Fostering soil management PRACtices and uptake and developing decision support TOols through LIVing labs in EU (PRAC2LIV)

Executive Summary

PRAC2LIV Final Report — Stocktake and Stakeholder Exchanges on Decision Support Tools for Soil Organic Matter, Nutrient Use Efficiency, and Water Retention Across EJP SOIL Countries

EXECUTIVE SUMMARY

Background and objectives

EJP SOIL is a European Joint Programme on Agricultural Soil Management (EJP SOIL) addressing key societal challenges, including climate change and future food supply. Threats to soil health and climate change are increasingly impacting farming conditions across Europe, creating an urgent need for advanced Decision Support Tools (DSTs) to effectively manage soil health, water retention, and nutrient efficiency. However, the adoption of these tools varies significantly due to challenges including accessibility, data availability, and regional variations in tool reliability. In response to these challenges, EJP SOIL commissioned a stocktake on the availability and use of DSTs in the EU, focusing on nutrient use efficiency, soil organic matter, and moisture retention. In support of the EU Soil policy, e.g. the Soil Deal for Europe (European Commission, 2022) and the Soil Monitoring Law (European Commission, 2023), PRAC2LIV also discusses DSTs with a wide variety of stakeholders during live meetings.

The overall objective of the PRAC2LIV project was to assess the availability and uptake of DSTs within EJP SOIL countries, and to provide recommendations for their development and broader adoption to promote sustainable soil management. This objective was pursued through a comprehensive research approach that included a detailed literature review, systematic stocktake and evaluation of existing DSTs via surveys, stakeholder workshops, development and testing of mock-up designs, and an example for DSTs for soil health in Living Labs, contributing to a common vision on the advancement of sustainable soil management practices across Europe. The work covered the majority of EJP SOIL countries, providing insights across different agricultural and environmental conditions in Europe.

Key findings

Literature review

Agricultural management practices are significantly shaped by socio-economic, biophysical, and technological factors, including policies, market dynamics, technological advancements, and climate change. These influences affect soil management decisions, ultimately impacting crucial soil functions such as carbon sequestration, water retention, and nutrient cycling, all of which are vital for sustainable agriculture.

The literature emphasizes the need for robust monitoring networks and the integration of soil quality into environmental and agricultural policies. These policies aim to establish common criteria for soil health, promote restoration efforts, and improve data sharing among EU countries, formalizing comprehensive data collection and reporting processes. DSTs play a crucial role in analysing complex soil data, supporting policymakers, and ensuring sustainable land management practices. The review further calls for simple, accurate tools to enhance decision-making at the farm level. However, current DSTs often prioritize productivity over the multi-functionality of soils, limiting their adoption for diverse soil functions due to weak drivers and insufficient legislation. Implementing DSTs in agriculture is further complicated by the varied needs and conditions of farms. A holistic approach that incorporates multiple soil functions and engages stakeholders is essential for effective adoption. The review underscores the importance of aligning DSTs with farmers' real-world needs, supported by appropriate policy frameworks.

The literature review also reveals that scientifically validated DSTs are limited and often obscured by non-scientific ("grey") publications, leading to poor information exchange between researchers, developers, and end-users. Additionally, an expert-driven approach is recommended for regional

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case studies to better incorporate diverse insights, compared to strict scientific protocols. To enhance transparency and accessibility, a centralized public database of DSTs should be developed, allowing farmers, researchers, and policymakers to access organized and practical information, thereby bridging communication gaps and promoting broader adoption of DSTs.

Stocktake and evaluation of Decision Support Tools

The stocktake was conducted with two questionnaires, one distributed via email to the national coordinators of EJP SOIL countries, and the other to farmers' groups. These questionnaires focussed on a wide range of tools for soil organic matter, water retention, and nutrient use efficiency. Survey responses were received from 18 European countries, including Türkiye, and they identified 156 DSTs with 112 fitting the project's definition of digital DSTs. These tools vary significantly in type, technology, and purpose, ranging from simple calculators and activity planners to more complex models, monitoring systems, and remote sensing-based systems. The primary users of these DSTs include agronomists, consultants, advisors, and farmers, with less frequent use by researchers, private companies, NGOs, and policymakers (Figure ES1).

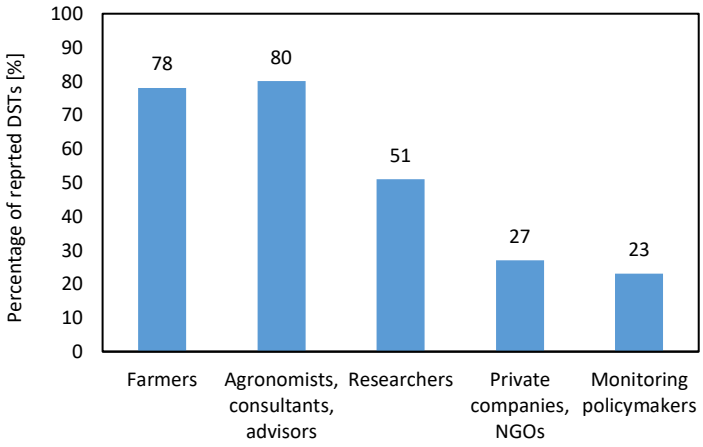

Figure ES1. Users of the commonly used DSTs.

The evaluation shows that the adoption of DSTs by end-users is generally moderate, with factors such as user-friendly interfaces, low costs, and alignment with user goals contributing to their adoption (Table ES1). However, the involvement of end-users in the development of these tools has been modest, indicating a need for greater stakeholder participation in the design process. The information available on the reported DSTs was often limited, presenting another potential hindrance to their adoption.

Table ES1. Average values of features ratings of commonly used DSTs..

Question	Rating	Value
Adoption by end-user	1= little or no use, 5= widely adopted	3.1
Is the use of the tool optional?	1= Yes, 2= No	1.1
Data input	1= few data needed, 5=many data needed	2.7
User friendly interface	1= too complex for users, 5= very user friendly	3.7
Perceived reliability of the DST	1= low reliability, 5= very high reliability	3.8
Cost of the DST	1= Free of charge, 5=Very expensive	1.8
The tool has been developed with participatory approach	1= no users involvement, 5=user-centred design	3.3
Suitable to reach national goals	1= not suitable, 5= very suitable	3.5
Suitable to reach regional goals	1= not suitable, 5= very suitable	3.6
Suitable to reach farmers goals	1= not suitable, 5= very suitable	4.1

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The evaluation emphasizes the importance of accounting for local and regional conditions in the development of Decision Support Tools (DSTs) and highlights the need for enhancements to existing tools. Farming needs and challenges differ across regions, and very few DSTs were commonly reported across multiple countries. Proposed improvements include integrating newer practices, such as organic farming and agroforestry, refining process descriptions and data inputs, and optimizing user interfaces to enhance usability (Figure ES2). Additionally, there is a call for new DSTs that address various spatial scales—from individual farms to regional levels—and provide comprehensive data integration. Overall, the evaluation stresses the need for DSTs that are adaptable to local and regional conditions, scientifically rigorous, and user-centered, to better support sustainable soil management practices across Europe.

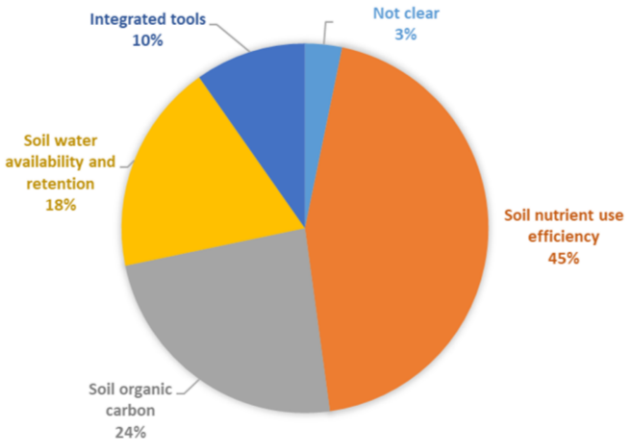

Figure ES2. Percentage of reported development needs in commonly used DSTs by type.

Stakeholder exchanges on DSTs

The results of the stocktake were discussed with a wide variety of stakeholders during live meetings. Regional workshops were held with farmers, advisors, and researchers, following a similar script in Sweden, Latvia, Italy, and Türkiye. Taking into account regional differences in soils and climate, soil-related challenges were addressed, emphasizing the need for DSTs specifically designed for soil nutrient management, particularly for optimizing fertilization practices.

Several barriers to DST adoption were identified, including the high cost of technology, insufficient user-friendliness, lack of technical support, and resistance to change, particularly among older generations. The adoption of DSTs by small and medium-sized farmers was highlighted as a challenge in all four workshops, with participants noting that DSTs are generally more suitable and viable for larger farms. Proposed solutions included positive demonstrations by experienced farmers, financial and technical support for implementation, and the development of simpler, more user-friendly tools accessible to all generations. The magnitude of these barriers varied across different contexts, underscoring the need for tailored solutions and implementation strategies.

In addition, DSTs were also discussed in meetings organized by other parties, such as National Hubs, EJP Soil Annual Science Days, and bilateral meetings with experts in agro-ecological agriculture and business models. The purpose of these meetings was to communicate the results of the stocktake and invite input for the future development of DSTs. Valuable input was obtained on socio-economic and policy aspects of DSTs.

A participatory design approach was also used to develop a common vision on the broader topic of "DSTs for Soil Health in Living Labs." In subsequent meetings led by a moderator, stakeholders discussed this topic while a designer simultaneously created sketches and drawings, which were incorporated into the overall visualization. The final version was reached after several iterations

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(Figure ES3). During this process, new subtopics were identified, such as ‘digital twin,’ ‘business model,’ and ‘ecosystem services.’ Furthermore, it was found that the participatory process enhanced stakeholder commitment to the outcomes.

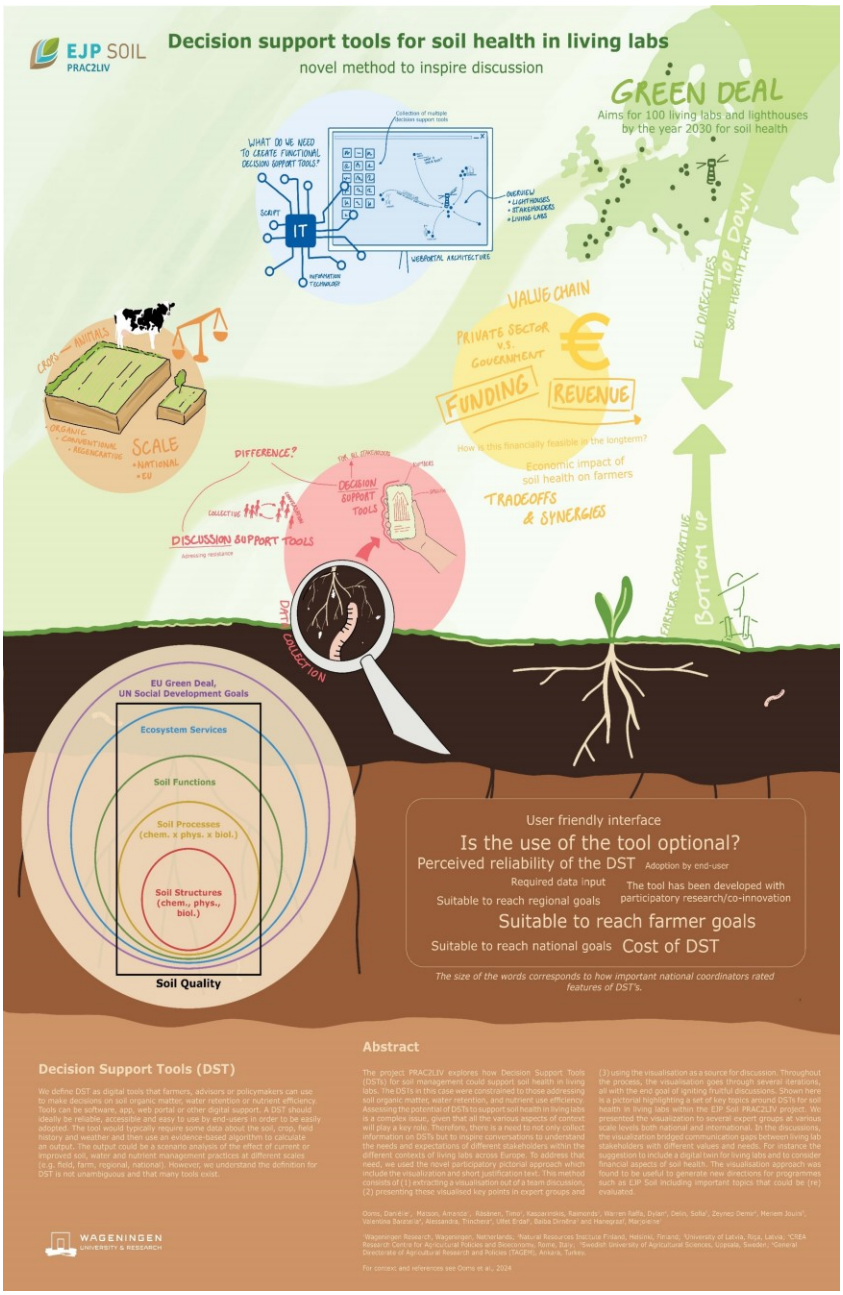

Figure ES3. A poster presenting the results of a participatory design approach for developing a common vision on the wider topic of “DSTs for Soil Health in Living Labs”.

Decision Support Tool mock-ups

DSTs may be developed in many different ways, and thus their actual (digital) form and presentation may vary, such as mobile apps, web portals, sensors/instruments, etc. Good DSTs will have algorithms that fit their purpose and deliver satisfying results. This is true not only in terms of reliability and accuracy but also with respect to the desired functions, such as monitoring, registration, or providing advice. Additionally, for high adoption rates of DSTs by end-users, the interface and presentation are considered to be very important. Mock-up designs for DSTs are a

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means to visualize the desired tools, inviting feedback and supporting structured programming. The mock-up designs developed for PRAC2LIV emphasize the importance of user-friendly interfaces, real-time data integration, and adaptability to different farming conditions.

A Web Portal on Decision Support Tools

Finally, the report discusses the development of a web portal for soil health, transitioning from single, stand-alone DSTs to integrated tools that support soil health across various scales. This shift aligns with broader European policy initiatives, such as the Green Deal, Soil Mission, and Climate Change Regionalization, which emphasize the need for tools that address multiple aspects of soil health simultaneously at different levels.

While single-purpose tools remain valuable, there is growing interest in creating web portals that integrate multiple tools to provide comprehensive support for soil health management. The report suggests that these portals should be scientifically robust, user-friendly, and adaptable to various agricultural contexts, supporting sustainable practices in line with European policy objectives.

Conclusions

The report underscores the transformative potential of decision support tools (DSTs) in advancing sustainable agricultural practices while highlighting several gaps that hinder their full effectiveness in enhancing soil management across Europe. Many current DSTs are primarily focused on productivity or single purposes, often neglecting the combined effects of crucial soil functions such as carbon sequestration, water retention, and nutrient cycling, which are vital for long-term environmental and social sustainability. Addressing this limitation requires a shift toward integrated, multifunctional DSTs that not only optimize agricultural outputs but also promote the health and resilience of entire agro-ecosystems. These tools should align with evolving European agricultural and environmental policies, such as the Green Deal and the Soil Mission, to contribute to broader societal goals.

The report's assessment of existing DSTs reveals a diverse range of tools with varying levels of adoption. However, significant improvements are needed in areas such as user-friendliness, adaptability to different farming systems, and better integration of diverse data sources. Additionally, the importance of designing DSTs that can adapt to different scales of operation, from small farms to larger agricultural enterprises, is emphasized. This can be achieved through active user involvement and co-creation during the development process, ensuring that tools are practical, intuitive, and aligned with the realities faced by farmers.

Furthermore, the report advocates for the creation of a European web portal for Soil Health, a centralized platform where various DSTs can be accessed, offering region-specific tools and data integration. This portal would provide a comprehensive solution for managing soil health at multiple scales, enabling farmers and other stakeholders to make informed decisions that align with both productivity and sustainability goals. The incorporation of user feedback, continuous evaluation, and alignment with policy frameworks are also crucial for ensuring the long-term success and relevance of these tools.

Ultimately, the future of DSTs in European agriculture lies in their ability to evolve from simple productivity tools into comprehensive systems that integrate the ecological, social, and economic dimensions of sustainability. This evolution will require collaboration among researchers, policymakers, farmers, and technology developers to design tools that are scientifically sound, practically applicable, and adaptable to local contexts. By addressing the challenges outlined in this report and leveraging emerging technologies, DSTs have the potential to play a key role in achieving sustainable soil management and enhancing agricultural resilience across Europe.

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Recommendations

The work presented here offers a broad understanding of the current use, challenges, and potential of DSTs in enhancing agricultural practices and sustainable soil management. Building on these insights, specific recommendations have been formulated to guide the development and increased adoption of DSTs, as well as the creation of a European web portal for Soil Health. These recommendations are summarized in Table ES2, with a more detailed explanation provided in Section 5.

Table ES2. Summary of recommendations for enhanced adoption and effectiveness of DSTs and for web portal on DSTs for soil health.

Enhanced adoption and effectiveness of DSTs	Web portal on DSTs for soil health
Existing DST effectiveness: • Improve data integration and accessibility • Increase usability and flexibility • Monitor and evaluate DST performance **DST improvement:** • Include soil health and economic indicators • Explore new technologies and guarantee continuous improvement • Focus on multi-functional and integrated tools **Participatory approach on DST use and development:** • Promote knowledge exchange and capacity building • Enhance user engagement and co-creation **EU policy:** • Align with policy and regulatory frameworks • Foster collaboration and cross-border integration	**Participatory approach on web portal on DST development and use:** • Use a participatory approach • Functional design, an architecture • Customizable user dashboards **User-friendly and interoperable interface:** • Centralized access to diverse tools • Interoperability with existing systems • Scalable solutions for different users • Interactive decision-making tools • Real-time data integration • User support and community forums **Data ownership and security:** • Data privacy and security **Customization and user exploitation:** • Regional customization and localization • Educational resources and best practices • Continuous feedback and improvement loop • Integration with policy and regulatory frameworks

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