their progress and assess their contributions to the EU Soil Mission (Vervoort & Campodonico, 2025). Developed collaboratively with diverse stakeholders, including LL practitioners, soil advisors, and Mission Soil representatives, the framework aims to monitor and evaluate both the strategic and operational aspects of SHLLs at different scales as set out in Figure 2.

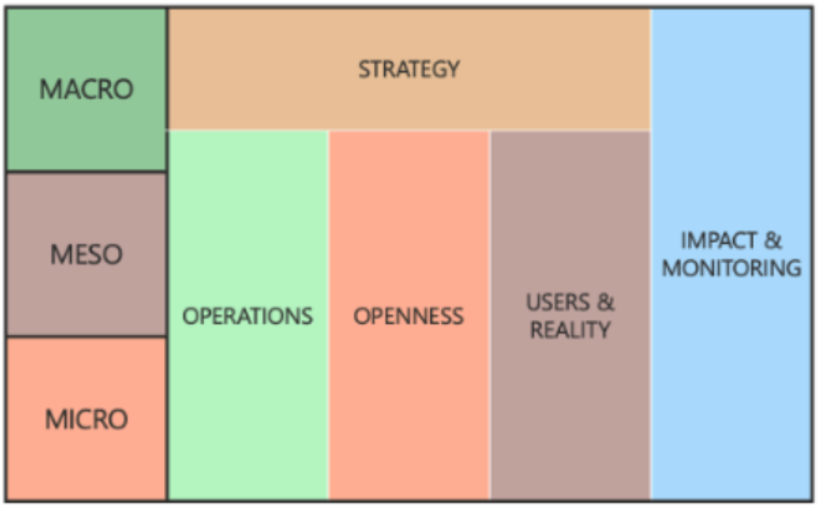

Figure 2 SOILL M&E framework chapters distribution across the three-layered LL model (Vervoort & Campodonico, 2025)

The framework elements across the different scales can be summarised as follows:

- Strategy – the long-term and strategic positioning of a SHLL, including its vision, governance, and operational model.
- Operations – the internal processes, human resources, and infrastructure to support effective execution of LL activities.
- Openness – transparency, knowledge sharing, and intellectual property protection
- Users & Reality – engaging stakeholders and integrating real-life contexts into innovation processes.
- Impact & Monitoring – the outcomes generated by SHLL activities, including their contributions to soil health, knowledge dissemination, and scalability of solutions.

By combining these elements, the framework aims to provide a standardised structure for evaluating SHLLs to enhance comparability across diverse contexts while ensuring alignment with Mission Soil objectives and supporting certification processes. Additionally, the acceptance of a mixed-methods approach combines quantitative self-assessment with qualitative questionnaires, allowing for standardised, comparable data collection while addressing the contextual nuances of individual LLs.

However, while comprehensive in scope, the SOILL framework also faces several challenges relating to practical implementation, which potentially limit the framework's ability to reflect the full complexity of individual LL experiences. These include the administrative burden of completing two annual questionnaires, participating in training sessions, and engaging in review processes, especially for SHLLs with limited human or economic resources. The framework's reliance on self-reporting also creates an inherent risk of biased or incomplete information, as its success depends largely on the skills, accuracy and integrity of data provided by the SHLLs themselves. Furthermore, closed-ended survey questions, although important for enabling comparability across different contexts, may not capture context-specific challenges that do not align with predefined response options.

The SALAM-MED project did not adopt the above framework as the project and the M&E approach (Section 2.3) pre-dates the publication of the SOILL M&E Guidelines. However, it is important to note that many of the best practice elements and the content of the above framework are to be found in the SALAM-MED M&E aims and approach set out below.

2.2 Aim and process of M&E in Salam-Med

The aim of M&E was, in simple terms, to improve the work of each LL and the overall outcomes of SALAM-MED through a reflective process of learning within each LL, between LLs and the overall research network.

The SALAM-MED living labs theory of change (ToC) centres on co-researching for achieving systemic change (Figure 3). This approach integrates and iterates scientific and local knowledge through **social learning** processes to develop innovative strategies for sustainable land and water management that are both scientifically rigorous and contextually appropriate. The ToC for SALAM-MED living labs operates through interconnected cycles where co-researching generates innovations that undergo testing for ecological and social impacts. These results feed back into re-assessment cycles that refine the research approach, creating continuous improvement loops based on learning. The dynamic and iterative design is a key and unique aspect of the SALAM-MED ToC compared to the usual linear assumption inherent in many ToC models, such as Figure 1 above. Successful innovations are expected to create business opportunities that enable dissemination and scaling beyond individual LLs.

In this way, the M&E process was deliberately designed to be formative, i.e. a periodic review during the research to inform and shape the research, rather than simply summative, i.e. an end-of-project evaluation. Formative learning involves a process of first-order documentation of activities and events (what did we do) and then a higher-order reflection (why did we do that) in relation to a set of criteria in order to determine next steps and possible changes. The key element is that formative learning involves review and iteration of ideas and practices based on insight and learning from assessing one's own experiences and the experiences of others in relation to a set of predetermined criteria.

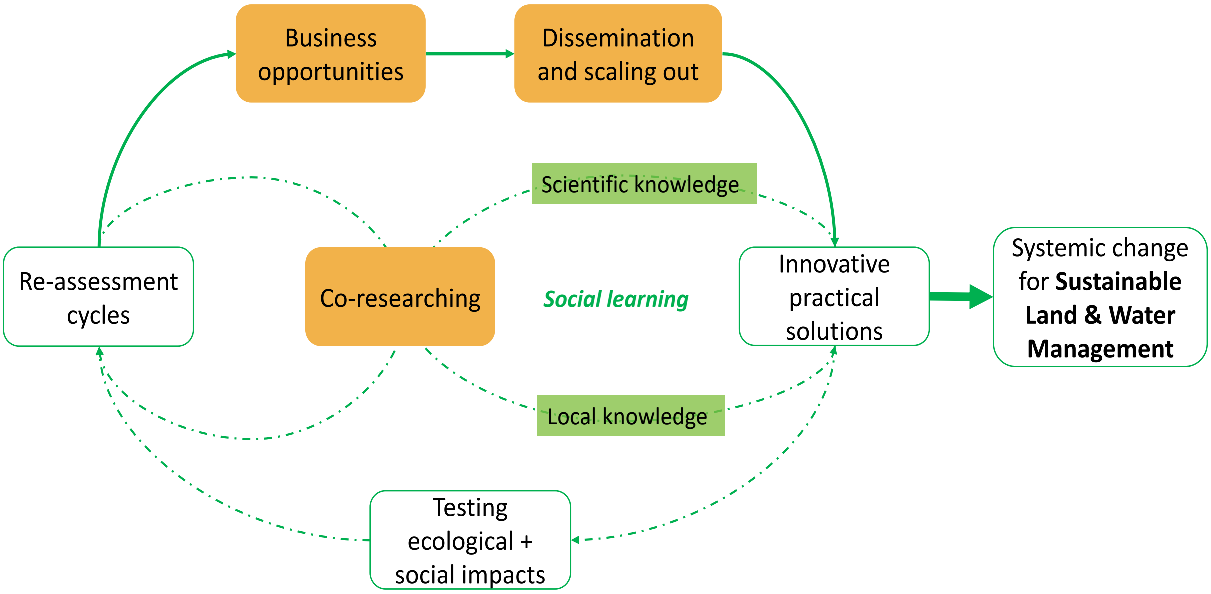

Figure 3 Theory of Change for SALAM-MED Living Labs

2.3 M&E framework

The M&E framework applied in SALAM-MED integrates specific criteria, key performance indicators, and data collection tools designed to systematically assess the progress, processes, and impacts of the Living Labs. This section outlines the core components of the framework, detailing the criteria used to evaluate efficacy, efficiency, and effectiveness, the selection of relevant indicators aligned with project objectives, and the reporting process that supports continuous learning and adaptive management across the Living Labs.

2.3.1 Criteria - Efficacy Efficiency Effectiveness

The criteria for the M&E framework used in SALAM-MED are based on a combination of design thinking and systems thinking, where the LL is assessed through the 3 Es criteria derived from soft systems traditions (Checkland & Scholes, 1990), namely:

- Efficacy: has the LL achieved its specific purpose, as collaboratively defined with stakeholders?
- Efficiency: has the LL used resources well, including budget, time, energy, skills and enthusiasm?
- Effectiveness: has the LL contributed to the overall purpose of the project?

The 3 Es criteria encompass many aspects of the SOILL framework set out above. For example, the first and third criteria approximate to an 'operational – strategy' division and also a 'micro-macro' scaling, while the second criterion encompasses the resource considerations of 'operations'. The first criterion emphasises the importance of stakeholder collaboration, which maps onto the 'openness' and 'users and reality' elements of the SOILL framework. In so doing, the 3 Es and their associated questions provide a more 'user-friendly' set of understandable criteria for use in the field by non-experts on M&E.

The role of M&E in the context of each LL is set out in Figure 4 below.

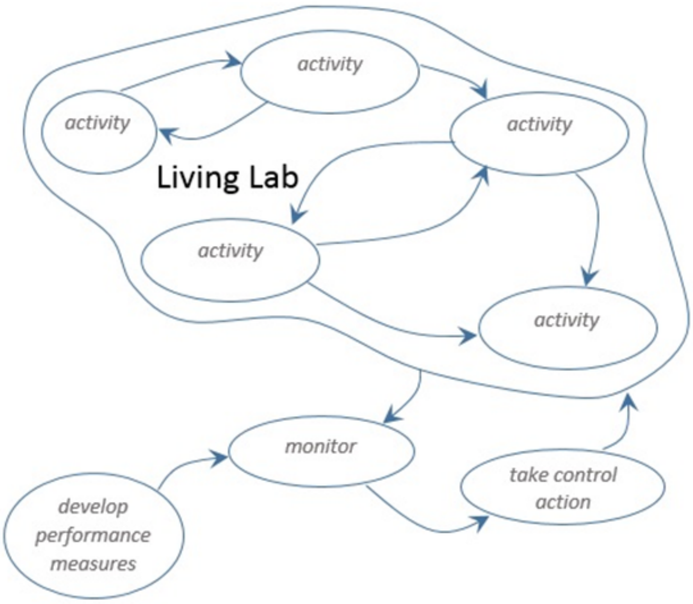

Figure 4 A Monitoring & Evaluation System for Living Labs as a Learning System (REF for diagram)

In Figure 4, criteria (performance measures) are developed to assess the activities undertaken within the LL system. The monitoring process is then used to identify any actions necessary to alter the LL to achieve or meet the existing (and perhaps newly developed) performance measures. The key message of Figure 4 is that the monitoring process is continuous and is not focused on one specific activity, but on how the LL *as a system* is performing. In other words, how do the various activities interact with each other over time in relation to expected deliverables.

Criteria and indicators used in monitoring processes are usually pre-determined, but can also be derived from a dialogue-based learning approach to develop criteria 'in situ' to reflect the experiences and insights of those stakeholders involved (Amin et al., 2023). Developing new criteria and indicators over time can help expand existing areas of interest and/or fill gaps in understanding, as well as discontinuing those which are no longer relevant.

2.3.2 Key Performance Indicators for SALAM-MED

The aims and expected contributions of SALAM-MED are centred on the following main areas:

- Restore degraded land and enhance resilience in endangered dryland socio-ecological systems
- Identify business and economic development opportunities aligned with soil fertility and conservation objectives
- Promote women and youth empowerment, enhancing their agency and inclusion within the agri-food sector.

The evidence base for the KPIs is derived from a mix of quantitative and qualitative data. Quantitative data may relate to, for example, the number of youth or female participants engaged with the Living Labs as participants in meetings or involved in ongoing trials and field experiments or as direct beneficiaries of the research outcomes. Qualitative data may include a participant's and/or a researcher's own narrative assessment of the research experiments or LL process at any stage.

While there was some variation during the course of the research, each of the Living Labs summarised the performance of the LL using a template setting out the KPIs.

2.3.3 Reporting Process and Timeline

The M&E reporting process has been achieved in a number of ways. These include:

- M&E reporting and synthesis by individual LL
- Peer-to-peer review of LL activities during GA meetings
- Review of contributions of LL to SALAM-MED aims and outcomes.

Using a common template, each LL reported on and evaluated their LL activities and ongoing learning on a six-monthly basis, with annual reports being more extensive. The design of the M&E template evolved over the course of the project from a focus on a simple narrative account and the 3Es to a more integrated design linking the 3Es to the KPIs of SALAM-MED. This was a pragmatic decision based on the familiarity of the researchers with both LL and M&E processes.

The synthesis of annual reports and key insights was developed by the NRD research team and the OU advisory board member, and then critically reviewed at GA meetings on 28/30/2023, 24/04/2024, and 21/05/2025. The annual synthesis report aimed to deepen understanding in the consortium of the work, successes and practical difficulties encountered when establishing and facilitating LL in different countries and agricultural contexts. Based on this learning, each LL team was also able to review and adjust their expected work agenda for the next stage of their LL. The timeline of the M&E process is summarised in Table 1.

Table 1 Timeline of M&E reporting

Date	Activity
May 2023	Intermediate M&E report
September 2023	GA first synthesis M&E report and review by consortium
December 2023	Annual M&E report
April 2024	Intermediate M&E report
April 2024	GA second synthesis M&E report and review by consortium
January 2025	Annual M&E report
May 2025	GA third synthesis M&E report and review by consortium
August 2025	Final M&E report

3 Overview of the SALAM-MED Living Labs

3.1 Italy: the Làcani LL in Berchidda-Monti long-term observatory

The long-term observatory of Berchidda-Monti, located in North-Eastern Sardinia, Italy, was established in 2008 and spans approximately 20,000 ha at altitudes between 250-300 meters above sea level (Figure 5). This area represents an example of Mediterranean silvopastoral system, distinct in the landscape pattern from the extensively studied large-scale dehesas and montados of the Iberian Peninsula. The dominant tree species is cork oak, in a dehesa-type agroforestry system integrated with large scale grazing systems (Caballero et al., 2011).

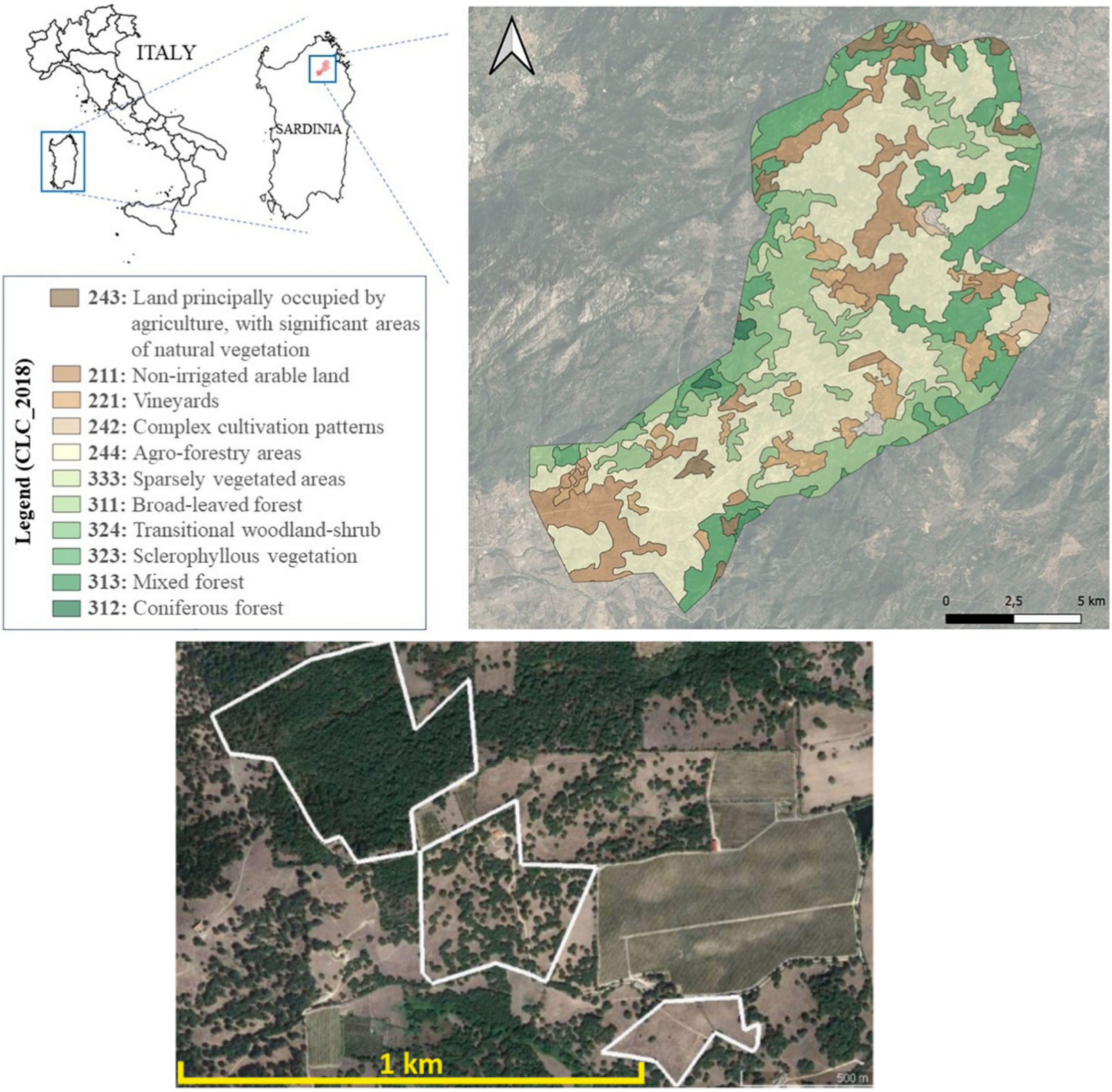

Figure 5 Patchy silvopastoral landscape in Sardinia, where the white polygons in the Google Earth image indicate a sample of oak woodlands (up), cork oak wood grasslands (middle) and open grasslands (down). Source: (Bagella et al., 2020).

The landscape is patchy and highly fragmented, shaped by diverse land ownership and land use practices, resulting in a complex mosaic of cork oak woodlands (WL), cork oak wood grasslands (WG), and open grasslands (OG). This patchwork reflects ongoing socio-economic transition and land abandonment trends. Since 1990, the region has experienced a net loss of approximately 17,000 hectares of silvopastoral land, largely due to cropland conversion and natural succession towards closed-canopy woodlands (Bagella et al., 2020). Climate pressures, marked by droughts, extreme rainfall, and water stress, create challenges for Sardinian silvopastoral systems, with dramatic consequences including wildfires, loss of cultural landscapes, changes in hydrology and water provisioning, and biodiversity loss. Furthermore, the socio-ecological stability of Sardinia silvopastoral systems faces threats from demographic trends (Sardinia has one of the lowest world's fertility rate: 0.91 children per fertile woman) and gaps in farming generational turnover due to youth abandonment of rural areas. Traditional silvopastoral family farms face uncertainty - in two decades, farms decreased from 107,000 to 47,000 while average farm size grew from 8 to over 26 ha.

Within this context, the Làcani living lab focuses on the sustainability of agro-silvopastoral systems in Sardinia. Named after the Gallurese word for "boundaries", Làcani represents navigating borders between locations and activities while promoting collaborative thinking and concerted actions. The main innovations co-designed within the Làcani living lab include:

1. Innovative agronomic strategies to bridge the gap between the seasonal nutritional requirements of grazing livestock and the availability of grazed grasslands. These strategies aim to achieve self-sufficiency in livestock farms while maintaining sustainable and efficient grazing systems that enhance soil fertility, mitigate soil acidification, improve water use efficiency, and contribute to biodiversity conservation.
2. Microbial-based technologies, specifically Trichoderma-based bioformulations, to enhance plant growth, suppress pathogens, and improve resilience to drought and salinity.
3. Combination of field observations and agroecosystem modelling tools to monitor and assess the impacts of extreme drought, combined with land abandonment, on silvopastoral systems (e.g. encroachment of grasslands with woody species).
4. Capacity development for farmers and practitioners through the living lab process, in synergy with the local regional agricultural extension agencies and agricultural product retailers, who often serve as the main interface between technology providers and farmers. This process innovation aims to identify practical solutions for improving water and land management, alongside creating business opportunities.

3.2 Greece: the Agora LL in Messinia

The Agora LL is a collaborative research initiative focusing on sustainable olive farming in Messenia, Greece. The word "ΑΓΟΡΑ" has its roots in ancient Greek cities, where it referred to an open space that served as a meeting place for various citizen activities, including discussions on diverse topics and leisure pursuits. The chosen Linear B symbols represent, from left to right, an olive tree, an olive fruit, and olive oil (Figure 6).

Figure 6 The Agora LL name symbols

The Agora LL was initiated in April 2023 as a space for researchers, farmers, and local stakeholders to work together on finding better ways to grow olive trees in a time of climate change and environmental challenges. The aim is to understand how farming and climate variability affect olive trees, and to test new, more sustainable farming methods. The main goals of the LL were to discuss the challenges of climate change and farming practices with farmers and local experts, explore NBS such as cover crops and phenology-based irrigation, and support a shift toward more sustainable olive farming.

The Agora LL focuses on testing two key nature-based solutions designed to improve soil management and water use in tree orchards (Figure 7). The soil management innovation involves the use of cover crops as an alternative to conventional practices, with mowing and herbicide application serving as the baseline treatments. The water management innovation introduces a phenology-based irrigation approach, compared against rainfed conditions and the traditional practice of restricted farmer-led irrigation. In total, six treatments are being evaluated, providing a comprehensive comparison of how alternative practices influence soil fertility, water efficiency, and crop performance under Mediterranean conditions.

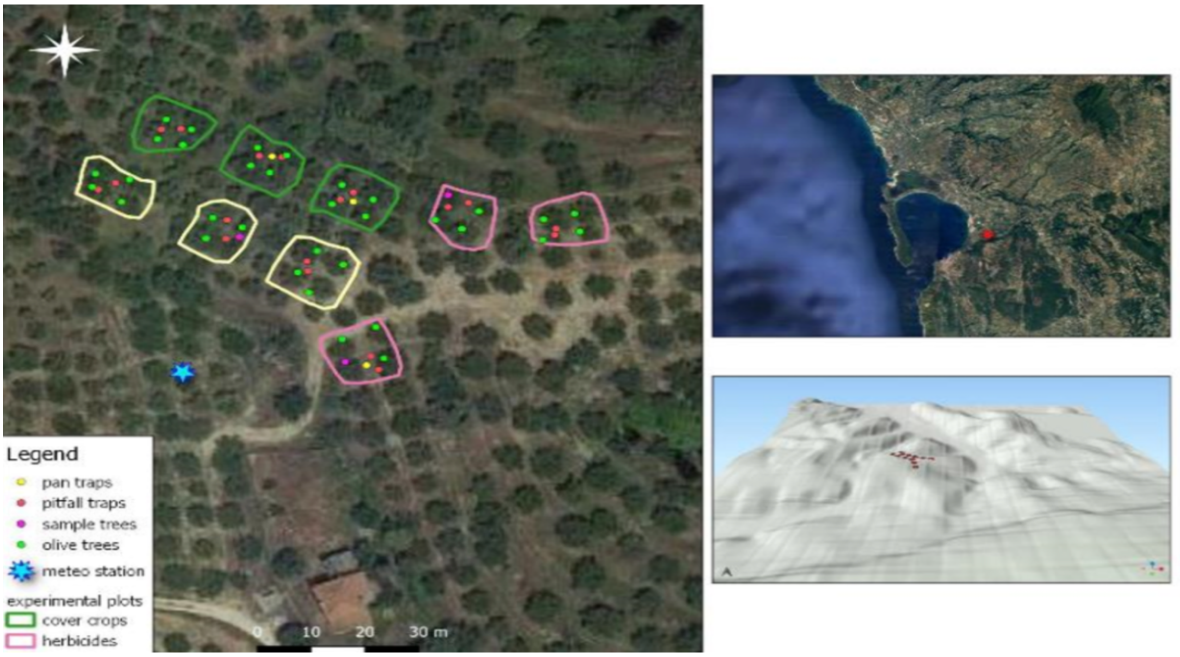

Figure 7 The Agora LL in Messinia, Greece

3.3 Spain: the LAB4-ES LL in the Hunde and Calderona areas

The LAB4-ES LL is located in the Valencian Community, and it includes two areas (Figure 8): Calderona and Hunde. These represent two contrasting yet complementary settings: Calderona represents a peri-urban protected area under high fire pressure and tourism demand, while Hunde offers a more remote and rural territory with strong community ties and abundant land but limited institutional presence. Together, they allow the project to explore diverse governance models and socio-ecological realities in the co-design and implementation of NBS.

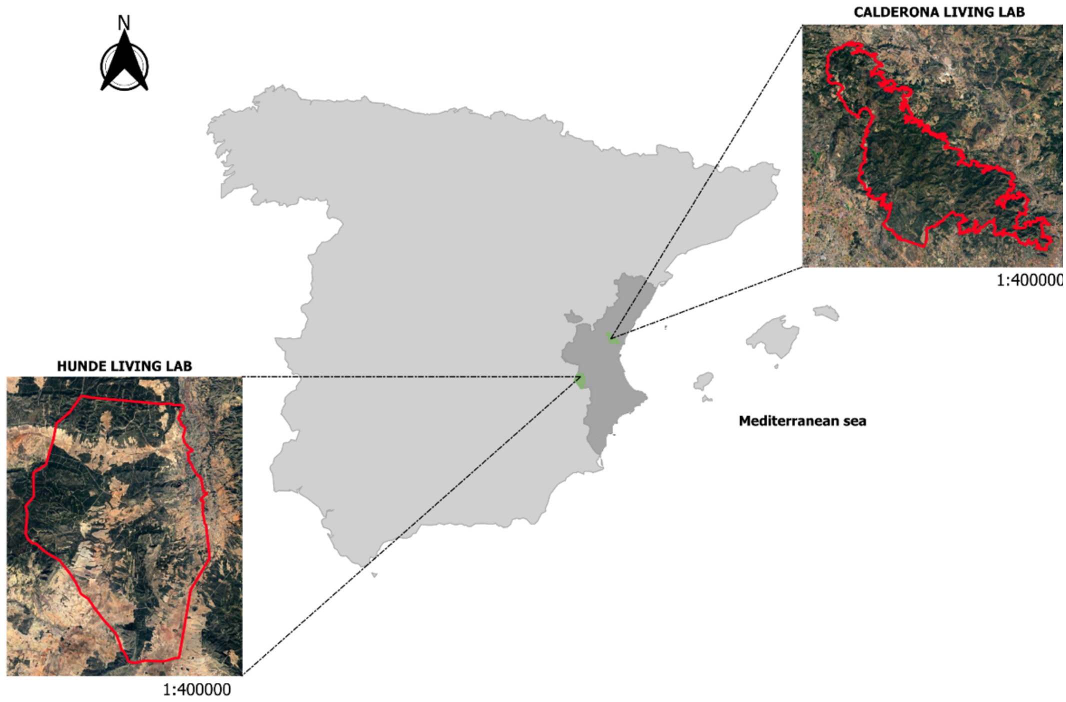

Figure 8 Location of the LAB4-ES Living Lab

The LL brought together a broad and diverse range of stakeholders, representing key sectors of society and playing complementary roles in the co-design and implementation of NBS (Table 2).

Table 2. Stakeholders participating in the LAB4-ES Living Lab

PUBLIC ADMINISTRATION	ACADEMY	SOCIETY	BUSINESS AND INDUSTRY
• Town Halls • Technical offices (Natural Parks) • Generalitat Valenciana	• Universities (e.g., UPV) • Research centers (e.g., CEAM)	• Associations (e.g, ANAV, mycology, traders, forest fire prevention) • Clubs (e.g., Hunters) • Councils and Communities (e.g., agricultural, irrigation)	• Public and Private companies (e.g., VAERSA, TRAGSA, ACCIONA) • Self-employed (e.g., forestry technicians)

The LAB4-ES LL aims to develop, assess and model ecosystem services (ES) and propose a multifunctional management proposal co-defined by stakeholders using the comprehensive CAFE (Carbon, Aqua, Fire, Eco-resilience) system tool. It is a multi-objective decision support system for forest management that quantifies and optimises the different ES derived from it and allows us to see the additionality generated. It is based on combining multiple eco-hydrological process-based models and multi-criteria optimisation with genetic evolutionary algorithms. This tool determines the silvicultural activities needed (thinning or plantation) to optimise multiple ecosystem services such as biomass production, carbon sequestration, fire risk, water provisioning, climatic resilience or biodiversity, which are simultaneously quantified in time and space.

3.4 Tunisia: the Jeffara LL in Médenine Governorate

The Tunisian LL is located in the Triassic aquifer region of Médenine Governorate in southeastern Tunisia (Figure 9), a semi-arid to arid dryland environment facing acute water scarcity challenges. The LL focuses on enhancing groundwater recharge and sustainable water management to combat land degradation and desertification that threaten both ecosystem integrity and rural livelihoods in the region. Central to the LL are Managed Aquifer Recharge (MAR) systems and innovative Water Harvesting Techniques (WHT), particularly recharge wells. The restoration of sustainable agriculture in arid lands (AI=0.05-0.2) through MAR systems has an out-scaling potential in 22% of the MED drylands of N-Africa, where drought, migrations and land abandonment are the main drivers of land degradation. The co-design process in the LL integrates local knowledge and scientific expertise to develop context-specific, practical strategies. LL activities have encompassed geophysical surveys, data collection, rehabilitation and improvement of recharge infrastructure, the co-design of management plans, the application of advanced modelling tools (SWAT and WEAP models) to assess and optimise aquifer recharge processes. Furthermore, the multi-stakeholder approach aimed at identifying sustainable business opportunities that could enhance economic viability while supporting water conservation objectives, notably in agricultural digitalisation and water-saving technologies.

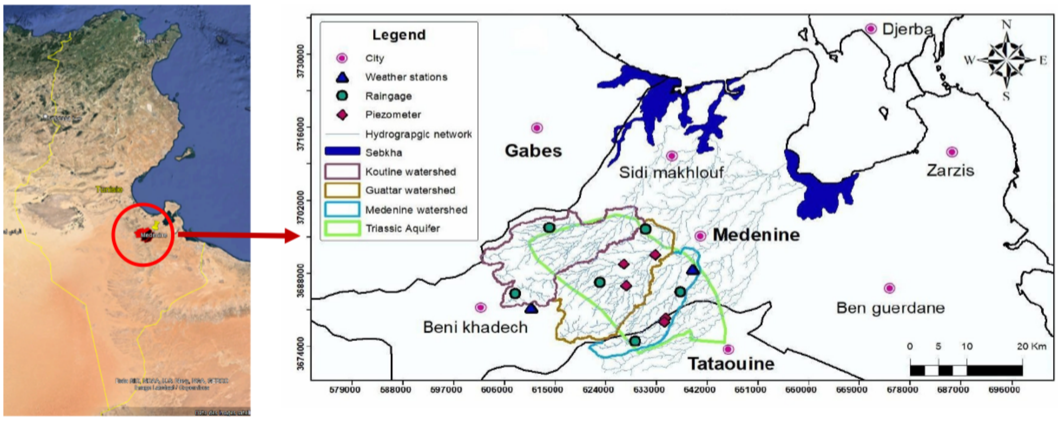

Figure 9 Jeffara case study

3.5 Morocco: the TAGANT living lab in the Essaouira region

In the semi-arid landscapes of the Essaouira region in Morocco (Figure 10), the argan forest plays a vital socio-ecological role. However, the area faces growing challenges, including prolonged droughts, overgrazing, and soil degradation, all of which threaten the resilience of the argan ecosystem and the livelihoods it supports. Local communities, many of whom depend on pastoralism and argan cultivation, are at the frontline of these pressures. To address this, the Moroccan TAGANT Living Lab fosters a participatory approach that brings together stakeholders from different sectors to co-develop sustainable, locally adapted solutions.

The TAGANT Living Lab has prioritised a nature-based solution tailored to the region's specific ecological and social context. SWRT, or Subsurface Water Retention Technology, improves water use efficiency and seedling survival in argan plantations and supports reforestation efforts. This technique, combined with compost and/or arbuscular mycorrhizal fungi (AMF) application, grazing pressure assessment, community-informed grazing management strategies, and local knowledge, helps restore argan trees and, in turn, revitalise the communities that depend on them.

Figure 10 The Tagant LL in Essaouira, Morocco

3.6 Egypt: The Kharrouba LL

The Egyptian LL is located on the Northwestern Coast of Egypt within the Matrouh Governorate, a region characterised by distinctive wadi basins typical of arid or semiarid environments (Figure 11). The area experiences a challenging hydrological regime where brief but intense rainfall events generate destructive flash floods, creating significant water management challenges for local communities.

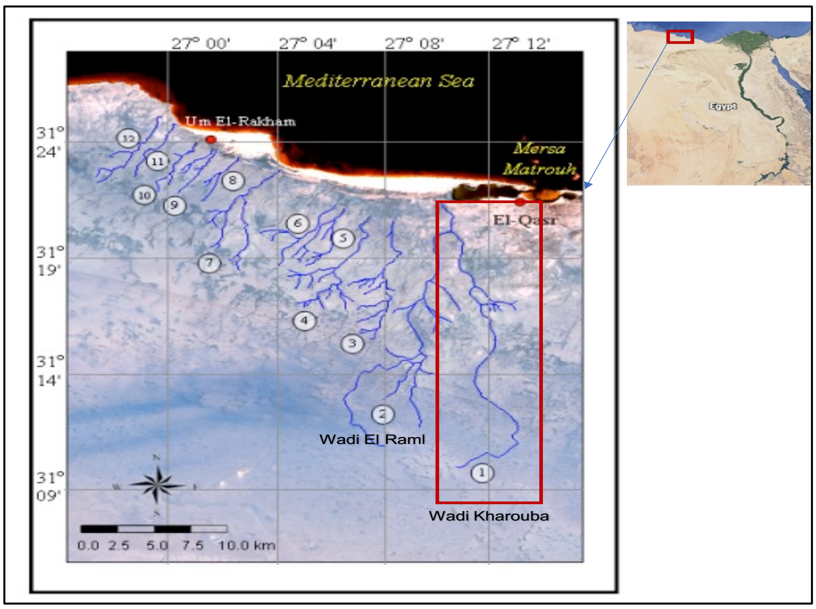

Figure 11 Egyptian LL site

Agriculture, predominantly involving olive and fig crops, accounts for approximately 70% of the regional livelihoods. The local Bedouin population has developed traditional adaptive strategies to cope with water scarcity, employing sophisticated rainwater harvesting systems, including strategically placed dykes and cisterns for water storage and management. The traditional water management approach involves reshaping wadi stream beds into a series of levelled terraces supported by spaced dikes. This system aims to decelerate water flow and enhance infiltration rates.

The Kharrouba LL faces multiple interconnected environmental and socio-economic challenges characteristic of dryland regions under increasing climate pressure: water scarcity, extreme flash flood events that damage infrastructure and agricultural systems, soil erosion and degradation that threaten long-term agricultural productivity and ecosystem stability and limited adaptive capacity to climate change.

The Kharrouba LL has tested two complementary NBS designed to address the primary environmental challenges while building upon existing traditional knowledge systems:

- **Enhanced water harvesting design using optimised dikes and levelled terraces**. This aims to optimise traditional water harvesting infrastructure through science-based design criteria derived from hydrological modelling tools (Figure 12). The modelling tools provide quantitative information regarding optimal water storage volumes, infiltration rates, and the most effective number and spacing of terraces for specific topographic and hydrological conditions. This data-driven approach offers significant advantages over purely empirical methods by enabling communities to maximise water capture efficiency before committing resources to infrastructure construction.

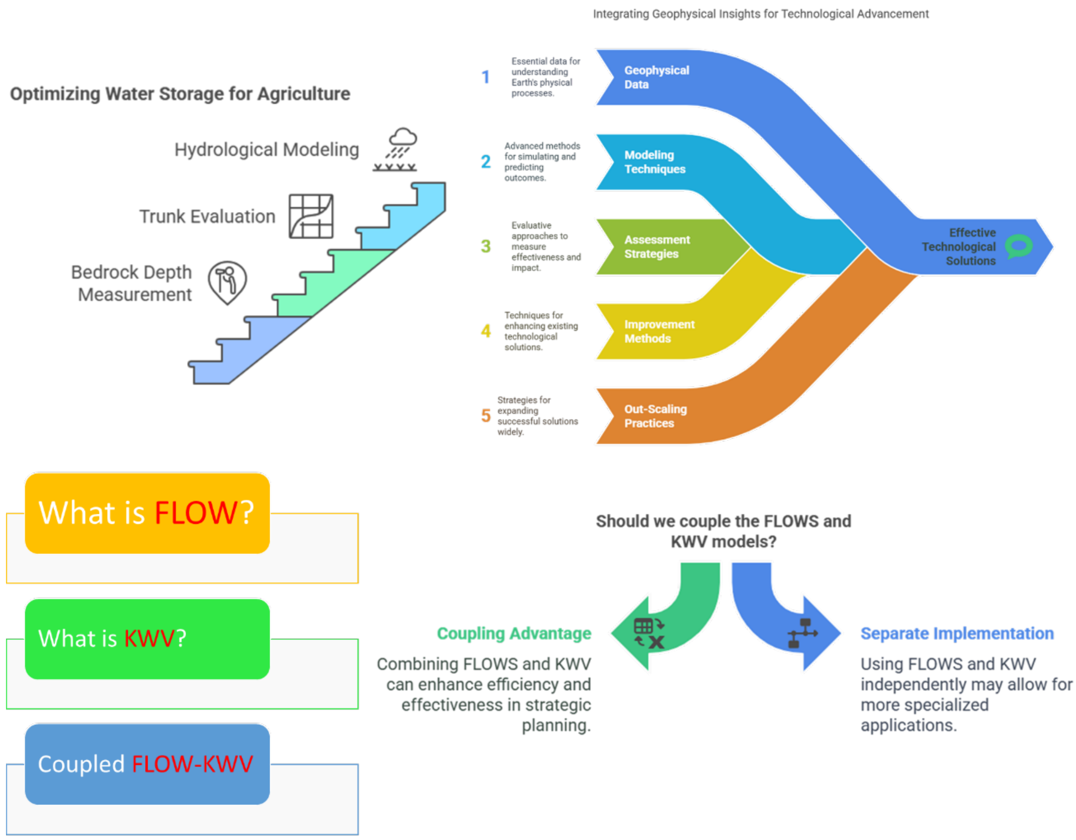

Figure 12 Modelling Wadi Levelled Terraces Water Harvesting with FLOW-KWV

- **Mycorrhizal applications for enhanced soil fertility and drought resilience** (Figure 13). This NBS employs microbial-based solutions (mycorrhizal inoculants and biofertilizers) to preserve and enhance soil health and fertility in degraded dryland ecosystems. This microbial-based approach specifically targets improving olive growth performance under water stress conditions prevalent in arid environments.

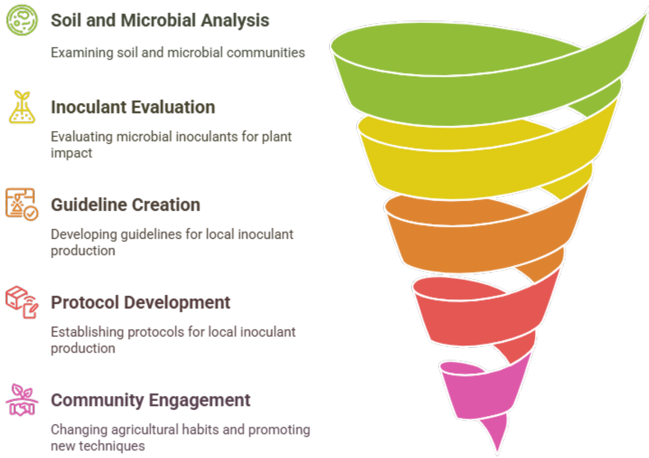

Figure 13 Co-designing microbial-based solutions for enhanced soil fertility and drought resilience

4 Findings from M&E

4.1 The Làcani LL in Italy

Progression and changes over time

The Làcani LL demonstrated significant evolution throughout the SALAM-MED project duration, transitioning from initial fragmentation to becoming a cohesive innovation hub. The monitoring and evaluation data reveal three distinct phases of development:

1. **Initial challenges and fragmentation**
   The LL began with considerable stakeholder **alignment** challenges. Initial M&E reports documented a fragmented landscape where diverse stakeholders struggled to establish a sense of unity and develop a common vision. Key challenges included power imbalances and unclear common objectives, **resource-intensive** coordination requirements, limited participation from **women and youth**, and **governance** challenges.
2. **Progressive integration**
   The M&E data shows a gradual but consistent improvement in stakeholder engagement and alignment. Critical turning points included: improved **integration of scientific expertise with traditional local knowledge** (e.g. recognising the significance of traditional land uses and pastoral activities in preventing land abandonment and habitat loss); organisation of targeted participatory activities for **underrepresented groups** (e.g. ad hoc involvement of female-led agricultural enterprises; organisation of ad hoc participatory activities targeting youth only); development of **strategic partnerships** with key institutional actors (AGRIS, Regional Agricultural Councillor, National GAL Coordination Group)
3. **Consolidation and recognition**

The final M&E reporting period demonstrates the LL's maturation into a recognised dynamic hub for knowledge-sharing, social learning, and innovation. Four formal agreements have been successfully established with GALs, marking progressive improvement and positioning the living lab as a catalyst for their mission to generate business opportunities and sustain local enterprises.

Summary of achievements

Efficacy: The Làcani LL made significant achievements in its core objectives, which were iteratively defined with local stakeholders based on their priorities and expectations. Specific achievements include:

- Increases in **soil fertility and grassland productivity**, as well as improvements in **grazing management** practices. Concerning *Trichoderma*-based bioformulations, field trials have demonstrated significant gains in crop yields and biomass, showing that microbial approaches can both reduce dependence on synthetic pesticides and improve soil health. Complementing this biological intervention are three soil and ecosystem management solutions. A digital ecosystem monitoring platform integrates drones, satellites, GPS collars, and artificial intelligence to provide real-time insights into environmental conditions, enabling more accurate responses to drought, pests, and land degradation. Biochar application offers a soil amendment that improves fertility, water retention, and microbial activity while sequestering carbon, contributing to both productivity and climate mitigation. Finally, liming practices target the correction of soil acidity, a widespread problem in Mediterranean agriculture, by neutralizing pH and improving nutrient uptake.
- **Co-design and adaptive management** approach, adjusting existing experimental activities and/or initiating new ones based on stakeholders' feedback and needs (e.g. field test on Sulla's acid-tolerant Rhizobia upon AGRIS' suggestion, testing GPS collars on donkeys).
- Establishment of a **social infrastructure** to promote capacity development, networking, and generational turnover, primarily by ensuring (i) active farmer **participation** in experimental design and solution testing and (ii) systematic organisation of LL events promoting both individual and social **learning**.

Efficiency: Despite initially being **resource-intensive**, the Làcani LL made significant progress through:

- Strategic valorisation of **traditional knowledge** about land uses and pastoral activities in preventing land abandonment and habitat loss.
- Leveraging of **diverse stakeholder contributions**, particularly from previously under-represented groups (women and youth).
- Promotion of **synergies** with existing national and international initiatives.

Effectiveness: the LL has demonstrated clear contributions to SALAM-MED objectives through:

- Co-design, testing and validation of **practical solutions for ecosystem resilience of Mediterranean agro-silvopastoral systems**, particularly microbial-based and other agronomic technologies for arid zones and acidic soils, as well as improved grazing management practices.
- Generating pathways for **business opportunities** aligned with sustainable water and land management objectives (e.g. creation of market potential through isolation, selection, and multiplication of local soil microbial strains successfully tested in the lab). Further details are provided in Deliverable 5.4.

- Developing a **robust community of young and female farmers and stakeholders** dedicated to addressing uncertainties and exploring new opportunities. Quantitative achievements include the engagement of approximately 100 youth reached through survey activities, and 60 youth engaged through direct participatory workshops (35 % women).

Research methodology transformation

The LL serves as a platform for the continuous monitoring and assessment of the socio-ecological impact of silvopastoral activities, e.g. enabling researchers to evaluate the potential consequences of abandonment on hydrological and soil fertility dynamics. More than just an observational space ("lab"), the LL is evolving into a dynamic hub for learning and innovation ("living"), where the integration of scientific and local knowledge enabled a collective understanding of the situation and resulted in the co-design of practical solutions aimed at enhancing ecosystem resilience.

A key strength of the LL lies in its participatory nature, which has fostered effective co-creation and innovation testing by integrating diverse stakeholder perspectives and knowledge. This approach has been instrumental in advancing the SALAM-MED objectives, not only concerning the validation of practical solutions for ecosystem resilience, but also the identification of new and enduring business opportunities for local enterprises. Evidence of the positive impact of the living lab includes the growing recognition among stakeholders (e.g. formal agreements signed with GALs) and the rising level of interest and participation of stakeholders in SALAM-MED experimental activities.

4.2 The Agora LL in Greece

Progression and changes over time

The Agora LL development throughout the SALAM-MED project was characterised by slow activation, followed by intensive collaborative engagement, and culminating in stakeholder recognition of practical solutions.

1. **Slow LL activation**
   The initial phase was marked by significant operational challenges. Substantial delays in experimental setup created difficulties in demonstrating tangible progress and expected results to stakeholders, while mixed stakeholder readiness revealed a clear distinction between participants familiar with collaborative engagement and those new to participatory approaches. Partial mistrust emerged among some stakeholders regarding the LL. Some viewed irrigation and soil management as secondary concerns, questioning the potential value of the proposed interventions.
   Despite initial challenges, M&E data revealed encouraging signs of stakeholder cohesion, with participants demonstrating increased comfort in interacting and exchanging ideas. Common challenges were identified across the sector, and a majority consensus began to emerge regarding approaches to improving olive oil production processes. A key adaptive response during this phase was the adjustment of LL goals to incorporate additional farmer inputs, ensuring that the process remained practical and applicable to real-life conditions.
2. **Active engagement in experimental activities**
   This phase represented the peak of collaborative activity and knowledge co-creation. Field experiments became the focal point of stakeholder engagement, with thorough discussions

between local farmers and researchers from regional institutes. The M&E data show that farmer input was systematically integrated into experimental design, representing genuine co-creation rather than consultation. The implementation of cover crop and phenology-based irrigation experiments, in collaboration with local olive oil producers, marked a successful transition from conceptual discussion to practical implementation.

3. **Consolidation and recognition**
   The final phase was characterised by stakeholder recognition of the LL as a credible platform for developing and testing sustainable olive farming solutions, overcoming initial scepticism and mistrust documented in the early phases. While implementation challenges persisted and some stakeholders continued to demonstrate resistance to change, the experimental design was successfully adjusted, and alternative sites were identified when needed. M&E data revealed genuine stakeholder engagement with scientific findings. Most significantly, stakeholder participation significantly increased (from 25 to 100) throughout the project lifespan, with particular increases among women and youth representatives.

Summary of achievements

Efficacy: The LL made significant progress in achieving its collaboratively defined goal of optimising olive oil production while preventing soil degradation and improving water use efficiency. Data collection integrated traditional monitoring approaches with innovative techniques, including ground-based instrumentation and airborne remote sensing, demonstrating the LL's capacity to bridge conventional and cutting-edge methodologies. Cover crop experiments demonstrated clear benefits in hilly orchards, reducing soil erosion, increasing biodiversity, and improving soil fertility. Simultaneously, phenology-based irrigation produced higher-quality olive oil with greater polyphenol content and lower peroxide levels. Significant progress has been made in raising stakeholder awareness about climate change impacts on olive cultivation, though translating this awareness into widespread behavioural change among farmers, particularly older practitioners, remains a long-term challenge.

Efficiency: Initial time management efficiency was suboptimal due to delays in selecting appropriate experimental fields and technical difficulties with equipment installation. Despite these challenges, the team's collaborative approach and consistent on-site presence facilitated effective coordination and a gradual enhancement in resource use. Synergies with other sustainable agriculture projects also optimised resource use. Efficiency was further improved by leveraging the existing knowledge and skills of stakeholders, including local farmers, agronomists, institutional partners, and young researchers. In this context, the LL demonstrated exceptional efficiency as a learning platform, supporting two PhD dissertations, three MSc theses, and training over seven summer interns. Results were disseminated through national and international scientific conferences (e.g. EGU, EMS, MedGU), two published journal papers (Bouizrou et al., 2025; Michail et al., 2025) with two additional papers currently under submission, as well as a local TV documentary. Together, these dissemination activities amplified the impact of the invested resources by building human capital and spreading best practices beyond the core project team.

Effectiveness: The LL has contributed to SALAM-MED's overall purpose by partially achieving the targeted aims, while demonstrating promising results for continued progress.

1. **Restoring degraded land and enhancing resilience in endangered dryland socio-ecological systems:** Two NBS were successfully tested in the LL. Scheduling irrigation around olive tree phenology and conserving soil through year-round cover are two main strategies that have proven

their worth. When guided by evapotranspiration data, phenology-based irrigation can reduce water use by around 20%, maintaining yields with approximately 2,000 m^3 ha^{-1} per season. Likewise, maintaining year-round soil cover has been shown to reduce erosion by 60–80% compared to bare soil conditions, greatly improving soil stability and long-term fertility.

2. **Promoting business opportunities associated with ecosystem restoration/resilience:** While direct economic benefits remain at early stages, the LL created foundations for linking sustainable practices to economic growth. Experimental results, such as the improved olive oil quality achieved through phenology-based irrigation, opened possibilities for accessing premium markets, while the use of cover crops offers long-term cost savings by enhancing soil fertility and reducing erosion. Stakeholders also identified synergies between agriculture and tourism through initiatives like olive harvesting experiences and agritourism activities. In addition, small-scale enterprises, such as producing and selling native-seed "seedballs" for cover-cropping, offer another practical income opportunity linked to restoration efforts. Further details are provided in Deliverable 5.4.
3. **Women and youth engagement**: The LL achieved significant progress in engaging women and young farmers, with over 60% of participants being women or individuals under 40. This represents a remarkable achievement given the predominantly older male composition of the local farming community.

Overall, the LL has successfully demonstrated the environmental benefits of NBS, identified pathways for economic opportunities, and fostered broad stakeholder engagement, with particular emphasis on the inclusion and empowerment of women and youth in agriculture. The main barriers remain cultural resistance to change, the dominance of an older farming population, and the need for stronger incentives to drive wider participation and adoption.

<u>**Research methodology transformation**</u>

To some extent, the LL process fostered researchers' early experience with co-design, helping build their confidence in interactive, stakeholder-driven modes of investigation beyond isolated scientific inquiry. Rather than working independently, research evolved into a continuous learning process shaped by ongoing stakeholder input, broadening the focus beyond experimental outcomes toward a more holistic understanding of local socio-ecological dynamics. Farmers actively participated in shaping experiments, with their feedback guiding practical adjustments. Cover crop species and irrigation management strategies were co-designed with local agronomists and farmers, enhancing both practicality and acceptance. This iterative process ensured an immediate connection between scientific results and real farming contexts.

The quality of interaction between the scientific community, farmers, and other stakeholders emerged as one of the LL's most positive outcomes. This open knowledge exchange fostered a truly collaborative environment where researchers and practitioners **learned from each other**, creating strong potential for continued activities beyond the SALAM-MED project timeline. However, it should be noted that younger farmers and women responded positively to co-creation activities and showed willingness to adopt new ideas, whereas older participants —who represent the the majority in the area, were generally more hesitant to change long-established practices and often required clearer evidence of benefits before considering adoption. Additionally, the M&E findings reveal that well-functioning LLs demand patience, empathy, and flexibility to build trust and meaningfully integrate diverse stakeholder perspectives. The human factor emerged as the most critical component, underscoring the importance of early stakeholder engagement, attentive listening to their concerns, and providing regular opportunities for reflection and evaluation.

4.3 The LAB4-ES LL in Spain

Progression and changes over time

The LL progression in Spain was characterised by an initial focus on understanding the range and scope of ecosystems goods and services as understood by stakeholders and identification of relevant indicators. Subsequently, the focus moved to prioritising the ecosystem services (ES) according to the type of forest management.

Over time the initially distant positions of stakeholders have become more aligned in the collaborative way of working. The tools and methods employed in the LL process have become more effective and relevant to stakeholders as a result.

Summary of achievements

Efficacy: The LL has promoted and consolidated the idea and practices of adaptive forest management (AFM) as a positive, resilience-building strategy among the different LL stakeholders to help improve or preserve current ESS to address land degradation in context. In particular, recognising that use of timber and biomass also requires a combination of improvements in management and guidance; better environmental education and awareness; improved biodiversity and conservation of habitats and species; climate change adaptations; and promotion of the local economy and sustainable development including employment in forest management and also tourism. All the stakeholders in the LL identify AFM as an effective means to improve or preserve the current state of ES and approximately 3000 ha (33%) of public land/forestry in the natural park of the Calderona LL is expected to be managed in accord with AFM guidance and tool.

Efficiency: The costs of establishing and running the LL are within budget limits as set out in the original research agreement. Some final adjustments were made to the budget for materials, travel, and external services to allow more research time. In terms of energy and enthusiasm of the stakeholders, the probably over-ambitious target of 67% of stakeholders participating in all workshops of each LL was not met. However, in the Calderona LL, 90% participated in the first two workshops, and 31% participated in all three workshops. In the Hunde LL, 76% participated in the first two workshops and 41% in all three. In both LLs, stakeholders who attended the previous workshops were absent from the third workshop due to their inability to attend for work reasons. Timing is likely to have been a key factor. The dates of the final workshops (late May and early June) coincided with the maximum workload for many actors in the territory, while the second workshops in March resulted in greater participation. Nonetheless, several key stakeholders demonstrated consistent and ongoing engagement, enabling progress on planned activities and maintaining a solid foundation for collaborative work. In addition, new actors did participate in later workshops of both LLs, signalling a growing interest in the work of the LL.

Effectiveness: The LL has contributed to SALAM-MED's overall purpose by mostly achieving the aims, while creating opportunities for continued progress.

1. **Restoring degraded land and enhancing resilience in endangered dryland socio-ecological systems:** In the Calderona LL, the end users were very satisfied with the LL activities and are keen

to begin using the AFM tool to plan and guide treatments in the natural park, potentially encompassing approximately 3000 ha of public area. In Hunde LL, the AFM tool has been used in an initial trial of about 20 ha.

2. **Promoting business opportunities associated with ecosystem restoration/resilience:** There were no direct business opportunities created through these LLs. Instead, business and commercial opportunities were promoted indirectly through networking, collaboration and developing a more sustainable forest management approach for deployment in other areas which will contribute to employment through sustainable ES.
3. **Women and youth engagement:** The target set for participation of women and youth in the Hunde and Calderona LLs was at least three women and three youth participation per LL throughout the process. In practice, female participation far exceeded the target with 16 women participating in Hunde (34% of the total) and 22 women in Calderona (61%), with females representing 46% of 102 participants across both LLs. These levels of participation indicate a high level of inclusion and commitment on the part of women, especially in the Calderona LL where they constituted the majority. In contrast, youth participation was more limited. In Hunde LL, only two young people (4%) were registered, and in Calderona, five (11 %), representing 6.86% of the total. While Calderona LL met the minimum target, Hunde LL did not reach the expected threshold. In Spanish rural societies, youth are not usually involved in local issues related to the primary sector (agriculture and forestry) and therefore their involvement in the LL activities was under-represented despite efforts to involve them. While effective in encouraging the participation of women, inclusion of young people is an ongoing challenges which needs to be addressed to ensure the long-term sustainability of the LL actions and forestry improvements.

Research methodology transformation

The LL approach and methodology has been a very valuable approach for co-creation and participatory research in the field of sustainable forest management. One of its main strengths has been the structured and facilitated environment enabling dialogue and knowledge exchange, alongside integration and generation of ideas and practices between diverse actors such as researchers, public agencies, private companies, and local communities each with their contrasting perspectives and expectations. To their surprise, the researchers found this approach enabled a consensus on priority ecosystem services and specific forestry actions such as prioritising understory management to reduce fire risk and enhance biodiversity. The LL has enabled more realistic, context-specific, and socially acceptable AFM decisions. The experience of using LL has transformed the researchers' approach to incorporate participatory processes and prioritise the social applicability of the results. Previously, the research team worked only with data and models 'in the office' without considering local knowledge of the territory, As a result of SALAM-MED, social validation and collaborative scenario building are now included in the research strategy which has improved the research and increased its impact. The approach has also prompted learning and reflection on participation. For example, future research design will include specific strategies to involve young people from the beginning, perhaps through social media or educational centers; and better workshop schedule planning to avoid periods of high workload to improve attendance.

4.4 The Jeffara LL in Tunisia

Progression and changes over time

Following initial stakeholder mapping and prioritisation, workshops and meetings were convened with diverse stakeholders to understand the context of the study site and select the best practices and options based on an evaluation of possible positive and negative impacts to the MAR system and impacts at the farmer scale. Subsequent work of the LL has been to refine, model and test the options for aquifer recharge. During the final workshop, stakeholders reviewed and re-evaluated the proposed solutions and the relevance of the selected indicators, along with discussions on the ongoing implementation activities. This revealed several important insights, particularly regarding the economic and technological feasibility of the solutions, as well as their medium- and long-term impacts. Social acceptance of the proposed solutions was also quantitatively assessed through a Cost-Benefit Analysis (CBA).

Summary of achievements

Efficacy: The LL has achieved the main objectives according to all stakeholders. Based on field visits, observations from the responsible services, and feedback from farmers, the managed recharge wells under this project have led to:

- An increase in infiltration around the recharge wells
- An improvement in the water filtration system
- Data collection in the IRA data platform
- Geophysical prospecting using electrical methods (indicator: geophysical profiles)
- Co-designing management plans for recharge, cropping and irrigation systems and procedures to exploit long-term benefits while ensuring technical efficiency and practical feasibility
- Modelling of the Triassic aquifer using the WEAP and SWAT models
- Modelling of water requirements for the cultivated crops to enhance the use of smart irrigation in the region
- Evaluation of the CBA of the proposed solutions to test the feasibility of the theoretical management scenarios.

In the region, water accessibility and availability remain the primary challenges to be addressed. Raising stakeholder awareness about the relevance of Nature-Based Solutions (NBS) for more sustainable development through open discussions and a participatory approach have strengthened the evaluation of the most appropriate solutions.

Efficiency: The LL effectively used resources in this project including the following:

- Financial resources relating to improved water productivity
- Water resources both level and quality
- Human resources including involvement of both male and female farmers, as well as young people
- Soil resources combating soil degradation and avoiding clogging of the recharge well
- Technical and technological resources e.g. sensors, databases.

Effectiveness: The LL is helping to restore ecosystems at the aquifer level (watershed scale) and water productivity (farmer scale). The monitoring parameter is being used to conserve water resources by applying best irrigation practices (time of irrigation, water flow) and sharing data with stakeholders.

Research methodology transformation

The implementation of the LL was based on interaction between different stakeholders taking into account strategy at regional and national level based on future scenarios. As a result of the LL, a key learning point is that stakeholder engagement is a fruitful and collaborative approach that may be successful once open discussion and free feedback opportunities are available. The LL has helped to analyse and provide an understanding of how participation helps public actors to reframe innovation and address public (ground water recharge) and societal (farmers activities) needs. This represents a new approach to research for this locality. Collaboration between research team and stakeholders has been beneficial and supported by stakeholders. However, the approach has been limited by the absence of precise standards to guide transdisciplinary stakeholder networks of academics and practitioners through the collaboration procedures in the LL ecosystem.

4.5 The TAGANT LL in Morocco

Progression and changes over time

LL activation was marked by several challenges, including conflicts between argan tree owners and goat herders regarding appropriate management of argan landscapes, ensuring gender balance in a cultural context where mixed-gender public gatherings are often not socially accepted, and addressing language barriers in a multilingual region. Aligning with local cultural frameworks, parallel workshops were organised, one engaging male and one engaging female participants. Furthermore, the workshops were held in both Arabic and Tamazight languages.

LL participants increasingly acknowledged the benefits of SALAM-MED NBS to protect the argan ecosystem while supporting the argan-based economy. Social acceptance of the proposed solutions was also quantitatively assessed through a Cost-Benefit Analysis (CBA).

Summary of achievements

Efficacy: Field results showed significant improvement in soil moisture levels of SWRT-treated plots compared to the control. The application of SWRT also improved the performance of the argan seedlings in comparison to the control. These findings encourage the adoption of this technology in the argan reforestation programs by both ANEF and ANDZOA in the future. In addition, the physiological and biochemical traits of the argan tree increased in areas with controlled grazing, confirming that reducing grazing pressure improves plant health. These findings confirm the efficacy of both technological and land-use practices and provide the basis for support by other organisations to adopt this approach more widely to restore argan forests.

Efficiency: In general, the resources were effectively used in the LL because early efforts were made to establish synergies with institutions such as ANDZOA and ANEF which helped save some time and energy, as well as other stakeholders such as argan tree owners, goat herders, women cooperatives and administrators. However, the efficient use of resources was impacted by the large distance between the LL and the Cadi Ayyad University (more than 200 km) and also by the availability of the stakeholders and difficulties in bringing them together for each workshop. In addition, organizing the workshops took more time and effort than expected which was due to the lack of information and/or coordination. For instance, sometimes workshops had to be cancelled and rescheduled at short notice because few stakeholders would attend, or they were not informed on time. The engagement of the stakeholders was difficult to maintain during the project period and needed to be effectively managed. Low literacy levels among local populations limit the communication process with the local population, which required more effort and time to overcome this issue. Despite logistical difficulties, the research team were committed to co-design approach and made considerable efforts to implement all the activities with strong local collaboration.

Effectiveness: The LL contributed to SALAM-MED's overall purpose by the application of SWRT and other nature-based solutions to help restore the argan forest. For instance, the application of SWRT promoted the reforestation process by promoting soil properties, including soil moisture and also the performance of the transplanted argan seedlings. In addition, the implemented management grazing activities revealed that the argan tree health was improved under moderate- and no-grazing regimes. The findings suggest that the Agdal system (moderate grazing) is the most suitable and sustainable management approach for the argan forest, as this system provides feed for goats, income for shepherds and preserves the argan stands. Both implemented activities will enhance argan production in the medium and long term, which will provide multiple business opportunities associated with the argan oil production and also the potential adoption of the SWRT by ANEF and ANDZOA in the argan reforestation programs. This adoption depends on the cost-benefit of the technology. The LL promoted the involvement of women since they are the main actors in the argan fruit collection and oil extraction in cooperatives. It was very difficult to involve youth in the LL since the majority of young people have left the area to seek better opportunities in the cities. Overall, the LL approach helped in achieving the SALAM-MED objectives by encouraging cooperation between various stakeholders, enabling practical testing, and placing the stakeholders at the centre of innovation. This approach increases the likelihood of project success and impact by enabling iterative development, integration of stakeholder feedback, and the identification of business opportunities.

Research methodology transformation

Using a LL changed the research by transferring it into a collaborative and co-creative process that involved different stakeholders from the outset. As a result, the research became a dynamic, iterative process of optimization and experimentation which can quickly align with stakeholders' goals. Refinements to the applied technology were made possible as a result of stakeholder feedback in the LL. While the LL enabled learning about the complex relationship between the different stakeholders and their different perceptions of their ecosystem, the implementation of a LL presented many challenges. LL require considerable resources, energy, time, and trained personnel to communicate with stakeholders, especially to manage the different conflicts between the stakeholders which were encountered.

One of the surprises of this LL and a key learning point, is that co-learning processes can take place beyond fixed experiments and occur in real-world settings such as the argan cooperative and the argan forest itself when engaging with diverse actors. In this LL, stakeholders were surprised by the equal value placed on their contributions by the researchers, which challenges stereotypes of solitary "ivory tower" scholars and a science-based top-down approach. Future research will build on these insights through proactive information sharing, equal co-creation opportunities, and expectation alignment and more opportunities for youth engagement.

4.6 The Kharrouba LL in Egypt

Progression and changes over time

Progression and changes of the Kharrouba LL have been marked by:

- **Evolving stakeholder readiness and mobilisation**
  The Kharrouba LL was fundamentally shaped by direct climate impacts that served as catalysts for stakeholder engagement, transforming their **attitudes t**oward NBS and **willingness to participate**. This climate crisis manifested in multiple ways: unexpected rainfall patterns disrupted traditional agricultural planning, extreme heat stressed both crops and communities, and a severe outbreak of *Panonychus citri* (citrus red mite) demonstrated the declining natural resistance of local plants. These tangible impacts generated unprecedented climate change **awareness** across all community segments, including previously sceptical ones and/or those with limited formal education.
  Responses to socio-environmental pressures, however, varied significantly between stakeholder categories. Private sector representatives became financially motivated to invest in NBS, following a surge in demand for Matrouh's organic olive and fig products and increased profits generated from the tourism boom. Conversely, Bedouin farmers and local agricultural communities, while demonstrating strong willingness to adopt innovations, remained financially constrained and driven primarily by survival needs rather than economic opportunity.
- **Growing interest in experimental results**
  These socio-environmental pressures created fertile ground for open innovation. Stakeholders expressed genuine enthusiasm for experimental results and demonstrated unprecedented openness to NBS. The community's call for increased biopesticide use to combat pest outbreaks exemplified this shift toward science-based approaches, marking a significant departure from purely traditional management practices.

Summary of achievements

Efficacy: The Living Lab achieved its co-defined objectives through two complementary interventions that directly addressed regional challenges of water scarcity and soil degradation.

- **Water harvesting optimisation**: Six deteriorated dikes in Wadi El Agarma were rehabilitated, restoring their capacity to capture and store runoff water. The development of the FLOWS-KWV modelling tool marked a significant advancement, providing quantitative guidance on the optimal number and location of terraces, water storage potential, and suitable crop selection. This tool facilitated **conflict prevention** by predicting downstream water availability, addressing a critical concern for watershed-scale water management.
- **Soil health enhancement**: The application of mycorrhizal inoculants demonstrated measurable improvements in olive growth under water stress conditions. The intervention enhanced plant nutrition, drought tolerance, and soil microbiological characteristics. Protocols for local production of microbial inoculants were established, aiming to promote community-level production capacity and facilitate scaling out.
- **Community coordination**: The LL served as a comprehensive platform uniting all stakeholders interested in wadi development and rainwater harvesting. This achievement was particularly significant given historically fragmented governance structures and limited inter-community coordination.

Efficiency: The LL demonstrated remarkable efficiency by building upon existing traditional infrastructure rather than requiring entirely new systems. The approach maximised resource use by enhancing rather than replacing traditional water management practices. This integration acknowledges the value of indigenous knowledge systems developed over centuries of adaptation to arid conditions while recognising opportunities for improvement through contemporary scientific understanding and modelling capabilities. Stakeholder commitment was inconsistent due to economic constraints faced by some stakeholder groups. Nonetheless, the LL paved the way for lasting institutional knowledge through protocol development and community training.

Effectiveness: The LL contributed to SALAM-MED purpose of improving soil and water management in arid lands. Significant achievements included:

- **Scaling out**: Concerning water harvesting, the calibrated modelling parameters were successfully extended to additional basins, enabling scenario analyses for different terrace configurations across the region. This out-scaling demonstrates the intervention's broader applicability beyond the immediate project site. Furthermore, a task force will promote biopesticide use among local farmers, reducing reliance on chemical pesticides to address *Panonychus citri* infestations.
- **Women and youth engagement**: Women, whose role in the agricultural sector is primarily related to harvesting and food processing activities, comprised approximately one-third of the stakeholders involved in the LL process. Despite improvements over the project's lifespan, youth engagement remained limited, with fewer than 17% of participants under 30 years old, highlighting an ongoing challenge for long-term sustainability.

Business opportunities associated with sustainable land and water management: An extended cost-benefit analysis was carried out (for further details, refer to deliverables 5.3 and 5.4). Ongoing discussions with local businesses and government bodies aim to establish profit-sharing mechanisms, but sustainable economic integration requires addressing structural inequalities in the organic product value chain.

<u>Research methodology transformation</u>

The research approach evolved to integrate traditional water management practices with contemporary scientific modelling capabilities. Rather than disregarding local knowledge and expertise, the research approach enhanced traditional practices through quantitative analysis and optimisation tools.

The research process shifted from external solution imposition to community-driven innovation. Traditional practices served as starting points for scientific investigation, ensuring cultural compatibility and local ownership of improvements. This transformation created sustainable innovation pathways that can continue beyond project completion, as demonstrated by the microbial production protocols and the transferable modelling tools that communities can apply to new sites.

However, the Kharrouba LL reveals both the potential and limitations of community-based co-design processes. The strong correlation between direct climate experience and stakeholder mobilisation suggests that experiential learning may be more effective than abstract climate communication for motivating community participation. However, translating such awareness into behavioural change and innovation uptake requires targeting of structural barriers that limit the local community's participation (e.g. economic constraints, dependence on external financial support, and limited educational attainment).

5 Comparative Analysis Across Living Labs

The comparative analysis across the six SALAM-MED LLs reveals both convergent patterns and context-specific variations in their development trajectories, governance approaches, and outcomes. This synthesis examines the cross-cutting themes that emerged from the M&E process.

5.1 Initiation and activation

The initiation and activation of SALAM-MED LLs revealed distinct patterns shaped by local contexts, prior experiences, and institutional environments. **Rapid activation** characterised LLs that benefited from pre-existing institutional relationships (e.g. Jeffara LL), community connections and clear alignment around water management challenges (e.g. Kharrouba LL). These cases demonstrate that when LLs can **anchor themselves to existing social or institutional infrastructure**, they bypass many of the trust-building and alignment challenges that typically slow initial progress.

In contrast, **gradual activation** characterised LLs that required more extensive groundwork to establish collaborative foundations. For instance, the Làcani LL initially encountered stakeholder **fragmentation** and the challenge of developing a shared vision across diverse actors; however, through systematic integration efforts and **strategic partnerships** with regional agencies and LAGs, it evolved from fragmentation to cohesion. The Agora LL followed a similar pattern, confronting initial barriers including **experimental setup delays**, mixed **stakeholder readiness** levels, and **scepticism** from participants **unfamiliar** with co-research approaches. Nevertheless, once activated, both LLs achieved strong engagement, especially among younger farmers and women.

Despite varied contexts and activation speeds, **successful activation strategies** emerged across LLs. One such strategy involved iterative engagement, progressing systematically from bilateral consultations to collective workshops. This gradual approach proved particularly effective in contexts marked by initial mistrust or unfamiliarity with participatory methods. Furthermore, living labs that successfully integrated traditional knowledge systems accelerated both activation and legitimation processes. For instance, the Tagant LL's incorporation of pastoral practices and the Jeffara LL's recognition of traditional water management enhanced technical solutions and also validated local expertise, thereby increasing stakeholder ownership.

Overall, while it was clear that pre-existing community connections, institutional relationships and tangible problem definitions significantly accelerate activation, it should be noted that initial fragmentation or delays do not necessarily hinder the quality of long-term engagement or outcomes. This suggests that **the quality of the activation process**, particularly the attention paid to trust-building, knowledge integration, and inclusive engagement, may be more critical than its speed. Therefore, M&E frameworks should assess not merely the pace of activation, but the depth and sustainability of the collaborative foundations established during this crucial phase.

5.2 Facilitation and governance

The SALAM-MED LLs employed various facilitation approaches and governance strategies, reflecting both contextual requirements, stakeholder compositions, differences in researchers' skills and expertise, and evolving understanding of effective collaborative management.

Three distinct governance models emerged across the LLs. The ***institutional model***, exemplified by the Làcani LL through its formal agreements with LAGs, provided clear legitimacy and resource pathways, but required extensive negotiation to establish. The ***network-based model***, exemplified by the Agora and LAB4-ES LLs, emphasised flexible collaborative networks over formal institutional structures, enabling rapid adaptation but sometimes lacking decision-making clarity. The ***hybrid model,*** implemented in the Kharrouba, Tagant, and Jeffara LLs, combined formal institutional partnerships with informal community-based coordination, balancing legitimacy with flexibility.

Despite these different approaches, **common facilitation challenges** emerged across all LLs: balancing scientific rigour with stakeholder accessibility, managing expectations around timelines for visible results, maintaining engagement during experimental delays, logistics issues associated with geographic locations; and navigating power dynamics among diverse stakeholder groups. In addition, as a new innovation in their research practice, the researchers' own experiences and competencies in facilitating LL were initially very limited and learned mostly 'on the job' with some training within the SALAM-MED project.

The **role of local champions** proved crucial across all LLs, fostering innovation adoption, social acceptance, and conflict mediation. Furthermore, even though a common framework was applied across LLs, facilitation strategies gradually evolved into more contextualised engagement methods, including gender-specific and age-specific sessions to address participation barriers, adapting meeting times to agricultural calendars, holding sessions in community spaces rather than institutional venues, and incorporating stakeholder feedback into LL and experimental design. This **adaptive facilitation** required significant investment in understanding local social dynamics but yielded substantially higher engagement quality and sustainability.

5.3 Performance and outcomes

5.3.1 Efficacy in achieving LL objectives

The M&E reports indicate that the SALAM-MED LLs demonstrated medium to high efficacy in achieving their collaboratively defined objectives, though the availability of quantifiable metrics and detailed outcome documentation varied considerably across LLs.

The **critical factors enabling efficacy** across LLs included clear, measurable objectives collaboratively defined with stakeholders (e.g. LAB4-ES LL), systematic integration of farmer and stakeholders' feedback into experimental design (e.g. Lacani LL), and adaptive management approaches that allowed for iterative correction based on emerging insights.

However, all LLs acknowledged that technical, economic, and sociocultural **barriers to innovation adoption** remained, with behavioural change proving to be a long-term process. For further information, please refer to deliverables D4.3 "Co-design and implementation of innovative NBS: results from the hotspots" and D5.3 "The determinants factors affecting stakeholders' adoption decision of innovations".

5.3.2 Efficiency in resource use

All LLs acknowledged significant **resource use intensity**, particularly during early establishment phases. Other substantial **efficiency challenges** included delays in experimental setup due to equipment procurement difficulties (e.g. Lacani LL), technical equipment installation issues (e.g. Agora LL), and equipment destruction by extreme weather (e.g. Kharrouba LL).

Despite initial challenges, the SALAM-MED LLs demonstrated **strategic resource allocation and adaptive management capacity**. Several factors emerged as efficiency enhancers across LLs: leveraging prior experience with participatory projects and established community relationships facilitated smoother stakeholder engagement (Agora LL); effective partnerships with research institutions and agricultural agencies maximised the impact of available resources (Tagant LL, Lacani LL); adaptive management enabled recovery from operational setbacks (Kharrouba LL, Agora LL, Lacani LL); integration of traditional knowledge about sustainable land and water management practices enhanced local relevance and feasibility (Tagant LL, Jeffara LL).

Furthermore, LLs generated multiple **simultaneous outputs**, including academic outputs, practical field-tested innovations, and capacity development through young researchers' training and stakeholder capacity development, substantially amplifying their investment value. This multiplicity of outcomes demonstrates how the living lab approach can achieve efficiency not only through minimising inputs, but also through maximising diverse and complementary outputs from shared activities.

5.3.3 Effectiveness in contributing to SALAM-MED objectives

All LLs contributed to SALAM-MED objectives of **land restoration and ecosystem resilience** through testing NBS for: soil erosion reduction and improved water use efficiency in olive orchard management (Agora LL); adaptive forest management and ecosystem optimisation (LAB4-ES), microbial-based technologies to improve soil fertility and drought resilience (Lacani LL, Kharrouba LL; Tagant LL); sustainable and efficient grazing systems that enhance soil fertility, mitigate soil acidification, improve water use efficiency, and contribute to biodiversity conservation (Lacani LL, Tagant LL); enhancing groundwater recharge and sustainable water management to combat land degradation and desertification through MAR systems (Jeffara LL), SWRT (Tagant LL), and wadi basin water harvesting (Kharrouba LL).

Business opportunity development varied significantly in maturity. The Làcani LL contributed to this objective through isolation and multiplication of local soil microbial strains with commercial potential, backed by formal GAL agreements creating institutional frameworks for business development. The Agora LL created foundations for business opportunities through improved olive oil quality, opening premium market access and agritourism activities. For further information, refer to deliverable D5.4 “Sustainable Business Model”.

The LL varied in their success in engaging underrepresented demographics, particularly **women and youth**. The Agora LL achieved exceptional results with over 60% of workshop participants being women and individuals under 40 years old. This is particularly significant given that the local farming community is predominantly older male farmers. The Làcani LL similarly made substantial progress, engaging approximately 100 under 40 year olds through surveys and 50 through direct participatory workshops. The living lab systematically integrated female-led agricultural enterprises into activities and organised targeted participatory activities specifically designed for youth engagement. The strategic importance of youth and women engagement was recognised not only for enriching discussions with diverse perspectives but also for building future leadership in sustainable agriculture and addressing the critical demographic challenge of ageing farming populations.

5.4 Barriers and success factors across LLs

The SALAM-MED LLs faced cross-cutting barriers at behavioural, operational, and structural levels. The most persistent behavioural barrier was **resistance to change**, with awareness not immediately translating to behavioural change, and farmers often requiring stronger economic incentives and tangible benefit demonstrations before adopting innovations.

Operational barriers manifested throughout different implementation stages even when aligning early on with existing initiatives or communities. All LLs experienced significant time and resource intensity during early phases, with substantial burdens in terms of human and economic resources for maintaining engagement. **Technical challenges** compounded these difficulties, including delays in experimental setup, equipment installation issues, and equipment failures due to extreme weather events. These operational setbacks were exacerbated by misalignment between **stakeholder expectations** for rapid results and the longer **timelines** required for rigorous experimental research, as well as **partial mistrust** from participants unfamiliar with collaborative processes.

Structural or strategic barriers centred on **governance and institutionalisation challenges.** LLs struggled to establish sustainable governance models that ensured continuation beyond project duration, with multiple models often requiring exploration before finding appropriate arrangements. **Knowledge and capacity gaps** emerged as factors that may further complicated progress, including disciplinary divides between social and natural scientists, limited familiarity with participatory co-design approaches among both researchers and some stakeholders, diverse perceptions and perspectives on 'what should be done', incomplete understanding of socioecological complexities, and volatility in stakeholder willingness to engage over extended timelines.

Nonetheless, the M&E process identified critical success factors enabling LLs to overcome barriers and achieve meaningful impacts. The **human factor** emerged as the most important component of the living lab process. **Trust-building** emerged as the foundation for effective collaboration, requiring substantial **time investment** that sometimes exceeded expectations but proved essential for all subsequent activities. This trust developed over time through **sensitivity** when integrating different knowledge systems. Beyond trust, LLs succeeded through leveraging **pre-existing community relationships** and ensuring **local presence**. Team members living and working in the area of interest proved invaluable for understanding contextual nuances, facilitating connections, and maintaining consistent engagement. Established **institutional partnerships** and **prior experience** with participatory projects accelerated activation and enhanced legitimacy. Strategic partnerships with regional and national agencies, research institutions, and other sustainable agriculture initiatives enabled **resource leveraging, knowledge exchange**, and enhanced **credibility** while creating pathways for post-project sustainability.

Methodologically, **adaptive and iterative approaches** characterised successful LLs. **Flexibility** to adjust experimental designs based on stakeholder feedback (e.g. modifying cover crop species selection, introducing new experimental activities in response to emerging interests) increased both practicality and acceptance. This required researchers to recognise the value and role of **empathy and patience** to incorporate different stakeholder views through iterative discussions. Finally, **demonstrable outcomes addressing** stakeholder concerns and priorities (e.g. soil loss reduction, improved product quality, or increased production) proved essential, particularly for motivating farmers who required clearer benefit demonstrations before adoption.

6 Lessons Learned for Scaling the Living Lab Innovation Process

The comparative analysis reveals that successful LLs are not characterised by the absence of barriers but by their **adaptive capacity** to respond to challenges as they emerge. The diversity of implementation approaches across the six SALAM-MED LLs demonstrates that standardised protocols are neither feasible nor desirable for LL implementation. Instead, success emerges through commitment to co-design, careful alignment of LL governance models, facilitation approaches, and stakeholder engagement strategies with local socio-ecological contexts, institutional environments, and community characteristics. This **contextual sensitivity**, combined with commitment to **iterative learning and adaptation**, represents the core strength of the LL approach for addressing complex sustainability challenges in Mediterranean SES.

The following subsections synthesise critical lessons learned across multiple dimensions of LL implementation, drawing on the systematic M&E process conducted throughout the SALAM-MED project. These lessons provide both conceptual insights and practical guidance for researchers and practitioners seeking to establish or scale LLs.

6.1 Role and importance of M&E

Developing, agreeing upon, and implementing a structured M&E process represents an essential methodological foundation for documenting, understanding, and evaluating LL activities and outcomes over time. While the specific structure varies according to context, resources, and objectives, establishing a **regular pattern of M&E**, such as quarterly and annual reporting, ensures that events and learning are systematically captured and available for review at any time.

The M&E process can vary considerably in complexity, ranging from simple documenting of activities to comprehensive evaluation workshops that synthesise accumulated evidence and facilitate collective reflection. However, perhaps the most critical element of any M&E approach is the **shift from understanding M&E as a post-event, end-of-project administrative summative process to recognising M&E as a formative learning process integrated throughout the research cycle**.

Formative M&E – the ongoing process of evaluation during the LL implementation – enables learning and insights to be systematically incorporated into subsequent phases of research and stakeholder engagement activity. This approach encourages **reflective behaviours** among those involved, as monitoring and evaluation require “stepping back” from the immediacy of LL operational activities to critically review all aspects of the LL. This includes reassessing foundational elements such as aims and assumptions; evaluating functional aspects, methods and governance structures; and analysing performance metrics, stakeholder dynamics, and outputs. This reflective stance transforms M&E from a bureaucratic compliance requirement into a catalyst for adaptive management and continuous improvement through learning.

However, evidence from the SALAM-MED LLs indicates that effective formative **M&E requires significant time and resources, as well as willingness and understanding among LL convenors to engage in reflective, critical processes** (see also next subsection). This investment, while substantial in terms of time and skills development, leads to enhanced learning, improved adaptation, and stronger evidence base for demonstrating impact and informing scaling strategies.

6.2 Role of LL in research: toward an operational re-definition

In the scientific discourse concerning sustainability transformations, co-design and knowledge co-production are increasingly acknowledged as effective strategies for addressing complex global challenges. Grounded in transdisciplinary and participatory research traditions, LLs have emerged as a distinctive co-design approach that prioritises stakeholders' experiences, local knowledge systems, application of innovation in a real-world context and collaborative innovation as pivotal to sustainability-oriented transformations (Busse et al., 2023). Initially developed in urban contexts as real-life settings for the development and testing of new products, services, or processes, the LL model has since expanded to rural contexts, where it supports co-design, experimentation, and social learning for sustainable rural development (Potters et al., 2022; Trivellas et al., 2023).

Despite growing interest and application, existing LL definitions vary considerably, creating risks of semantic stretch that can lead to methodological ambiguity and operational inconsistency (Ceseracciu et al., 2023). ENoLL defines LLs as "open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end-users at the centre of the innovation process" (ENoLL, 2025). The European Commission's Soil Mission Implementation Plan distinguishes between LLs – defined as "user-centred, place-based and transdisciplinary research and innovation ecosystems" involving "multiple partners to co-create, test, monitor and evaluate solutions to a common problem" – and Lighthouses – defined as "places for demonstration of solutions, training and communication that are exemplary in their performance" (European Commission, 2022). Academic literature further distinguishes agroecosystem LLs, noting their engagement with intensive scientific research, complex innovation cycles shaped by environmental and socio-economic variability, and particularly diverse and multisectoral stakeholder configurations (McPhee et al., 2021).

While these definitions provide valuable foundations, they often lack deeper conceptual grounding of LL as learning systems and may not fully capture the adaptive, context-responsive nature essential to effective LL implementation. This is particularly pronounced in rural settings where environmental variability, diverse and often marginalised knowledge systems, and complex socio-economic dynamics require flexible, place-based approaches. Building upon existing frameworks and enriched by the SALAM-MED M&E process, we propose the following refined operational definition:

Living Labs as open innovation social learning systems to co-create more sustainable socio-ecological relationships in context.

Expanding on this, the definition encompasses the following.

*Living labs embody a **co-design** approach that enables **adaptive social learning and innovation ecosystems** functioning as boundary spaces where scientific research and diverse knowledge systems – including tacit, traditional, and experiential knowledge – converge through iterative co-creation processes. Operating within the actual socio-ecological contexts and communities they seek to transform, LLs **develop, test, and refine place-based innovations and response strategies to complex sustainability challenges** through continuous cycles of **collective experimentation, social learning, and adaptation**. LLs serve simultaneously as sites of transdisciplinary knowledge co-production, social learning, and transformative social and technical innovation. Distinguished by their commitment to **reflexive practice**, LLs integrate **formative monitoring and evaluation** as core methodological components, enabling adaptive management in response to emerging insights, evolving stakeholder needs, and changing socio-ecological conditions.*

This refined definition, derived from the SALAM-MED experience, emphasises several critical dimensions:

- **LLs as systems**: the recognition that LL arise from a complex and dynamic interplay of multiple elements involving histories, people, environments, knowledge, traditions and practices of multiple stakeholders across space and time. LL cannot be reduced to simply a method or an activity that can be facilitated or implemented.
- **LL as choices**: the recognition that the boundary of a LL and its constituent elements and activities are shaped by the choices of those involved. A LL is not a 'given' structure or process but arises from a range of imperatives such as funding, researchers' interests and stakeholders perspectives.
- **Adaptive capacity**: the ability to evolve the system boundary of the LL, methodological approaches, governance structures, and engagement strategies in response to emerging stakeholder needs, contextual challenges, and new opportunities while maintaining coherent focus on core objectives.
- **Boundary-spanning** function: the creation of collaborative spaces that bridge disciplinary, institutional/administrative, and epistemological differences.
- **Epistemic plurality**: the explicit recognition and valuation of multiple knowledge systems, including scientific, traditional, and experiential forms of knowing, as legitimate and essential contributions to innovation processes.
- Integration of **reflexive practice and formative M&E**: the systematic integration of formative monitoring and evaluation as methodological imperatives rather than administrative burdens, enabling continuous learning and evidence-based adaptation.
- **Multi-dimensional success metrics** that extend beyond technical outcomes (productivity gains, soil fertility, water efficiency, etc.) to include relational, institutional, and transformative dimensions (the depth of collaborative relationships, the quality of knowledge integration, the engagement of marginalised groups, the sustainability of institutional/governance arrangements established, etc.).
- The potential to design LLs as **social infrastructures** that strengthen social capital and enhance adaptive capacity and community resilience.
- Recognition that **LLs are 'living'** and not simply technical, experimental spaces existing outside of their social context.
- **Ethics**: fundamentally, a LL is a commitment to social learning through co-design, which in turn requires ethical awareness and consideration of all participants' views, perspectives and roles. It also requires attention to be paid to who is *not* involved and the implications for the aims and work of a LL.

These elements, while relevant to LLs generally, hold particular importance in rural contexts where the interplay of environmental conditions, traditional resource management practices, and community social dynamics demands approaches capable of navigating socio-ecological complexity and uncertainty.

This refined conceptualisation emerged from the SALAM-MED experience, where LLs were designed to function as open innovation processes embedded within a research framework to advance project objectives. While the focus of each LL varied according to local contexts and priorities, **the M&E reports consistently indicate that LLs, as a concept and a set of practices, represent a substantial shift in research practice for the researchers involved**. In essence, the foundational requirement for meaningful stakeholder engagement and the emphasis on social learning and co-design fundamentally altered traditional research dynamics, where aims, focus, and process are no longer determined solely by researchers. This transformation required researchers involved in the LLs to design and implement inclusive engagement processes while remaining aware of and responsive to multiple perspectives on situations, key issues, and potential pathways forward. These encounters, while occasionally challenging, yielded important insights regarding contextual dimensions – environmental, agricultural, socio-economic, and cultural – that shaped activities and outputs while reinforcing existing collaborative networks and developing new partnerships with stakeholders and organisations.

However, incorporating LLs into "traditional" research frameworks has not been straightforward. Early M&E reports indicate uncertainty and significant variation in activation speeds, largely dependent on pre-existing stakeholder relationships and institutional support. LLs with established networks progressed more rapidly, while others required extensive time for priority determination and network development. However, slower initiation did not correlate with reduced effectiveness, as most LLs achieved comparable scope and scale in their final outcomes within the confines of their respective contexts.

6.3 Essential skills for LL implementation and facilitation

As relatively new approaches (at least for the researchers involved in SALAM-MED), the LLs were challenging to convene, manage and facilitate for at least three reasons. First, many researchers had no or limited prior **experience with stakeholder engagement** as part of their research tradition, personal experience and cultural context. Second, and for similar reasons, **moving from a "science provider of knowledge" to being a "reflective co-creator of knowledge and practice**" was a new and demanding task. Third, the **facilitation of LLs as social learning processes** requires insight into social relationships, individual and group behaviours, and concomitant skills to maintain focus and cohesion of the LL while **encouraging collaboration and managing conflicts** as needed. These skills are not usually expected or taught as part of disciplinary traditions in the sciences, and therefore, many of the researchers in the SALAM-MED LL were learning through direct experience for the first time.

Beyond facilitation skills, **critical self-reflection** emerged as essential for effective formative M&E. This capacity for reflexive practice – the ability to critically reflect on one's own knowledge and practices – remains uncommon in many research traditions. Despite strong inter-partner relationships and willingness to engage in LLs, some research teams naturally struggled to understand the more nuanced aspects of LL methodology and associated M&E processes, especially in the early stages of SALAM-MED.

SALAM-MED made several strategic efforts to address these capacity gaps. A comprehensive training session was convened during early project stages to introduce partners to LL approaches, required skills, and practical experiences from other projects using LLs in agricultural contexts. In addition, regular feedback sessions on M&E findings were integrated into each SALAM-MED General Assembly meeting, enabling partners to understand the progress of each LL individually and collectively. However, retrospective analysis suggests that appointing dedicated, trained facilitators for each LL would have helped improve the capacity of the research teams to overcome some of the more basic problems of organising LLs and facilitating them as co-creative processes.

6.4 What makes living labs work

Analysis of the SALAM-MED LL experience reveals several interconnected factors that consistently contributed to LL effectiveness across diverse contexts:

- **Shared problem recognition**: the existence of a commonly acknowledged issue/challenge requiring collective action provides essential motivation and focus. This shared recognition need not imply complete agreement on problem definitions or solutions, but rather acknowledgement of a common interest in addressing particular challenges.
- **Willingness of stakeholders to collaborate with each other and researchers.** This extends beyond passive participation or information provision to active engagement in problem definition, solution development, and implementation.
- **Adaptive facilitation:** effective management of group dynamics, maintaining collective focus, navigating conflicts, and fostering inclusive participation emerged as critical competencies. Facilitators who could read social dynamics, adapt approaches to emerging needs, and create comfortable spaces for diverse voices proved instrumental in maintaining momentum and productive engagement.
- **Development of mutual trust** among stakeholders and between stakeholders and researchers.
- **Tangible progress and practical added value**: evidence that LL activities yield relevant practical outcomes maintains stakeholder motivation and legitimises continued investment of time and resources.

6.5 Transformation of research practice through LLs

The LL approach has transformed, to different extents, how the participating research teams understand and conduct research. This transformation has been partly driven by the project's objectives to enhance opportunities for women, youth and small enterprises, which has meant the research has had to be contextualised within the communities in which and for which it is undertaken. The **research focus** has progressively shifted from purely experimental scientific investigations and outcomes toward a more systemic understanding of local socio-ecological dynamics. Researchers and practitioners have engaged in **social learning** through open knowledge exchange, with experimental designs shaped by the co-creation of knowledge, approaches, and adaptations with farmers, agronomists and community members, rather than being predetermined and driven solely by researchers. Evidence from the LLs indicates that this shift has been positively received by researchers, **enhancing the practicality, relevance, usefulness, and acceptance of the innovations explored in each LL, as well as generating broader support for the research overall**.

While positive outcomes are evident, the transformation of research has not always been straightforward for researchers, communities and stakeholders involved. Some researchers, trained in the hard sciences, have limited experience or skills in co-researching and co-design, and have had to adjust and learn a new approach. Similarly, communities and stakeholders, who may have expected researchers to provide definitive solutions and "*the* answer" to their concerns, have had to adapt to a different style of research and researcher. These tensions, while entirely 'reasonable' have been challenging. However, engaging with these tensions openly has ultimately enriched the research process by situating rigorous science – at the base of SALAM-MED LLs – firmly within social, cultural, and economic contexts. This integration has produced research that is simultaneously scientifically robust and socially relevant, addressing both technical challenges and the complex human dimensions that ultimately determine whether innovations are adopted and sustained within communities.

6.6 Enabling conditions for scalability

Scalability encompasses at least three interconnected dimensions: scale up, scale out and scale deep (Moore et al., 2024), as shown in Figure 14. Understanding these dimensions and their respective enabling conditions is essential for developing strategic approaches to amplifying LL impacts beyond individual sites and projects.

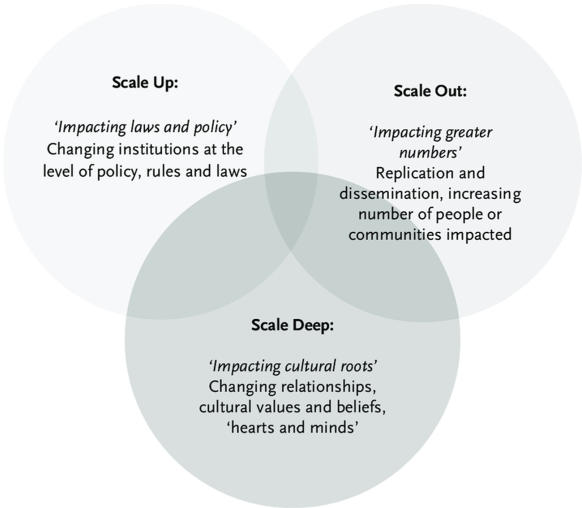

Figure 14 Scaling out, scaling up and scaling deep for social innovation (Moore et al., 2024)

Scaling out equates to the more usual interpretations of scaling, associated with extending innovations to greater numbers of people, communities, or geographic areas. SALAM-MED LLs, while locally focused, demonstrated significant potential for regional scaling to similar socio-ecological systems. The Tagant LL's approach to Argan forest restoration has been adopted by national agencies for broader reforestation programs. Similarly, the CAFE decision support system developed in the LAB4-ES LL has been implemented in other LLs to foster adaptive vegetation management. The scaling-out pilot in Palestine further demonstrated the adaptability of microbial-based and participatory nature-based solutions in new socio-ecological contexts while strengthening regional collaboration across the Mediterranean region. As another dimension of scaling out (reaching diverse social groups within communities), the LLs demonstrated various initiatives and strategies to engage with women, youth and small enterprises as active participants in social and economic dimensions of drylands restoration. **Enabling conditions** for scaling out include maintaining or developing relationships with researchers, agencies, sectors or communities; having access to experiences and learning from comparable contexts; clear communication of benefits and strong motivational factors that resonate with potential adopters. Furthermore, successful scaling out requires critical awareness that solutions and strategies cannot be simply transplanted from one context to another. A critical context-sensitive perspective is essential to appreciate and understand the context, actors, histories and socio-environmental dynamics.

Scaling up focuses on institutional integration, policy influence, and cross-sectoral application. SALAM-MED experience suggests that the LL approach can be successfully applied beyond agriculture to other environmental fields, due to its strong focus on co-creation and real-world testing. Policy briefs developed through SALAM-MED communication pathways aim to scale innovations into policy and practice, but implementation requires longer-term engagement with policy processes rather than one-time knowledge transfer. **Critical enablers** for scaling up include dedicated funding mechanisms ensuring continuity; development of simplified governance structures enabling non-research actors to establish and manage LLs; use of digital tools enhancing collaboration, data sharing, and stakeholder interaction; and continuous M&E providing evidence of impact and building confidence among funders, policymakers, and participants.

Scaling deep relates to a more fundamental aspect associated with changes in relationships, values, epistemologies, and cultural norms, including research practice culture. SALAM-MED experience reveals that successful LLs require substantial time investment in trust-building; flexibility to acknowledge, integrate with and adapt to diverse stakeholder perspectives, values and epistemologies; and commitment to knowledge integration. The **human factor** emerged as the most critical component, requiring early and sustained stakeholder engagement, active listening and responsiveness to concerns, and regular opportunities for reflexive evaluation within and across LLs. In this respect, the M&E findings reveal that effective LLs demand patience, empathy, and flexibility to incorporate different viewpoints in productive discussions and collaborative research innovation. Trust-building underpins the extent to which LLs achieve deep scaling.

The social learning and co-design principles fundamental to SALAM-MED LLs proved essential for situating scientific experiments and research outcomes within social and economic contexts, providing the foundation for multi-dimensional scaling. The integration of these scaling dimensions, rather than pursuing them independently, represents the most promising pathway for amplifying LL impacts.

7 Conclusions and Recommendations

The SALAM-MED LLs have provided invaluable insights into stakeholder engagement, interdisciplinary collaboration, and co-design approaches to drylands restoration and water management. While challenges emerged throughout the process, LLs and the researchers convening them have demonstrated resilience, creativity, and shared commitment to addressing complex socio-ecological challenges.

The synthesis of lessons learned across the six Living Labs yields several overarching conclusions with implications for future LL initiatives:

- **Context determines approach**: No standardised LL protocol proves universally applicable across diverse socio-ecological contexts. Success emerges from careful, context-sensitive alignment of governance structures, facilitation approaches, engagement strategies, and research methods with local socio-ecological contexts. This finding underscores the importance of flexibility and adaptive management in LL design and implementation.
- **Trust underpins collaboration**: Investment in relationship-building and trust development, while time-intensive and resource-demanding, proves foundational for all subsequent LL activities and outcomes. LLs that prioritised trust-building during formative stages, even at the cost of slower apparent progress, ultimately achieved more robust collaborative relationships and sustained engagement.
- **Knowledge integration enhances innovation quality and relevance**: LLs that successfully integrated scientific, traditional, and experiential knowledge systems developed more robust, contextually appropriate, and socially acceptable innovations.
- **Formative M&E drives adoption and adaptation**: Continuous monitoring and evaluation, when conceptualised and implemented as learning processes rather than administrative requirements, significantly enhance adaptive management. LLs that demonstrated greater impact were those that maintained flexibility to adjust approaches based on emerging insights and stakeholder

feedback. This adaptability requires systematic documentation, regular reflection, and a willingness to modify predetermined plans when evidence suggests alternative approaches would be more effective.

Building on these conclusions, several recommendations emerge to support future LL initiatives in carrying out robust, comparable, and learning-oriented monitoring and evaluation processes, developing necessary capacities, and creating conditions for successful scaling:

- Methodological recommendations:
  - **Establish structured, iterative monitoring processes** to ensure systematic tracking of LL processes and outcomes. While specific structures should be adapted to context, establishing a regular pattern of M&E, such as quarterly and annual reporting, ensures that events and learning are systematically captured and available for review at any time. When relevant and feasible, align monitoring approaches with structured frameworks such as the SOILL M&E guidelines for Soil Health LLs to facilitate comparability across initiatives (Vervoort & Campodonico, 2025).
  - Implement **formative M&E from project inception**: embed formative monitoring and evaluation as core components of Living Lab design from the outset rather than adding them retrospectively. Allocate sufficient human and financial resources for continuous reflection, documentation, and adaptive management. Ensure that evaluation findings systematically inform ongoing decision-making and strategic adjustments rather than being relegated to end-of-project reporting requirements.
  - **Employ mixed-methods approaches:** integrate quantitative and qualitative data collection methods to capture both comparable metrics and rich narrative insights revealing contextual nuances, process dynamics, and stakeholder experiences.
  - **Develop clear but flexible evaluation frameworks**: establish clear evaluation criteria aligned with project objectives while maintaining sufficient flexibility to recognise and document emergent outcomes that were not predetermined.
  - Invest in **facilitation training** for research teams before LL activation and consider appointing dedicated facilitators with expertise in participatory methods.
  - Need for **long-term (> 5 years)** Living Labs to comply with the corresponding agronomical and climatological time scales.

- Scaling recommendations:
  - Design for multi-dimensional scalability from inception, considering out, up, and deep dimensions simultaneously.
  - Maintain a critical perspective when transferring ‘solutions’, approaches, or lessons across contexts. Document adaptation processes and outcomes to contribute to collective learning about context-appropriate scaling strategies.
  - Document and share successes and failures to enhance collective learning.
  - Establish networks for knowledge exchange across LLs and regions.

Ultimately, the core finding of SALAM-MED is that all LLs are, and need to be understood, as social processes for innovation. This is the basis for a commitment to LL as dynamic social learning systems involving multiple stakeholders and using diverse knowledge and practices to enable more sustainable socio-ecological futures.

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