Soil-X-Change

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INITIATIVE OF FOSTERING CROSS-BORDER KNOWLEDGE EXCHANGE AND CO-CREATION ON SUSTAINABLE SOIL AND FARM MANAGEMENT

Soil-X-Change has received funding from the European Union’s Horizon Europe Framework Programme, Coordination and Support Actions under grant agreement No. 101133914

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Fostering cross-border knowledge exchange and co-creation on sustainable soil and farm management

Grant agreement number: 101133914

HORIZON Coordination and Support Actions

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DEC	Websites, patent fillings, videos, etc.	☐			
OTHER		☐	**CI**	Classified, as referred to Commission Decision 2001/844/EC	☐

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1. Executive Summary

This report presents the findings of a survey conducted with 391 farmers across 13 European countries as part of the Soil-X-Change initiative. The survey explored farmers' knowledge, attitudes, experiences and future plans regarding sustainable soil management practices, providing insights into patterns and relationships that may inform policy, research and agricultural extension work. While the sample size and selection methodology do not support definitive claims about European agriculture as a whole, the patterns identified offer valuable exploratory insights that can guide more targeted investigation and support initiatives.

With respondents representing diverse agricultural contexts, farm sizes, age groups and farming methods, the survey reveals patterns in sustainable soil management practice adoption and experience. The study was aiming to identify potential drivers and barriers to adoption, understand implementation experiences and explore the support mechanisms valued by participating farmers.

Key findings from this analysis include:

Awareness-implementation gap: Among survey respondents, awareness of sustainable soil management practices is high (over 90% for most practices), while actual implementation rates within this group are substantially lower (between 4% and 45% depending on the practice). This gap represents a significant opportunity for targeted support mechanisms that can bridge awareness and action.

Environmental values, economic realities: Farmers conceptually prioritize environmental benefits but report that economic factors are equally important drivers in actual implementation decisions. Economic constraints emerge as the dominant perceived barrier among survey participants across the represented countries, farm sizes, farming methods and age groups (mentioned by 80.1% of respondents who provided valid barrier rankings). The analysis reveals that farmers experience environmental benefits more frequently than economic benefits, suggesting that sustainable practices deliver stronger ecological than financial returns.

Peer learning primacy: Within our sample, other farmers and end-users represent both the top information source (69.8%) and a primary desired support mechanism (51.7%, tied with subsidies), highlighting the importance of peer networks among survey participants. This highlights the critical importance of farmer-to-farmer knowledge transfer and the need to leverage existing peer networks in educational initiatives.

Farm size and method influence: Different farm sizes and farming methods show distinct patterns in knowledge, implementation and support needs. Among survey participants, organic farmers reported implementing nearly twice as many sustainable practices as conventional respondents (6.1 vs. 3.7 practices per farmer).

Regional variations: Among survey participants clear geographic patterns emerge in practice preferences, knowledge levels and implementation barriers. For example, Austria leads in cover crop adoption (83%) and Italy in minimum tillage (64%), reflecting different agricultural traditions, environmental conditions and policy environments.

Practice-specific implementation patterns: Different sustainable practices show distinct adoption and continuation patterns. Among survey participants, practices like minimum tillage and cover crops show both high adoption rates and some discontinuation, suggesting the need for practice-specific technical support during implementation.

Strong future adoption intent: A substantial majority of survey respondents (68%) plan to implement new sustainable practices, with minimum tillage (42%) as the clear priority across all countries. Despite known implementation challenges, farmers continue to prioritize this practice, indicating recognition of its fundamental benefits and the need for better support through critical implementation periods.

Balanced support needs: Survey participants value both knowledge-based support (peer learning networks) and economic assistance (subsidies) equally (both 51.7%), highlighting the need for integrated approaches that address both dimensions of sustainable practice adoption.

These findings suggest several strategic directions for enhancing sustainable soil management adoption: (1) leveraging peer-to-peer knowledge networks, (2) providing targeted financial support during critical implementation phases, (3) developing practice-specific technical assistance, (4) tailoring approaches to different farm sizes and types and (5) accounting for regional variations in priorities and challenges.

By understanding the complex interplay of factors influencing sustainable practice adoption, stakeholders can design more effective interventions that recognize both the environmental and economic dimensions of agricultural sustainability. The high future adoption intentions identified in this survey demonstrate substantial momentum for agricultural transformation that can be accelerated through targeted, multidimensional support mechanisms.

2. Introduction

The transition to sustainable agricultural practices represents a critical pathway toward ensuring food security while addressing pressing environmental challenges, a process this study explores through the experiences of 391 farmers from 13 European countries. As agricultural systems face increasing pressures from climate change, resource degradation and economic volatility, the adoption of sustainable soil management practices has become essential for maintaining long-term productivity and environmental health. However, the successful implementation of these practices depends on understanding the complex interplay of factors that influence farmers' decisions, including economic considerations, environmental awareness, knowledge accessibility and contextual constraints.

Soil-X-Change aims to connect farmers, actors, policy makers, projects and initiatives to accelerate innovation and promote wider co-creation and implementation of innovative solutions in agricultural practice. By intensifying thematic cooperation between researchers, farmers and other stakeholders across the European Union, Soil-X-Change contributes to effective Agricultural Knowledge and Innovation Systems (AKIS), supporting green transition, smart agriculture, climate-neutrality and sustainability goals. Initiated by EIP-AGRI Operational Group practitioners (OGs), the project reflects the needs of 151 direct partners across 9 member countries. It focuses on collecting, combining, harmonizing, analysing and integrating results and data products developed by different EIP-AGRI OGs and project partners to disseminate and share innovative practices for sustainable soil and farm management.

This deliverable (D4.2) presents the findings from Task 4.1, which involved collecting data on the needs and barriers faced by farmers, practitioners or other key stakeholders in sustainable soil and farm management. Through both online and in-person discussions and survey, we sought to understand why the adoption of beneficial agricultural practices sometimes fails, often due to insufficient information for decision-making. Unlike technical documentation of best practices, this survey sought to understand the human dimension of agricultural innovation, exploring farmers' motivations, barriers, implementation journeys and future plans. The survey was designed to address several key questions:

- What is the current state of awareness about sustainable soil management practices among surveyed European farmers?
- Which practices have been successfully implemented and what benefits have participating farmers experienced?
- What are the primary barriers and challenges to adopting sustainable soil management approaches?
- What drivers motivate surveyed farmers to implement sustainable practices?
- What support mechanisms would most effectively facilitate wider adoption?

The insights gathered will help remove barriers to adoption by identifying drivers of farmers' preferences toward technology adoption and understanding differences in implementation across diverse agricultural contexts. The results presented in this report could inform the development of tailored educational initiatives, policy support and incentive programs to accelerate the adoption of sustainable soil management practices across European farming systems.

3. Methodology and sample characteristics

3.1 Survey design and implementation

The survey methodology was designed to capture insights into farmers' experiences with sustainable soil management practices across diverse European agricultural contexts. The approach integrated both quantitative and qualitative elements to ensure data collection and analysis. The survey was structured into four interconnected sections to provide a holistic view of sustainable practice adoption:

Demographic and operational context

- Farm location (country)
- Farm size
- Farming method (conventional/organic)
- Agricultural sectors
- Farmer age

General knowledge and attitudes toward sustainable practices

- Awareness of different sustainable soil management practices
- Information sources
- Perceived motivations for adoption
- Perceived barriers to implementation

Implementation experiences – Drivers and Barriers

- Actual practice implementation
- Drivers for adoption
- Benefits experienced
- Practice effectiveness
- Challenges encountered
- Practice abandonment reasons

Future adoption plans and support needs

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- Intentions regarding new practice adoption
- Desired future practices
- Implementation barriers
- Expected benefits
- Support needs

The survey employed multiple question formats to capture different types of information:

- Closed-ended questions: Used for demographic information, practice identification and implementation status
- Likert-scale questions: Employed for evaluating effectiveness, benefits and cost-benefit relationships
- Ranking questions: Used for prioritizing barriers, drivers and benefits
- Multiple-choice questions: Applied for identifying information sources and support needs
- Open-text fields: Provided for qualitative insights on specific experiences, benefits and challenges

Questions were formulated based on extensive literature review and input from agricultural experts across participating countries to ensure relevance and clarity. Definitions of sustainable soil management practices were provided to ensure consistent understanding across respondents. To ensure accessibility across linguistically diverse regions, the survey was translated into nine languages: Bulgarian, English, German, Hungarian, Italian, Polish, Slovakian, Slovenian and Spanish. Each translation underwent review by native-speaking agricultural experts to ensure technical accuracy and cultural appropriateness.

Prior to full deployment, the survey underwent pilot testing with small groups of farmers (5-8 participants) in Hungary and Slovak Republic. This critical preparatory phase served multiple purposes:

- Question clarity assessment: farmers were asked to identify unclear or ambiguous questions, leading to the refinement of some questions that originally caused confusion.
- Translation validation: agricultural experts reviewed translations alongside farmers to ensure technical terminology was accurately conveyed while maintaining cultural appropriateness. This process identified several key terms that required standardization across languages to ensure conceptual equivalence.
- Response option refinement: farmers' feedback led to the expansion of practice categories and the addition of "Other" fields with free-text options to capture country-specific approaches not anticipated in the original design.
- Usability testing: for the online version, we conducted usability testing to ensure the digital interface was accessible to farmers with varying levels of technological familiarity.

This iterative development process significantly improved survey quality before full-scale implementation and helped establish methodological consistency across all participating countries.

3.2 Data collection

Recruitment strategy and sampling approach

This study employed a multi-channel non-probability sampling strategy designed to maximize participation across diverse European farming contexts while working within practical constraints of cross-national agricultural research.

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Multi-channel recruitment approach:

The survey was distributed through multiple complementary channels to reach farmers across different networks and communication preferences:

- Professional networks: consortium partners utilized their established relationships with farming communities, drawing on years of agricultural research collaboration and extension work. This approach leveraged existing trust relationships that are essential for farmer participation in research.
- Extension service distribution: agricultural advisory services and extension organizations in participating countries promoted the survey within their client networks. Extension services serve as crucial intermediaries between research institutions and farming communities, providing credible endorsement for research participation.
- Open online access: the survey was made publicly available online and promoted through the project website and social media channels, allowing any interested farmer to participate regardless of their connection to formal agricultural networks.
- Organizational partnerships: farmer associations, cooperatives and agricultural organizations were engaged to share the survey with their members, expanding reach beyond direct research networks.

Rationale for non-probability approach: This sampling strategy was adopted due to several methodological and practical considerations common in agricultural research:

- Regulatory constraints: European data protection regulations (GDPR) and national privacy laws generally prevent researchers from accessing official farm registers for random sampling purposes, even for legitimate scientific research.
- Participation barriers: agricultural research consistently demonstrates that farmers have significantly higher response rates when approached through trusted intermediaries rather than unsolicited contact from unknown researchers. Trust relationships are particularly important in agricultural communities.
- Geographic and linguistic scope: conducting probability-based sampling across 13 countries with different languages, agricultural systems and institutional structures would require substantially greater resources and time than available within the project framework.
- Network dependency: accessing farming communities effectively requires leveraging existing agricultural networks, advisory relationships and professional organizations that have established credibility within farming communities.

Within the constraints of network-based recruitment, the sampling strategy actively sought diversity across:

- Geographic distribution within and across participating countries
- Farm size categories (from small holdings to large commercial operations)
- Agricultural sectors (arable, livestock, mixed farming, specialty crops)
- Management approaches (conventional and organic farming systems)
- Farmer demographics (age groups, experience levels)

Data collection implementation

The data collection process employed multiple complementary approaches to maximize both reach and depth of insights:

Online questionnaire

- Implemented through the EU Survey platform

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- Distributed via agricultural networks, extension services and farmer associations and promoted via Soil-X-Change website and social media channels
- Designed for self-completion with clear instructions and definitions

In-person group discussions

- Conducted by local agricultural experts
- Facilitated completion of the questionnaire in a supportive environment
- Allowed for clarification of questions and concepts
- Provided additional contextual observations

Farmer visits

- One-on-one completion of the survey with farmers collaborating with consortium members
- Captured insights from farmers less comfortable with digital tools
- Enhanced representation of diverse farm types

The survey was administered through these three complementary channels, all utilizing the same questionnaire content. For responses collected on paper during in-person sessions or farm visits, country representatives entered these directly into the online system using the same digital survey form, ensuring data format consistency across all collection methods. A standardized data entry protocol was followed for all paper questionnaires, with representatives instructed to enter responses exactly as recorded by farmers, including free-text comments. The unified online data collection system ensured that all responses, regardless of initial collection method, were compiled in a consistent format for integrated analysis. The survey was conducted between August and November 2024, collecting 391 completed responses across 13 European countries.

This multi-channel non-probability approach introduces limitations that affect interpretation of findings:

- Results cannot be statistically generalized to the broader European farming population because of possible limited statistical representativeness. Findings represent insights from the specific group of participating farmers rather than population estimates.
- Reliance on agricultural networks may have created bias toward:
    - Farmers already engaged with extension services or agricultural organizations
    - Operations with higher connectivity to agricultural innovation networks
    - Regions with more developed agricultural advisory infrastructure
    - Farmers with greater digital literacy (for online participation)
    - The open access recruitment may have attracted farmers with particular interest in sustainable agriculture or stronger opinions about soil management practices.

Also, despite efforts to achieve broad coverage, participation varied across countries, potentially reflecting differences in network engagement, survey promotion effectiveness, or farmer willingness to participate in research.

3.3 Data analysis approach

The data analysis employed a comprehensive approach to extract meaningful insights from the survey data while ensuring statistical validity and practical relevance:

Data preparation and quality control

- identification and handling of missing values
- removal of duplicate responses

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- validation of logical consistency across responses: we implemented systematic cross-checking procedures to identify and address inconsistent responses.
- standardization of free-text responses: free-text fields were processed using a systematic approach to enable quantitative analysis. For example: for practice descriptions (Q12), we developed a keyword dictionary with standardized terms (e.g., "no-till," "zero tillage," and "direct drilling" were all mapped to "minimum tillage"); we employed a semi-automated coding approach where text responses were first machine-categorized, then manually verified by researchers familiar with agricultural terminology.

Data harmonization

- integration of responses from different collection methods
- standardization of categorical variables (age, farm size)
- creation of consistent coding schemes across languages

Variable transformation

- categorization of continuous variables where appropriate
- standardization of measurement scales for comparative analysis

Analysis methods

- descriptive statistics: frequency analyses and distributions across demographic variables
- thematic analysis: systematic text analysis of qualitative responses
- duration and abandonment analysis: categorization of practice discontinuation timeframes
- regional comparison analysis: systematic comparison of patterns across different European regions
- weighted ranking analysis: used for barrier ranking questions where farmers ranked from least to most important

Countries with very small samples (Belgium, Ireland, Lithuania and Portugal, all with 3 or fewer respondents) were included in EU-level analyses but excluded from detailed country-specific conclusions to maintain statistical integrity.

3.4 Study scope and interpretative context

Analytical framework

Given the sampling limitations described above, the analysis focuses on:

- Identifying patterns and relationships within the surveyed farmer group
- Exploring factors associated with sustainable practice adoption among participants
- Generating insights that can inform targeted support strategies and future research
- Developing hypotheses about farmer decision-making processes that warrant further investigation

The value of this exploratory analysis lies in understanding the diverse experiences and perspectives of 391 farmers across varied European agricultural contexts, while explicitly acknowledging that different sampling approaches might yield different patterns and conclusions.

3.5 Sample characteristics

This section presents the demographic and operational characteristics of the survey participants, providing context for interpreting the findings presented in subsequent sections.

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Geographic distribution

The survey captured 391 responses from 13 EU countries (9 consortium countries: Austria, Bulgaria, Germany, Hungary, Italy, Poland, Slovak Republic, Slovenia and Spain) and 4 others (Belgium, Ireland, Lithuania and Portugal). The highest participation came from Hungary (17%), Spain (12%) and Bulgaria (11%).

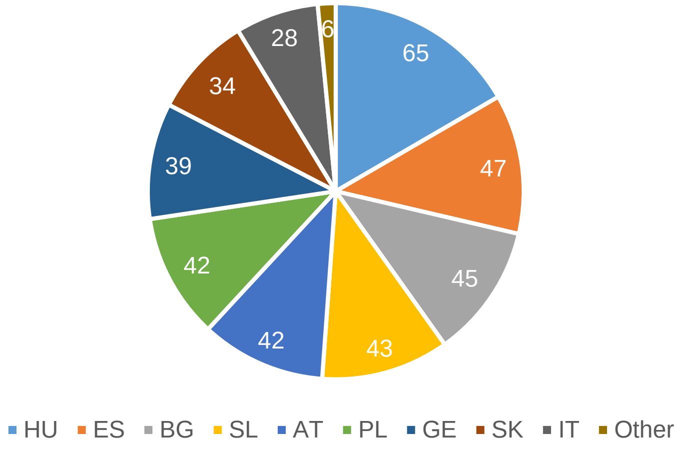

Figure 1 Distribution of survey respondents across participating countries

When grouped by region according to the UN definition, Eastern European countries represented the largest portion of respondents (48%), followed by Southern Europe (31%) and Western Europe (21%), with Northern Europe having minimal representation (<1%).

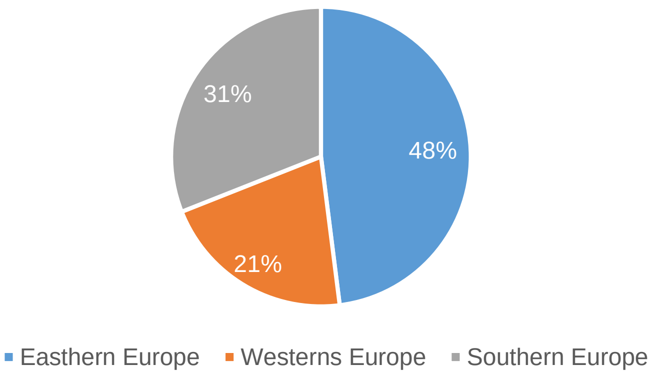

Figure 2 Regional distribution of survey respondents by European geographic regions

Farm size distribution

Farm size distribution shows that small to medium-sized farms dominate the sample, with 35% in the 6-50 ha range and 19% less than 5 ha. Medium-sized farms (51-100 ha) represent 13% of respondents, while farms of 101-250 ha constitute 8%. Larger operations represent 18% of respondents, with 6% in the 251-500 ha range and 12% exceeding 500 ha.

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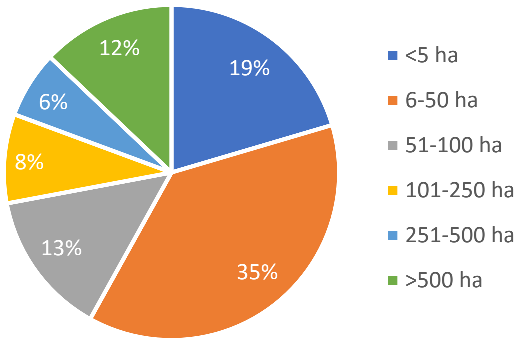

Figure 3 Farm size distribution among survey respondents

Farming methods

The sample shows that 73% of surveyed farms operate using conventional methods, while 27% practice organic farming. This proportion of organic farms is higher than the EU average.

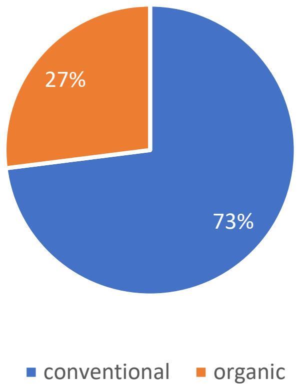

Figure 4 Distribution of farming methods among survey respondents (conventional vs. organic)

Sector diversity

The survey reveals that 39% of farms operate in multiple agricultural sectors, while 61% focus on a single sector. Among all surveyed farms, arable farming is the most common sector (59% of respondents), followed by mixed farming combining crops and animals (32%), fruit farming (19%) and animal farming (15%). Specialized production systems represent smaller segments: viticulture (7%), olive farming (6%), greenhouse horticulture (4%), and agroforestry (5%).

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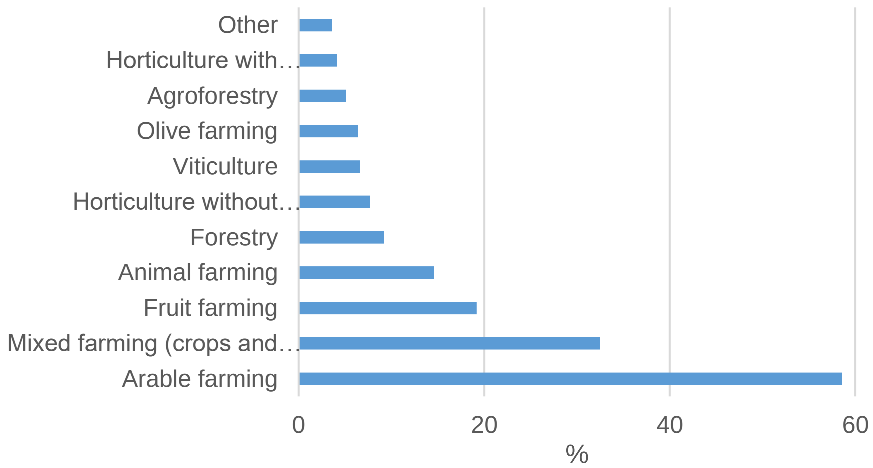

Figure 5 Agricultural sectors represented among survey respondents (percentage of farms by sector type)

Among farms operating in multiple sectors, most engage in 2-3 sectors (32.2% of all respondents), while 6.7% manage 4 or more sectors.

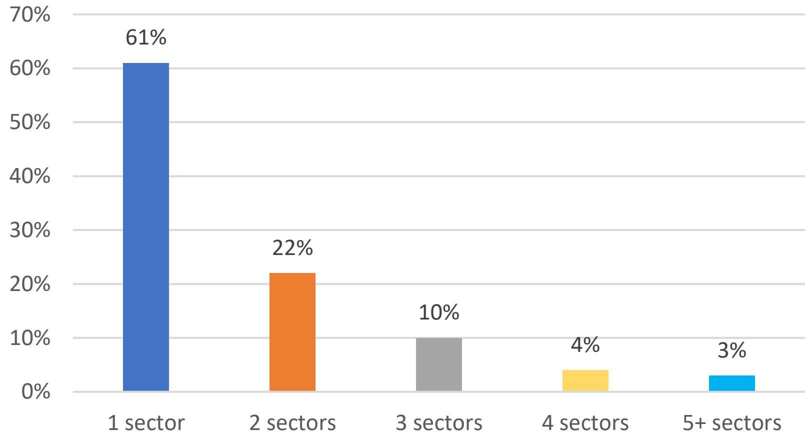

Figure 6 Number of agricultural sectors per farm among survey respondents

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Age distribution

The survey captured responses from farmers across diverse age groups. The age distribution shows that the largest age group is 50-64 years (34.0%), followed by 40-49 years (28.9%). Farmers aged 30-39 years represent 20.7% of the sample, while those below 30 constitute 10.0%. Farmers aged 65 and over represent 6.4% of the sample.

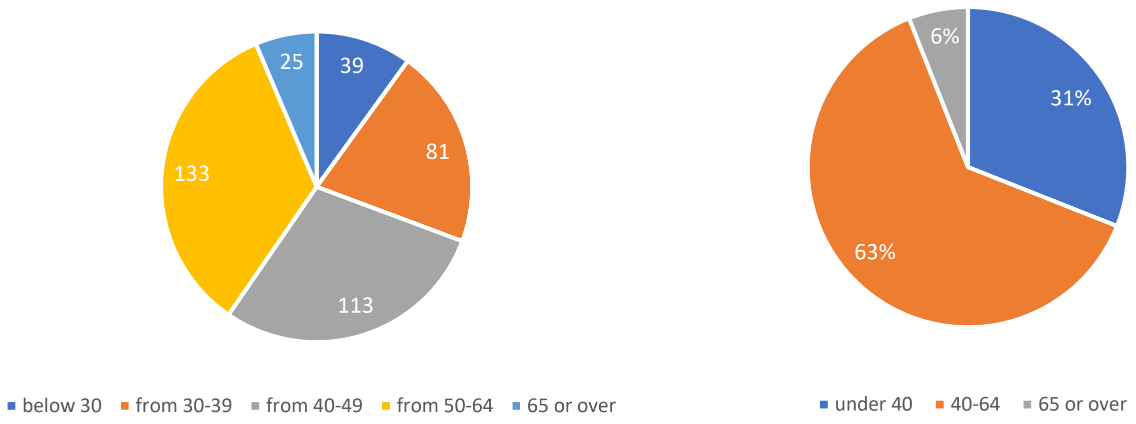

Figure 7 Age distribution of survey respondents

3.6 Methodological framework and cross-sectional interpretation

This survey was designed to capture multiple dimensions of farmers' engagement with sustainable soil management practices through distinct yet complementary methodological approaches across different sections. Understanding these methodological distinctions is essential for accurately interpreting and comparing findings across sections.

Perceptions, experiences and intentions: different knowledge frameworks

The survey intentionally examines three different knowledge frameworks that each provide valuable insights:

Perceptual knowledge collects data on farmers' general understanding, beliefs and perceptions regarding sustainable practices. This reflects their conceptual frameworks and value orientations rather than direct experience. Data in this section should be interpreted as reflecting how farmers think about sustainability in general terms.

Experiential knowledge focuses on farmers' direct personal experiences implementing specific practices. This represents applied, contextual knowledge gained through practical implementation. Data in this section should be interpreted as reflecting what farmers have actually experienced rather than what they believe in theory.

Future-oriented knowledge examines farmers' intentions, plans and expectations regarding practices they have not yet implemented. This combines elements of both perceptual and experiential knowledge, filtered through the lens of specific implementation planning. Data in this section should be interpreted as reflecting farmers' synthesis of general beliefs and specific experiences into actionable intentions.

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4. Survey Results

4.1 GENERAL KNOWLEDGE AND ATTITUDES TOWARD SUSTAINABLE PRACTICES

Farmers' knowledge of sustainable soil management practices

As outlined in our methodological framework (Section 3.6), this section examines perceptual knowledge, farmers' general understanding and perceptions regarding sustainable practices. These data reflect conceptual frameworks and value orientations rather than direct experience, providing insight into how participating farmers think about sustainability in broad terms. When interpreting the findings in this section, it's important to remember they represent theoretical perspectives that may differ from actual implementation experiences analysed in Section 4.2.

Knowledge distribution across practices (Q7)

For each pre-defined sustainable soil management practice, we categorized participating farmers' knowledge into three levels: "never heard of it", "heard but never used it" and "have practical experience." This approach allows us to distinguish between awareness and actual implementation among survey participants.

Most familiar practices

The practices with the highest levels of practical experience among surveyed farmers are:

1. Cover crops (67.8%): More than two-thirds of surveyed farmers have hands-on experience with cover crops, making it the most widely implemented practice among participants. Only 1.5% had never heard of this technique.
2. Minimum tillage (63.4%): Nearly two-thirds of participating farmers have implemented minimum tillage in their operations, with only 1.0% unfamiliar with this approach.
3. Mulching (61.1%): A strong majority of surveyed farmers have practical experience with mulching, while just 1.0% were unfamiliar with the practice.
4. Liming (60.9%): This traditional soil amendment practice remains widely implemented among participants, with only 1.5% of farmers reporting no knowledge of it.
5. Integrated Pest Management (53.5%): Over half of the surveyed farmers have practical experience with IPM strategies, while 4.3% had never heard of this approach.

Knowledge gaps: least familiar practices

The practices with the highest percentages of "never heard of" responses among participants highlight potential knowledge gaps:

1. Biochar (28.4%): More than a quarter of surveyed farmers have never heard of biochar, making it the least known practice among participants. Only 9.2% have practical experience with it.
2. Bush and tree fallows (20.7%): One in five participating farmers are unfamiliar with this practice, though 23.0% report having implemented it.
3. Contour farming (16.4%): A significant portion of surveyed farmers have never heard of contour farming, with just 18.7% having practical experience.
4. Agroforestry (16.4%): Despite growing attention to agroforestry systems, 16.4% of participating farmers remain unfamiliar with this approach and only 12.8% have implemented it.

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5. Non-rotational grazing (16.1%): A considerable knowledge gap exists for this practice among participants, with just 17.1% of farmers having practical experience.

The "awareness but no experience" category reveals practices that surveyed farmers know about but have not implemented:

- Terraces (72.9%): While most participating farmers are aware of terracing, very few (11.3%) have implemented this practice.
- Agroforestry (70.8%): Despite growing prominence in sustainability discussions, agroforestry remains largely unadopted despite awareness among participants.
- Rotational grazing (68.5%): Many surveyed farmers know about this practice but have not implemented it.
- Water harvesting (67.3%): While known to most participating farmers, practical adoption remains limited.

Age-related knowledge patterns

Analysis revealed that the youngest farmers (below 30) in our sample demonstrated the highest overall awareness, with only 5.6% reporting they had "never heard of" the defined practices. However, this group also showed the highest proportion of "heard but no experience" responses (61.7%) and a slightly lower rate of practical implementation. The 65+ age group among participants exhibited the largest knowledge gap, with 17.6% reporting they had "never heard of" various practices, more than three times the rate of the youngest farmers.

The highest rate of practical experience was found in the 50-64 age bracket (35.3%) among participants, closely followed by those aged 40-49 (34.8%). These patterns reveal an important distinction between awareness and implementation: while younger farmers demonstrate higher awareness of sustainable practices, middle-aged farmers achieve the highest implementation rates.

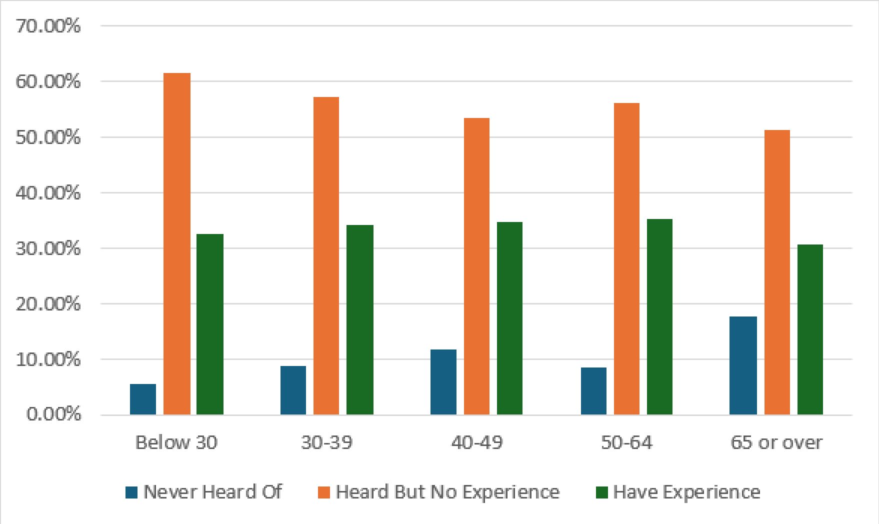

Figure 8 Sustainable practice knowledge levels by farmer age group among survey participants

Farming method and farm size considerations

When considering farming methods among participants, organic farmers generally reported higher familiarity and implementation rates for practices like cover crops, intercropping and mulching, while

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conventional farmers showed relatively higher adoption rates for precision agriculture techniques and drainage systems.

Regarding farm size among participants, larger operations (>100 ha) reported higher adoption rates for mechanized and precision agriculture approaches, medium-sized farms (6-100 ha) showed the most diverse implementation of practices, and smaller operations (<5 ha) demonstrated higher rates of labour-intensive practices like mulching.

Additional practices reported by farmers

Several participating farmers provided information about other sustainable soil management practices not explicitly pre-defined in our survey:

1. Grazing on arable land in rotation: an organic farmer (40-49 age group, 51-100 ha) mentioned using grazing in rotation to build up soil fertility.
2. Economic concerns affecting adoption: an organic farmer (40-49 age group, 6-50 ha) highlighted that "due to poor pricing of crops, it is difficult to carry out proper tillage," noting it is "not economically viable in the long term."
3. Scale limitations: a conventional small-scale farmer (50-64 age group, <5 ha) mentioned being "too small to use precision farming," adding they only use mineral fertilizer for specific crops and avoid plant protection products.

These additional comments highlight the diverse approaches to sustainable soil management among participants, as well as the economic and scale constraints that influence adoption decisions.

Implications and recommendations

Based on the survey results from participants, key actions emerge:

1. **Target biochar education**: With 28.4% of surveyed farmers unaware of biochar, targeted educational campaigns could increase awareness of this promising carbon sequestration technique among similar farming communities.
2. **Age-specific outreach**: The significantly higher "never heard of" rates among farmers over 65 in our sample suggest a need for specialized outreach to this demographic, potentially through traditional media and established agricultural networks.
3. **Bridging awareness to implementation**: The high percentage of practices in the "heard but no experience" category among participants indicates a need for demonstration projects, farmer-to-farmer learning and implementation support to bridge the gap between awareness and adoption.
4. **Peer-to-peer learning networks**: The 50-64 age group's high implementation rates among participants suggest they could serve as valuable mentors for younger farmers who have high awareness but lower implementation rates.

Geographic patterns in farmers' knowledge and practice

The agricultural practices across European countries represented in our sample reveal diverse sustainable farming approaches, each reflecting unique environmental, economic and cultural contexts.

Convergence and differentiation of agricultural practices

Cover crops have emerged as a cornerstone of sustainable agriculture among participants, demonstrating remarkable prevalence across multiple countries in our sample. In Austria, 95.2% of surveyed farmers have integrated cover crops into their agricultural systems, reflecting a comprehensive approach to soil health and erosion protection. Similarly, Slovenia (79.1%), the

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Slovak Republic (79.4%), Poland (73.8%) and Germany (89.7%) among participants have embraced these practices, transforming agricultural landscapes.

Unique regional approaches

Some practices reveal the distinctive agricultural character of specific countries among participants. Spanish respondents stand out with leadership in agroforestry, achieving a 36.2% adoption rate that far surpasses other surveyed nations. This approach is deeply rooted in the country's traditional dehesa and montado farming systems, which have long integrated trees and crops in sophisticated land management strategies. Poland and Bulgaria present another pattern among participants with their significant adoption of bush and tree fallows, with 50.0% and 40.0% adoption respectively.

Specialized soil management techniques

Among our participants, microbiological products have found particular traction in Hungary and Italy, with adoption rates of 75.4% and 67.9%. This emphasis suggests a more nuanced approach to soil management among surveyed farmers in these countries, recognizing the critical role of soil microorganisms in agricultural productivity. Austria provides another unique perspective among participants with its widespread adoption of contour farming at 45.2%, likely influenced by the country's mountainous topography.

The persistent practice of minimum tillage

Among participants, minimum tillage has achieved nearly universal status across surveyed countries, appearing among the top three practices in nearly all countries, indicating a fundamental transformation in agricultural thinking among participants.

Conclusion

Our analysis reveals patterns among participants in farmers' knowledge and implementation of sustainable soil management practices across represented European countries. While certain practices, such as minimum tillage and cover crops have achieved mainstream adoption among participants, others remain unfamiliar to significant portions of the surveyed farming community. These findings among participants suggest strategic directions for enhancing sustainable soil management adoption: (1) leveraging peer-to-peer knowledge networks, (2) providing targeted financial support during critical implementation phases, (3) developing practice-specific technical assistance, (4) tailoring approaches to different farm sizes and types and (5) accounting for regional variations in priorities and challenges among similar farming communities.

Information source analysis: channels for sustainable soil management knowledge (Q8)

The survey investigated where participating farmers obtain information about sustainable soil management practices. Understanding these information pathways among participants is crucial for designing effective knowledge transfer strategies.

Overall information source usage

The survey results reveal clear preferences in participating farmers' information-seeking behaviour:

Information Source	Usage Rate	Rank
Other farmers/end users	69.8%	1
Advisors	58.6%	2

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Information Source	Usage Rate	Rank
Own experience/experiments	56.3%	3
Agricultural journals	54.5%	4
Exhibitions/fairs/expo	45.8%	5
Researchers	38.1%	6
Input dealers/technology suppliers	25.8%	7
Officials at regional/national authorities	13.0%	8
Innovation brokers	12.8%	9
Other	9.2%	10

Table 1 Information sources for sustainable soil management ranked by usage frequency among survey respondents

The hierarchy highlights the critical importance of peer-to-peer knowledge exchange among participants, with nearly 70% of surveyed respondents reporting that they learn from other farmers. Professional advisors, farmers' own experimentation and agricultural publications form a second tier of highly utilized sources (>50%) among participants, followed by exhibitions and fairs.

Information sources by farm size

Small-scale farmers show relatively balanced utilization of different information sources, with notable emphasis on their own experimentation (58.1%) and peer learning (58.1%). They access research institutions at higher rates than the overall average (41.9% vs. 38.1%).

Medium-sized operations show strong reliance on advisor/extension services (63.2%) and significantly higher use of peer farmers (70.9%) compared to small farms, suggesting a more socially networked approach to information gathering. Large-scale operations demonstrate remarkably high rates of peer networking (91.3%), more than 20 percentage points above the overall average. They also show substantially higher use of agricultural shows/fairs (73.9% vs. 45.8% overall) and are the only size category where input suppliers rank in the top five sources (52.2%).

Figure 9 Information source preferences by farm size among survey participants

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Country-specific patterns
Different countries show distinct preferences for information sources:
- **Austria**: Agricultural journals dominate (90.5%)
- **Bulgaria**: Advisors are primary (77.8%)
- **Germany**: Other farmers/end users lead (87.2%)
- **Hungary**: Other farmers/end users dominate (83.1%)
- **Italy**: Researchers are uniquely prioritized (71.4%)
- **Poland**: Advisors are primary (78.6%)
- **Slovak Republic**: Other farmers/end users lead (91.2%)
- **Slovenia**: Advisors dominate (81.4%)
- **Spain**: Other farmers/end users are primary (66.0%)

Institutional source utilization
Formal institutional sources (research organizations and government authorities) show interesting patterns: **Research institutions** are most accessed by small farms (41.9%), moderately accessed by large farms (34.8%) and least accessed by medium farms (32.7%). This suggests that small farms may seek direct research connections to compensate for fewer resources, while large farms maintain research relationships due to their scale and influence. **Government authorities** are consistently among the least-used information sources across all farm sizes. The data shows slightly higher usage among large farms (21.7%) than small farms (12.2%) and medium farms (10.8%). The low overall use suggests potential opportunities to improve government authority communication and engagement with farmers of all sizes. **Innovation brokers** show similar utilization rates across farm sizes (small: 13.5%, medium: 9.4%, large: 13.0%), indicating that these specialized intermediaries have not yet gained widespread adoption in any farm size segment.

Analysis of "other" information sources
Approximately 9.2% of participating farmers indicated using information sources beyond the predefined categories. The most common alternative sources include:
- **Internet/digital resources** (12 responses): Websites, online resources, webinars, educational videos
- **Associations/communities** (6 responses): Farming associations, community groups, soil associations
- **Universities** (4 responses): Academic institutions, university teachers and researchers
- **Educational programs** (2 responses): Further education programs, specialized training courses

This diversity highlights the evolving information landscape in agriculture, particularly the growing importance of digital resources and specialized communities focused on sustainable practices.

- **Implications for knowledge transfer**

Based on these insights from participants, we can identify several implications for knowledge transfer strategies:
1. Leverage peer networks
The dominant role of peer farmers as information sources across all farm sizes among participants suggests that peer-to-peer knowledge exchange should be a centrepiece of knowledge transfer strategies:
- **Size-specific peer networks**: Create peer learning groups specific to farm size to address common challenges

- **Cross-size learning**: Facilitate knowledge exchange between different farm sizes to share complementary insights
- **Formalize informal learning**: Support farmer-led demonstrations and field days to enhance peer learning quality and establish lighthouse farms in a region that can showcase the implementation of sustainable methods to neighbouring farmers.

2. Target shows and fairs for large farms

The high attendance of shows/fairs by large farm operators (73.9%) among participants makes these venues prime opportunities for reaching this segment:

- **Focus advanced content**: Present more complex, scale-dependent sustainable practices at these events
- **Showcase implementation at scale**: Demonstrate how practices work on larger operations
- **Leverage peer influence**: Engage large farm operators as speakers and demonstrators to reach their peers

3. Diversify channels for small farms

Small farms' more balanced use of diverse information sources among participants suggests the need for multiple, complementary channels:

- **Research connections**: Strengthen direct links between small farms and research institutions
- **Specialized advising**: Develop advisory services tailored to small farm constraints and opportunities
- **Resource-appropriate guidance**: Ensure information accounts for the resource limitations of small operations

4. Address government authority and innovation broker communication gaps

The consistently low use of government authorities and innovation brokers as information sources among participants suggests the need for improved outreach. Additionally, in some regions official agricultural advisory services may not exist, further complicating access to reliable information.

- **Communication review**: Assess current government and innovation broker communication channels and messages for relevance
- **Intermediary partnerships**: Work through more trusted sources (advisors, peer networks) to share government information
- **Simplify access**: Make government resources more accessible and user-friendly

5. Develop digital resource strategy

The emergence of internet and digital resources as important "other" sources among participants suggests opportunities to expand digital knowledge transfer:

- **Curated online content**: Develop high-quality online resources specifically for sustainable soil management
- **Digital communities**: Foster online communities for knowledge sharing and discussion
- **Webinar series**: Create regular online learning opportunities focused on practical implementation

Conclusion

This analysis reveals that participating farmers' information-seeking behaviour varies significantly by farm size, with each size category showing distinctive patterns and preferences among surveyed respondents. Rather than a one-size-fits-all approach to knowledge transfer, these findings suggest the need for tailored, multi-channel strategies that account for these differences. The survey data among participants suggests the importance of social learning through peer networks, among

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respondents, particularly for larger operations among participants, while highlighting the diverse information ecosystem that farmers navigate. By strategically leveraging these preferred information pathways and strengthening underutilized channels, knowledge transfer initiatives can more effectively reach farmers with sustainable soil management information. The substantial variation in information source usage also suggests that the recognized awareness-implementation gap may be partly explained by how farmers participating farmers receive information. Strategies that work with, rather than against farmers' established information-seeking preferences are likely to be more successful in bridging this crucial gap.

Farmers' perceived motivations for adopting sustainable soil management practices (Q9)

The survey asked participating farmers to rank their top three reasons they believe generally drive the adoption of sustainable soil and farm management practices. This analysis reveals a clear hierarchy of perceived motivational factors among participants. The analysis includes the 387 respondents who provided valid motivation rankings.

Motivation	First Choice	Second Choice	Third Choice
Improving soil properties	55.8%	15.8%	10.6%
Adaptation to climate change	23.0%	25.3%	11.9%
Reducing effect on the environment	16.3%	11.4%	11.9%
Increasing agricultural productivity	12.4%	14.0%	11.9%
Adhering to EU agricultural policies and subsidies	8.8%	5.4%	5.2%
Increasing profitability	8.5%	7.0%	11.4%
Increasing food security	2.6%	3.6%	6.5%
Enhancing welfare	2.6%	1.6%	4.4%
Adaptation to consumer demand	0.5%	1.6%	2.8%
Strategic market position	0.5%	0.5%	0.5%
Demonstration of success from other farmers	0.0%	1.0%	2.1%

Table 2 Top three perceived motivations for adopting sustainable soil management practices among survey respondents

These rankings among participants reveal that improving soil properties is overwhelmingly the primary perceived motivation, selected as the first choice by more than half of all surveyed respondents (55.8%). This is followed at a considerable distance by adaptation to climate change (23.0%) and reducing environmental impact (16.3%). Economic factors are often assumed to be primary drivers of agricultural decision-making, yet increasing profitability was selected as the first choice by only 8.5% of respondents.

When grouping these motivations into broader categories among participants, environmental concerns dominate (accounting for 76.4% of weighted responses), significantly outweighing economic considerations (23.6%), policy factors (8.4%), and social concerns (8.0%).

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Perceived motivations by farming method

Organic and conventional farmers among participants show distinct motivational patterns. Organic farms prioritize environmental concerns even more strongly (82.6% of weighted responses) compared to conventional farms (74.0%). Economic considerations account for only 9.0% of organic farmers' motivational priorities compared to 29.1% for conventional farmers.

Country-specific patterns

Environmental factors are the top category among surveyed respondents in all represented countries, though the strength varies. Most countries rank improving soil properties as the top motivation, while Bulgaria and the Slovak Republic uniquely prioritize adaptation to climate change. Spain and Poland are the only countries where EU agricultural policies appear in the top three motivations, suggesting stronger policy influences in these regions.

Country	Top Factor	2nd Factor	3rd Factor
Austria	Improving soil properties	Adaptation to climate change	Increasing agricultural productivity
Bulgaria	Adaptation to climate change	Improving soil properties	Reducing effect on the environment
Germany	Improving soil properties	Adaptation to climate change	Increasing profitability
Hungary	Improving soil properties	Adaptation to climate change	Reducing effect on the environment
Italy	Improving soil properties	Adaptation to climate change	Reducing effect on the environment
Poland	Improving soil properties	Reducing effect on the environment	Adhering to EU agricultural policies and subsidies
Slovak Republic	Adaptation to climate change	Improving soil properties	Reducing effect on the environment
Slovenia	Improving soil properties	Adaptation to climate change	Reducing effect on the environment
Spain	Improving soil properties	Adhering to EU agricultural policies and subsidies	Increasing agricultural productivity

Table 3 Perceived motivations for sustainable practice adoption by country among survey respondents

Implications

The findings suggest that environmental considerations, particularly improving soil properties, are the primary perceived motivators for sustainable practice adoption across all farm types and countries among participants. This indicates that messaging focused on soil health and climate resilience is likely to resonate most strongly with farmers. However, the variations across countries and farming methods suggest that tailored approaches addressing specific priorities and concerns will be more effective than one-size-fits-all promotion strategies.

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Analysis of perceived barriers to sustainable agricultural practice adoption (Q10)

The survey asked participating farmers to rank what they perceive as the main barriers to implementing sustainable agricultural practices in their countries. This analysis highlights common challenges across different regions and reflects farmers' general opinions rather than their personal experiences. The analysis includes 357 respondents who provided valid barrier rankings.

The analysis shows a clear hierarchy of perceived barriers:

Barrier	Average Rank*	Top 3 Frequency**
Economic constraints	2.00	80.1%
Policy frameworks	3.13	52.7%
Infrastructure and technology limitations	3.18	54.2%
Knowledge gaps	3.53	43.5%
Social dynamics	4.57	19.9%
Climate and environmental risks	4.59	23.5%

**Average_Rank = Sum of all rankings / Number of times ranked*

***Top_3_Frequency = (Times ranked in top 3 / Total valid responses) × 100*

Table 4 Perceived barriers to sustainable practice adoption ranked by importance among survey respondents

Economic constraints stand out as the dominant perceived barrier, with an average rank of 2.00 and appearance in the top three barriers for 80.1% of surveyed respondents. This is significantly ahead of infrastructure/technology limitations (54.2% in top three) and policy frameworks (52.7% in top three).

Regional patterns

Economic constraints dominate in 8 of 9 countries represented in our sample, with particularly high rates among surveyed farmers in Germany (61.1%), Bulgaria (58.5%) and Poland (55.3%). Slovenia uniquely prioritizes infrastructure and technology limitations (23.3% ranking this first) rather than economic constraints as the primary barrier.

Country	Primary Perceived Barrier	Secondary Perceived Barrier
Austria	Economic constraints (38.9%)	Policy frameworks (27.8%)
Bulgaria	Economic constraints (58.5%)	Climate and environmental risks (12.2%)
Germany	Economic constraints (61.1%)	Policy frameworks (25.0%)
Hungary	Economic constraints (53.4%)	Knowledge gaps (15.5%)
Italy	Economic constraints (42.9%)	Knowledge gaps (17.9%)

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Country	Primary Perceived Barrier	Secondary Perceived Barrier
Poland	Economic constraints (55.3%)	Policy frameworks (18.4%)
Slovak Republic	Economic constraints (38.2%)	Policy frameworks (29.4%)
Slovenia	Infrastructure and technology limitations (23.3%)	Economic constraints (20.9%)
Spain	Economic constraints (43.5%)	Policy frameworks (26.1%)

Table 5 Primary and secondary perceived barriers to sustainable practice adoption by country among survey respondents

Perceived barriers by Farm Size

Different farm sizes among participants show notable variations in their barrier priorities:

Small farms (< 5 ha) Top first-ranked perceived barriers:

1. Economic constraints (38.2%)
2. Knowledge gaps (20.2%)
3. Policy frameworks (14.6%)

Medium farms (6-250 ha) Top first-ranked perceived barriers:

1. Economic constraints (46.1%)
2. Policy frameworks (16.9%)
3. Infrastructure and technology limitations (11.9%)

Large farms (> 250 ha) Top first-ranked perceived barriers:

1. Economic constraints (57.6%)
2. Policy frameworks (19.7%)
3. Knowledge gaps (13.6%)

This analysis reveals size-based patterns among participants:

1. Increasing economic concerns with size: The importance of economic constraints as a primary barrier increases with farm size among surveyed farmers, from 38.2% for small farms to 57.6% for large farms.
2. Knowledge gaps more critical for small farms: Knowledge gaps rank as the second most important primary barrier for small farms (20.2%) among participants, but are less prioritized by medium farms. This suggests that smaller operations may face greater challenges with technical knowledge and expertise.
3. Infrastructure concerns for medium farms: Medium-sized farms among participants uniquely rank infrastructure and technology limitations as their third most important primary barrier, possibly reflecting a transition point where technical resources become more crucial.
4. Policy priorities for large farms: Policy frameworks appear in the top three barriers across all farm sizes among participants, but are more prominently ranked by large farms (65.2% in top three), suggesting increased regulatory engagement for larger operations.

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Perceived barriers by Farming Method

Organic and conventional farms among participants show both similarities and differences in their barrier perceptions:

Top first-ranked perceived barriers by **organic farmers**:

1. Economic constraints (43.2%)
2. Policy frameworks (25.3%)
3. Knowledge gaps (20.0%)

Top first-ranked perceived barriers by **conventional farmers**:

1. Economic constraints (49.2%)
2. Policy frameworks (16.0%)
3. Infrastructure and technology limitations (12.2%)

Key differences between farming methods among participants include:

1. Economic focus in conventional farming: Conventional farmers among participants place greater emphasis on economic constraints as their primary barrier (49.2% vs. 43.2% for organic).
2. Policy importance for organic farmers: Organic farmers among participants rank policy frameworks as their second most important barrier at a significantly higher rate than conventional farmers (25.3% vs. 16.0%).
3. Knowledge gaps for organic farmers: Knowledge gaps are ranked as the third most important primary barrier by organic farmers (20.0%) among participants, but do not appear in the top three for conventional farmers, suggesting greater technical information needs in organic systems.
4. Infrastructure focus for conventional farmers: Conventional farmers among participants place greater emphasis on infrastructure and technology limitations (12.2% ranking it first, 56.6% in top three) compared to organic farmers.

Conclusions

The analysis reveals that economic considerations are the primary perceived barrier across nearly all participant groups, regardless of country, farm size or farming method, cited by 80.1% of farmers providing valid barrier rankings. Policy frameworks, infrastructure limitations and knowledge gaps form a second tier of consistently important barriers, though their relative importance varies by context.

These findings suggest that financial viability must be central to any effort to promote sustainable agriculture, while still addressing other important barriers. The variations across farming contexts indicate that targeted approaches addressing the specific priorities and concerns of different farmer segments are likely to be more successful than uniform policies or programs.

4.2 IMPLEMENTATION EXPERIENCES

Experience with sustainable soil management practices (questions 11-22)

Following our methodological framework (Section 3.6), this section explores farmers' experiential knowledge, their direct personal experiences implementing specific sustainable practices among

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participants. This represents applied, contextual knowledge gained through practical implementation, which may differ from the perceptual knowledge examined in Section 4.1.

Farmer experience with sustainable practices analysis (introductory question before Q11)

We asked participants whether they have experience with such practices and concluded that at the EU level, more than two-thirds of surveyed farmers (68.0%, 266 out of 391) indicated they have experience with sustainable soil and farm management practices, while about one-third (32.0%) reported no experience among participants. The country level analysis revealed significant variation in farmers' experience with sustainable soil and farm management practices across EU countries represented in our sample. Austria, Germany and the Slovak Republic stand out with over 90% of surveyed farmers reporting experience with these practices among participants, while Bulgaria shows the lowest experience rate at only 33.3%. This disparity in experience levels may reflect differences in agricultural policy, education, extension services, economic factors or historical farming traditions across EU member states. Countries with high experience levels might offer valuable knowledge-sharing opportunities to accelerate adoption in regions where sustainable practices are less established.

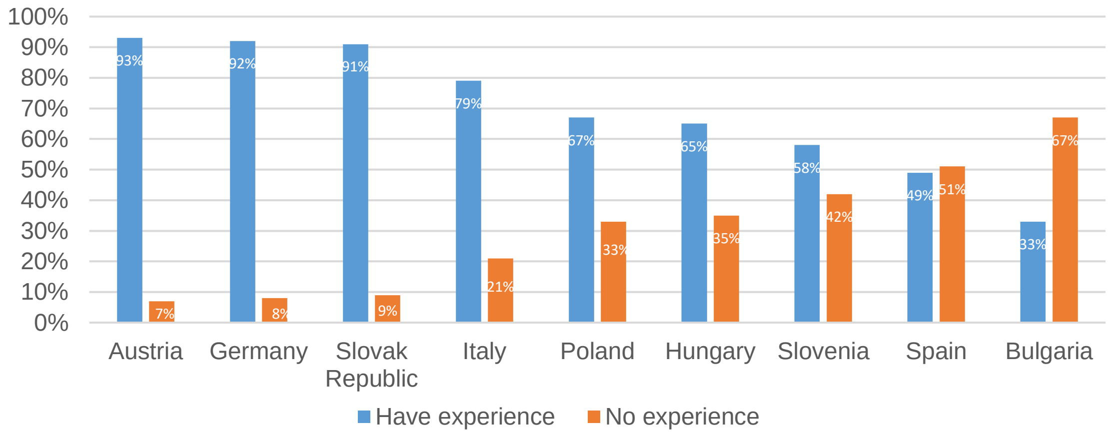

Figure 10 Percentage of farmers with experience in sustainable soil management practices by country among survey respondents

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Q11: Our study employed a structured survey approach to assess farmer engagement and real experience with different sustainable soil management practices across the European Union. For each practice, respondents could select from three engagement levels: "Tested it" (experimental implementation), "Use it" (current implementation), or "Used it and quit using it" (discontinued implementation). The survey presented respondents with 20 predefined sustainable practices and allowed for free-text additions of other relevant techniques. Analysis was performed to identify patterns of adoption, testing and discontinuation across different farming demographics. Implementation rates are calculated as the percentage of all survey respondents to provide population-level adoption estimates that account for both active non-adoption and lack of awareness. Correlation analyses were conducted to examine relationships between practice implementation and key variables including farm size, farmer age and farming method (conventional vs. organic).

Current Implementation: practices with established adoption

The analysis reveals that certain sustainable soil management practices have achieved notable adoption among the surveyed farming community. Cover crops represent the most widely implemented practice, with 178 farmers (45.5%) currently using this technique. This adoption rate reflects the versatility of cover crops in addressing multiple agricultural challenges simultaneously, including erosion control, soil structure improvement, and nutrient management. Minimum tillage follows as the second most commonly implemented practice, with 169 farmers (43.2%) currently using reduced soil disturbance approaches. The substantial adoption of both liming (156 farmers, 39.9%) and mulching (155 farmers, 39.6%) indicates recognition of these fundamental soil health interventions among participants. Integrated Pest Management (IPM) shows significant presence with 133 farmers (34.0%) implementing ecological approaches to pest control that reduce chemical inputs while maintaining productivity.

Country-level implementation patterns

Country-level analysis reveals substantial variation in sustainable practice preferences. Austrian farmers demonstrate high adoption of cover crops (83.3%) and liming (73.8%), while Slovak Republic farmers show strong preference for mulching (79.4%). Italian farmers particularly favour minimum tillage (64.3%) and cover crops (46.4%), while German agriculture embraces diverse practices, with strong implementation of cover crops (76.9%), liming (74.4%), and minimum tillage (59.0%). These geographic patterns suggest opportunities for knowledge transfer between member states where successful implementation strategies from high-adoption regions might be adapted for areas showing lower engagement with specific practices.

Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
Austria	Cover crops (83.3%)	Liming (73.8%)	Mulching (52.4%)	Minimum tillage (50.0%)	IPM (50.0%)
Bulgaria	IPM (20.0%)	Mulching (20.0%)	Minimum tillage (17.8%)	Liming (15.6%)	PA site-specific mgmt. (15.6%)
Germany	Cover crops (76.9%)	Liming (74.4%)	Minimum tillage (59.0%)	Mulching (56.4%)	IPM (46.2%)
Hungary	Minimum tillage (44.6%)	Microbiological products	IPM (41.5%)	Mulching (33.8%)	Cover crops (30.8%)

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Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
		(43.1%)			
Italy	Minimum tillage (64.3%)	Cover crops (46.4%)	Microbiological products (32.1%)	Livestock integration (28.6%)	Intercropping (25.0%)
Poland	Liming (61.9%)	Cover crops (47.6%)	Mulching (40.5%)	Minimum tillage (35.7%)	Microbiological products (35.7%)
Slovak Republic	Mulching (79.4%)	Cover crops (61.8%)	PA site-specific mgmt. (55.9%)	Minimum tillage (52.9%)	Liming (52.9%)
Slovenia	Liming (51.2%)	Cover crops (46.5%)	Minimum tillage (41.9%)	PA site-specific mgmt. (34.9%)	IPM (20.9%)
Spain	Mulching (34.0%)	Minimum tillage (31.9%)	Cover crops (27.7%)	Buffer strips (25.5%)	IPM (23.4%)

Table 6 Top five most commonly implemented sustainable practices by country among survey respondents (percentage of farmers using each practice)

Experimental implementation: practices under evaluation

Practices in the testing phase provide insight into technologies and approaches that farmers are actively exploring but have not yet fully incorporated into their standard operations. Biochar leads this category with 61 farmers (15.6%) currently testing, indicating interest in carbon sequestration technologies that offer potential climate mitigation benefits alongside soil improvement. Intercropping (57 farmers, 14.6%) and microbiological products (55 farmers, 14.1%) show similar testing frequencies, reflecting farmer curiosity about biological approaches to soil health and productivity. The presence of precision agriculture practices, specifically digital soil mapping (48 farmers, 12.3%), among frequently tested methods highlights growing farmer interest in technology-driven solutions for resource optimization.

Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
Austria	Minimum tillage (23.8%)	Biochar (16.7%)	PA site-specific mgmt. (16.7%)	PA digital soil mapping (16.7%)	Terraces (14.3%)
Bulgaria	Intercropping (20.0%)	Microbiological products (20.0%)	Cover crops (15.6%)	Biochar (15.6%)	Minimum tillage (11.1%)
Germany	Minimum tillage (15.4%)	Intercropping (15.4%)	IPM (12.8%)	PA site-specific mgmt. (12.8%)	Cover crops (10.3%)
Hungary	Terraces (16.9%)	Contour farming	Water harvesting	Non-rotational grazing	Bush and tree fallows

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Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
		(16.9%)	(16.9%)	(16.9%)	(16.9%)
Italy	Microbiological products (25.0%)	Biochar (25.0%)	PA digital soil mapping (21.4%)	Cover crops (17.9%)	Liming (14.3%)
Poland	Minimum tillage (16.7%)	PA digital soil mapping (16.7%)	Terraces (16.7%)	PA site-specific mgmt. (14.3%)	Contour farming (14.3%)
Slovak Republic	Microbiological products (35.3%)	Water harvesting (29.4%)	IPM (20.6%)	Intercropping (17.6%)	Liming (17.6%)
Slovenia	Intercropping (25.6%)	Biochar (23.3%)	Mulching (18.6%)	Microbiological products (16.3%)	Terraces (16.3%)
Spain	Biochar (17.0%)	Liming (14.9%)	Contour farming (12.8%)	Drainage system (12.8%)	Bush and tree fallows (12.8%)

Table 7 Top five sustainable practices currently being tested by country among survey respondents (percentage of farmers testing each practice)

Discontinued practices: implementation challenges

The patterns of practice discontinuation provide insight into implementation barriers or performance issues with specific approaches. Microbiological products show the highest discontinuation rate (30 farmers, 7.7%), suggesting potential challenges related to effectiveness, cost-benefit ratio, or application complexity. Similarly, the discontinuation rates for intercropping (25 farmers, 6.4%) and biochar (23 farmers, 5.9%) indicate that despite initial interest, some farmers encounter obstacles when integrating these practices into their operations. The presence of minimum tillage (22 farmers, 5.6%) among discontinued practices presents a notable pattern given its high overall adoption rate, suggesting that while many farmers successfully implement this approach, others find it challenging to maintain in their specific agricultural contexts.

Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
Austria	Microbiological products (19.0%)	Biochar (19.0%)	Minimum tillage (14.3%)	Non-rotational grazing (14.3%)	Rotational grazing (11.9%)
Bulgaria	Cover crops (8.9%)	Intercropping (2.2%)	PA digital soil mapping (2.2%)	Water harvesting (2.2%)	Drainage system (2.2%)
Germany	Minimum tillage (12.8%)	Intercropping (12.8%)	Microbiological products (10.3%)	Biochar (7.7%)	Non-rotational grazing (7.7%)

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Country	Practice 1	Practice 2	Practice 3	Practice 4	Practice 5
Hungary	Cover crops (7.7%)	Microbiological products (7.7%)	Minimum tillage (4.6%)	Non-rotational grazing (4.6%)	Intercropping (3.1%)
Italy	Liming (10.7%)	IPM (7.1%)	Mulching (7.1%)	Intercropping (3.6%)	Biochar (3.6%)
Poland	Biochar (11.9%)	Intercropping (9.5%)	Minimum tillage (7.1%)	Microbiological products (7.1%)	Rotational grazing (7.1%)
Slovak Republic	Microbiological products (11.8%)	Drainage system (11.8%)	Buffer strips (11.8%)	PA site-specific mgmt. (8.8%)	PA digital soil mapping (8.8%)
Slovenia	Microbiological products (9.3%)	Intercropping (7.0%)	IPM (7.0%)	Biochar (7.0%)	Minimum tillage (4.7%)
Spain	Intercropping (6.4%)	Cover crops (4.3%)	IPM (4.3%)	Microbiological products (4.3%)	Mulching (4.3%)

Table 8 Top five most frequently abandoned sustainable practices by country among survey respondents (percentage of farmers who discontinued each practice)

Age-related adoption patterns

The relationship between farmer age and practice adoption follows a curved pattern, with middle-aged farmers (40-64 years) implementing the most practices (approximately 4.6 practices per farmer), while both younger (<30) and older (65+) farmers show lower adoption rates (3.7 and 3.4 practices, respectively). This pattern may reflect the positioning of middle-aged farmers at the intersection of accumulated experience, openness to innovation, and longer planning horizons that make investments in soil health more appealing.

Age Range	Have Experience	No Experience
From 40-49	72.6%	27.4%
From 50-64	69.9%	30.1%
From 30-39	64.2%	35.8%
Below 30	64.1%	35.9%
65 or over	56.0%	44.0%

Table 9 Experience with sustainable soil management practices by farmer age group among survey respondents

Implementation patterns by farm characteristics

Farm size effects: Implementation patterns vary systematically across farm sizes. Larger operations (251-500 ha) implement an average of 7.5 practices per farm, while smaller operations (<5 ha) implement 3.7 practices on average. This likely reflects greater financial capacity and technical resources among larger farms.

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Farm Size	Have Experience	No Experience
251-500 ha	91.3%	8.7%
More than 500 ha	80.4%	19.6%
101-250 ha	78.8%	21.2%
6-50 ha	69.8%	30.2%
51-100 ha	68.6%	31.4%
Less than 5 ha	54.1%	45.9%
No land	40.0%	60.0%

Table 10 Experience with sustainable soil management practices by farm size among survey respondents

Practice	Small Farms (<5 ha)	Medium Farms (6-250 ha)	Large Farms (>250 ha)
Minimum tillage	35.1%	43.2%	56.5%
Cover crops	25.3%	50.5%	58.0%
Mulching	32.3%	37.2%	58.0%
Liming	21.2%	42.6%	56.5%
IPM	24.2%	34.1%	47.8%
PA site-specific management	19.2%	26.0%	53.6%
PA digital soil mapping	15.2%	14.3%	37.7%
Intercropping	19.2%	19.3%	30.4%
Microbiological products	19.2%	27.4%	33.3%
Livestock integration	10.1%	18.4%	33.3%
Buffer strips	18.2%	13.9%	26.1%

Table 11 Implementation rates of sustainable practices by farm size among survey respondents (percentage of farmers in each size category using each practice)

Key observations include a size effect where large farms consistently show higher implementation rates across nearly all practices, often at double the rate of small farms. The gap is particularly pronounced for technology-intensive practices like precision agriculture, where large farms implement at nearly three times the rate of small farms. Medium-sized farms show inconsistent patterns, sometimes closer to small farms and sometimes to large farms, suggesting this diverse group may face unique implementation opportunities and challenges.

Farming Method	Have Experience	No Experience
Organic	82.9%	17.1%
Conventional	62.6%	37.4%

Table 12 Experience with sustainable soil management practices: organic vs. conventional farmers among survey respondents

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Farming Method	Tested	Currently Used	Discontinued
Organic	2.1	6.1	1.1
Conventional	2.2	3.7	0.6

Table 13 Average number of sustainable practices implemented per farmer by farming method among survey respondents

Practice	Organic	Conventional
Cover crops	54.8%	42.0%
Intercropping	39.0%	14.7%
Minimum tillage	52.4%	40.4%
Mulching	48.6%	36.4%
Liming	46.7%	37.1%
IPM	45.7%	29.7%
Biochar	12.4%	1.4%
Water harvesting	32.4%	10.8%
Agroforestry	19.0%	5.9%
Rotational grazing	21.0%	8.4%
Buffer strips	32.4%	11.5%

Table 14 Implementation rates of specific sustainable practices by farming method among survey respondents

Key findings include an organic advantage where organic farms show higher implementation rates across all practices, with particularly pronounced differences for intercropping (+24.3%), water harvesting (+21.6%), and buffer strips (+20.9%). The narrowest differences are for precision agriculture practices and liming, suggesting these are equally valuable to both farming systems. Both organic and conventional farms prioritize the same top practices (cover crops, minimum tillage, mulching, liming, IPM), but organic farms consistently implement them at higher rates.

Practice-specific implementation patterns

The demographic analysis shows distinct patterns in which specific practices are favored by different farmer groups:

By farm size: Larger operations (>250 ha) show stronger preference for technology-intensive approaches like precision agriculture and larger-scale interventions such as cover cropping. Smaller farms (<50 ha) demonstrate greater interest in water harvesting and minimum tillage, possibly reflecting smaller-scale resource optimization strategies.

By age: Middle-aged farmers (40-64) show strongest engagement with cover crops and mulching, while younger farmers demonstrate greater interest in integrated approaches like livestock integration. Older farmers (65+) show particular interest in precision agriculture site-specific management, perhaps reflecting interest in technology that can reduce physical labor requirements.

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By farming method: Organic practitioners show substantially higher adoption of core ecological practices including cover crops (55.2%), minimum tillage (51.4%), and mulching (48.6%). Conventional farmers demonstrate more interest in testing precision agriculture technologies but lower overall rates of sustainable practice implementation.

Implications and recommendations

The demographic patterns identified in this analysis suggest several targeted approaches that could enhance sustainable practice adoption:

1. **Small farm support**: Develop specialized programs addressing the resource constraints and unique implementation challenges faced by small-scale operations (<50 ha), potentially including equipment-sharing cooperatives, tailored financial incentives, or adapted techniques that require lower initial investment.
2. **Age-targeted knowledge transfer**: Establish mentorship programs connecting middle-aged farmers (who show highest adoption rates) with both younger and older colleagues to facilitate knowledge transfer and address age-specific implementation barriers.
3. **Conventional agriculture transition pathways**: Design incremental adoption pathways for conventional farmers based on practices that show highest success and retention rates in similar conventional operations, potentially using organic systems as reference models while acknowledging differences in production contexts.
4. **Practice-specific implementation support**: Provide targeted technical assistance addressing the specific challenges associated with frequently discontinued practices like microbiological products, intercropping, and biochar, potentially including improved formulations, application techniques, or management systems.
5. **Regional knowledge exchange**: Facilitate cross-border learning between regions showing high success with specific practices and those with lower adoption rates, accounting for contextual factors such as soil type, climate, and farming systems.

Conclusion

The analysis of sustainable soil management practice adoption across European agriculture reveals a complex landscape of implementation influenced by farm characteristics, farmer demographics, and agricultural approach. While certain practices like cover crops and minimum tillage have achieved widespread acceptance, others remain in experimental phases or face implementation challenges. The significant variation in practice adoption between demographic groups, particularly between organic and conventional farmers, different farm sizes, and age cohorts, highlights both challenges and opportunities. These patterns suggest that targeted, context-specific approaches to supporting sustainable practice implementation may prove more effective than uniform policies or programs. By addressing the specific barriers faced by different farmer groups and leveraging the successful implementation strategies identified in high-adoption demographics, agricultural support programs can more effectively promote the transition toward more sustainable soil management across European farming systems.

Bridging awareness and implementation: correlation between Q7 and Q11

By examining both awareness (what farmers know about - Q7) and implementation (what they actually use in their operations - Q11), we gain crucial insights into adoption barriers and opportunities for targeted support. Our survey reveals patterns in how different sustainable soil management practices move from awareness to active implementation among participating farmers.

We calculated two key metrics for each sustainable practice:

- **Heard About Rate**: Percentage of farmers who have heard about but not tried the practice (from Q7)
- **Currently Using Rate**: Percentage of farmers actively implementing the practice (from Q11)

Practice	Heard About Only Rate (Q7)	Currently Using Rate (Q11)	Implementation Pattern
Cover crops	30.40%	45.40%	Implementation > Awareness
Minimum tillage	35.50%	43.60%	Implementation > Awareness
Liming	37.60%	39.60%	Implementation ≈ Awareness
Mulching	37.90%	39.60%	Implementation ≈ Awareness
IPM	42.20%	34.00%	Awareness > Implementation
Microbiological products	47.80%	26.30%	Awareness > Implementation
PA site-specific management	50.40%	29.20%	Awareness > Implementation
Bush and tree fallows	56.30%	10.50%	Awareness > Implementation
Buffer strips	58.60%	17.10%	Awareness > Implementation
Intercropping	59.30%	21.20%	Awareness > Implementation
Drainage system	61.10%	16.90%	Awareness > Implementation
Livestock integration	61.40%	18.90%	Awareness > Implementation
Biochar	62.40%	4.30%	Awareness > Implementation
Contour farming	65.00%	13.30%	Awareness > Implementation
PA digital soil mapping	65.20%	18.70%	Awareness > Implementation
Non-rotational grazing	66.80%	9.20%	Awareness > Implementation
Water harvesting	67.30%	16.60%	Awareness > Implementation

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Practice	Heard About Only Rate (Q7)	Currently Using Rate (Q11)	Implementation Pattern
Rotational grazing	68.50%	11.80%	Awareness > Implementation
Agroforestry	70.80%	9.50%	Awareness > Implementation
Terraces	72.90%	6.60%	Awareness > Implementation

Table 15 Awareness versus implementation rates for sustainable practices among survey participants (percentage who have heard about vs. currently use each practice)

Two distinct implementation patterns emerge:

1. **Successful implementation practices** (4 practices): Cover crops, minimum tillage, liming and mulching show more farmers currently using them than those who have only heard about them. These fundamental soil management approaches achieve implementation rates of 39.6-45.4% while maintaining relatively low awareness-only rates of 30.4-37.9%.
2. **Implementation challenge practices** (16 practices): All other practices show substantially more farmers who have heard about them than are currently using them. These range from moderate challenges like IPM (42.2% awareness vs 34.0% implementation) to severe implementation barriers like biochar (62.4% awareness vs 4.3% implementation) and terraces (72.9% awareness vs 6.4% implementation).

Age-related implementation patterns

Implementation success varies significantly across farmer age groups:

Age Group	Heard About Only Rate	Currently Using Rate
Below 30	61.7%	18.5%
From 30-39	57.3%	19.9%
From 40-49	53.5%	23.1%
From 50-64	56.1%	23.2%
65 or over	51.5%	17.2%

Table 16 Awareness and implementation patterns of sustainable practices by farmer age group among survey participants

Older farmers demonstrate higher implementation rates, with farmers aged 50-64 showing the highest implementation success (23.2%) and farmers aged 40-49 following closely (23.1%). Younger farmers, despite having the highest awareness-only rates (61.7% for below 30, 57.3% for 30-39), show significantly lower implementation rates (18.5% and 19.9% respectively). This pattern suggests that while younger farmers are more likely to have heard about sustainable practices, they face greater barriers to implementation, likely related to resource constraints, experience limitations, and access to capital.

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Geographic implementation patterns

Substantial differences exist in implementation success across the participating countries:

Country	Heard About Only Rate	Currently Using Rate
Germany	49.0%	36.2%
Austria	53.9%	31.2%
Slovak Republic	51.3%	29.0%
Poland	57.6%	22.9%
Italy	57.3%	20.0%
Spain	51.7%	18.0%
Hungary	62.9%	16.7%
Slovenia	59.4%	14.8%
Bulgaria	56.9%	10.0%

Table 17 Awareness and implementation patterns of sustainable practices by country among survey participants

Among countries three distinct groups emerge:

Higher implementation countries: Germany (36.2%), Austria (31.2%) and Slovak Republic (29.0%) demonstrate relatively successful conversion from awareness to implementation, with Germany showing the most balanced pattern of moderate awareness-only rates (49.0%) and highest implementation rates among our surveyed population.

Moderate implementation countries: Poland (22.9%), Italy (20.0%) and Spain (18.0%) show moderate implementation rates with awareness-only rates ranging from 51.7% to 57.6%.

Lower implementation countries: Hungary (16.7%), Slovenia (14.8%) and Bulgaria (10.0%) show the greatest implementation challenges despite high awareness-only rates (56.9-62.9%), indicating substantial barriers to converting knowledge into practice.

Practice-specific implementation analysis

Successfully implemented practices

The four practices achieving Implementation > or ≈ Awareness patterns share common characteristics that enable successful adoption:

Traditional soil management practices:

- Cover crops
- Minimum tillage
- Liming
- Mulching

These practices benefit from established knowledge networks, proven economic returns, relatively straightforward implementation requirements and compatibility with existing farming systems. They represent the most mature and accessible sustainable soil management approaches.

Implementation-challenged practices

Practices showing large awareness-implementation differences face distinct barrier types:

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Infrastructure-intensive practices:

- Terraces
- Agroforestry
- Water harvesting
- Drainage system

These require significant capital investment, long-term commitment and substantial changes to farm infrastructure, creating major barriers despite high awareness.

Emerging technologies:

- Biochar
- PA digital soil mapping
- PA site-specific management

These face barriers related to high costs, technical complexity, uncertain return on investment, and limited availability of technical support.

Specialized management systems:

- Rotational grazing
- Non-rotational grazing
- Livestock integration

These require specific livestock management expertise and infrastructure that many crop-focused operations lack.

Complex management practices:

- Intercropping
- IPM
- Microbiological products
- Buffer strips
- Contour farming
- Bush and tree fallows

These face implementation barriers related to increased management complexity, additional inputs, specialized knowledge requirements, or land use changes.

Implications for extension and policy

Shift focus from awareness to implementation support

The analysis reveals that awareness is not the primary constraint for sustainable practice adoption. Even the most challenging practices show substantial awareness levels (42-73% awareness-only rates), while implementation rates remain low (4-45%). Extension and policy efforts should prioritize addressing implementation barriers:

- **Build on successful models**: The four practices showing successful implementation patterns (cover crops, minimum tillage, liming, mulching) demonstrate that barriers can be overcome. These should serve as models for understanding successful implementation pathways and scaling proven approaches.
- **Target specific implementation barriers**: Different practice categories require tailored support strategies:
    - Infrastructure-intensive practices need long-term financial support and investment mechanisms
    - Emerging technologies require cost reduction, technical training, and demonstration of economic viability

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- Specialized management systems need expertise development and equipment access
- Complex management practices require simplified implementation pathways and decision support tools

Age-targeted implementation strategies

- **Support older farmers (40-64)** as implementation leaders: With the highest implementation rates (23.1-23.2%), they should be supported as mentors, demonstration hosts and knowledge bridges to younger farmers.
- **Address young farmer barriers (under 40)**: Despite high awareness (57-62%), they show low implementation (18-20%). Targeted support should include:
  - Access to startup capital and equipment
  - Risk-sharing mechanisms for practice adoption
  - Mentorship programs with successful implementers
  - Simplified implementation pathways

Geographic implementation support

- **Learn from higher-performing countries**: Germany, Austria and Slovak Republic should serve as models for policy frameworks and support mechanisms that can be adapted to other contexts.
- **Address country-specific barriers**: Lower-performing countries (Hungary, Slovenia, Bulgaria) require comprehensive assessment of implementation barriers and development of targeted support mechanisms.

Practice-specific policy recommendations

- **Mainstream successful practices**: Focus resources on scaling and optimizing the four successfully implemented practices as entry points for broader sustainable agriculture adoption.
- **Targeted support for challenge practices**: Develop practice-specific interventions:
  - Infrastructure grants and long-term financing for terraces, agroforestry, water harvesting
  - Technology access programs and cost-sharing for precision agriculture and biochar
  - Cooperative approaches and shared resources for livestock integration and grazing systems
  - Technical assistance and simplified protocols for complex management practices

Conclusions

This analysis reveals a substantial implementation challenge in sustainable soil management, with only four out of twenty practices achieving implementation rates that exceed awareness-only rates. While 42-73% of farmers have heard about various sustainable practices, implementation rates remain low across most approaches (4-45%), indicating that awareness building alone is insufficient to drive widespread adoption.

The success of cover crops, minimum tillage, liming and mulching demonstrates that implementation challenges can be overcome when appropriate conditions exist. These practices achieve implementation rates of 39.6-45.4% while maintaining relatively low awareness-only rates, suggesting effective pathways from knowledge to action.

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The analysis shows that sustainable practice adoption requires systematic attention to implementation barriers rather than continued focus on awareness building. Most practices face substantial barriers including capital requirements, technical complexity, management demands and infrastructure needs that prevent farmers from moving from awareness to implementation.

Age patterns reveal that older, more experienced farmers achieve higher implementation rates, suggesting the importance of experience, resources and established farming systems in enabling practice adoption. Geographic variations indicate that policy environments, economic conditions and support systems significantly influence implementation success.

Moving forward, extension services and agricultural policies should prioritize addressing specific implementation barriers through targeted interventions that recognize the diverse challenges faced by different practices, age groups and geographic contexts. Success will require coordinated efforts involving financial support mechanisms, technical assistance programs and institutional changes that reduce barriers to implementation while building on the knowledge foundation that has created widespread awareness of sustainable soil management practices.

Farmers experience with the reported sustainable management practices (Q12)

At this point of the survey, we wanted to establish clear connections between specific sustainable soil management practices and the corresponding drivers and barriers experienced by participating farmers. Therefore, we asked surveyed respondents to identify and name a sustainable soil management practice or combination of practices (holistic approach) with which they had the most direct experience. This allowed us to correlate reported drivers and barriers with specific farming methods that participants were actively implementing. By requesting that surveyed respondents reference the definitions provided in the previous question, we ensured terminological consistency across responses. This approach facilitated more precise data analysis and enabled us to develop understanding of how different sustainable soil management practices are experienced and perceived by practitioners in real-world agricultural contexts among participants.

To analyse the free text responses regarding sustainable soil management practices, we employed a systematic keyword-based categorization approach. The process began with text standardization, converting all responses to lowercase and removing punctuation to ensure consistent analysis of variations like "no-till" and "no till." We created a dictionary of sustainable farming practices as category keys, with each practice associated with multiple related keywords and phrases that farmers might use in their descriptions. Using pattern matching, we identified which practices were mentioned in each response, with the system designed to recognize multiple practices within a single response. This methodology successfully categorized the responses, allowing us to quantitatively analyse qualitative data while accommodating natural language variations in farmers' descriptions of their sustainable soil management approaches.

EU level results

Top 3 practices at EU level among participants:

1. Minimum tillage: 86 mentions (32.7%)
2. Cover crops: 73 mentions (27.8%)
3. Precision agriculture: 36 mentions (13.7%)

Country level results

Analysis by country reveals regional variations in practice preferences among the survey respondents:

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Country	Rank 1	Rank 2	Rank 3
Austria	Cover Crops (48.7%)	Minimum Tillage (35.9%)	Intercropping (20.5%)
Bulgaria	Minimum Tillage (33.3%)	Precision Agriculture (26.7%)	Mulching (20.0%)
Germany	Minimum Tillage (52.9%)	Cover Crops (17.6%)	Mulching (14.7%)
Hungary	Minimum Tillage (46.3%)	Precision Agriculture (24.4%)	Cover Crops (17.1%)
Italy	Minimum Tillage (45.5%)	Cover Crops (31.8%)	Intercropping (13.6%)
Poland	Cover Crops (42.9%)	Minimum Tillage (14.3%)	Liming (10.7%)
Slovak Republic	Precision Agriculture (29.0%)	Cover Crops (22.6%)	Minimum Tillage (16.1%)
Slovenia	Minimum Tillage (32.0%)	Cover Crops (28.0%)	Liming 20.0%)
Spain	Cover Crops (30.4%)	Minimum Tillage (8.7%)	IPM (8.7%)

Table 18 Most frequently mentioned implemented sustainable practices by country among survey respondents

Key observations

1. **Minimum tillage dominance**: Minimum tillage appears as one of the top three practices in all countries, indicating broad acceptance of this conservation agriculture technique.
2. **Cover crops prevalence**: Cover crops are widely practiced throughout the represented EU countries, appearing in the top three for all countries.
3. **Regional variations**: Precision agriculture features prominently in Slovak Republic, Hungary and Bulgaria, while intercropping appears in the top three for Austria and Italy.

This analysis shows that while there are regional differences in preferred sustainable soil management practices across EU countries represented in our sample, minimum tillage and cover crops form the backbone of sustainable farming approaches among participants across the region. Precision agriculture emerges as the third most significant practice at the EU level, with particular strength in Eastern European countries like Slovak Republic and Hungary among participants.

Analysis of drivers for sustainable soil management practices adoption (Q13)

As the next step, we have asked the participating farmers about the drivers that impacted their adoption of the applied sustainable soil management practice(s) among surveyed respondents. Multiple answers were possible. We've identified the most common and least mentioned drivers impacting farmers' adoption at both EU and country levels by implementing a multi-step mixed methods approach combining quantitative frequency analysis with qualitative categorization. This analytical approach accommodated multiple-response selection, enabled comparative analysis across regions and revealed how driver importance varies by practice type among participants, providing robust insights into what motivates farmers to adopt sustainable soil management practices.

EU level driver analysis

Driver Category	EU Level Selections	Percentage of Respondents
Economic factors	168	63.2%
Environmental Concerns	164	61.7%
Farmers' Values and Beliefs	109	41.0%
Risk Management and Resilience	84	31.6%
Policy and Regulatory Support	64	24.1%
Access to Knowledge and Extension Services	61	22.9%
Community and Social Networks	27	10.2%
Market Demand and Consumer Preferences	24	9.0%

Table 19 Frequency of reported drivers for implementing sustainable soil management practices among survey respondents

The table above presents the frequency of each driver category selected by surveyed respondents across the EU. Economic factors and environmental concerns emerge as the primary motivators among participants, selected by approximately 63.2% and 61.7% of respondents respectively. This suggests that farmers are nearly equally motivated by financial considerations and environmental stewardship when adopting sustainable soil management practices among participants. The significant gap between these top two drivers and other categories such as community and social networks (10.2%) and market demand (9.0%) highlights the dominance of economic and environmental motivations in farmers' decision-making processes among surveyed respondents.

Country level driver analysis

Country	Top Driver	2nd Driver	3rd Driver
Austria	Economic Factors (71.8%)	Environmental Concerns (66.7%)	Risk Management (56.4%)
Bulgaria	Economic Factors (53.3%)	Environmental Concerns (53.3%)	Farmers' Values (33.3%)
Germany	Environmental Concerns (63.9%)	Economic Factors (58.3%)	Risk Management (52.8%)
Hungary	Economic Factors (61.9%)	Environmental Concerns (54.8%)	Farmers' Values (40.5%)
Italy	Environmental Concerns (72.7%)	Economic Factors (63.6%)	Farmers' Values (22.7%)

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Country	Top Driver	2nd Driver	3rd Driver
Poland	Economic Factors (71.4%)	Environmental Concerns (57.1%)	Farmers' Values (32.1%)
Slovak Republic	Farmers' Values (74.2%)	Economic Factors (67.7%)	Environmental Concerns (64.5%)
Slovenia	Economic Factors (56.0%)	Environmental Concerns (48.0%)	Access to Knowledge (36.0%)
Spain	Environmental Concerns (73.9%)	Economic Factors (69.6%)	Access to Knowledge (34.8%)

Table 20 Top three drivers for sustainable practice implementation by country among survey respondents

Drivers by farming method

The analysis by farming method further demonstrates that organic farmers among participants are significantly more motivated by environmental concerns (79.3%) compared to conventional farmers (53.1%), while economic motivations remain relatively consistent across both groups among surveyed respondents.

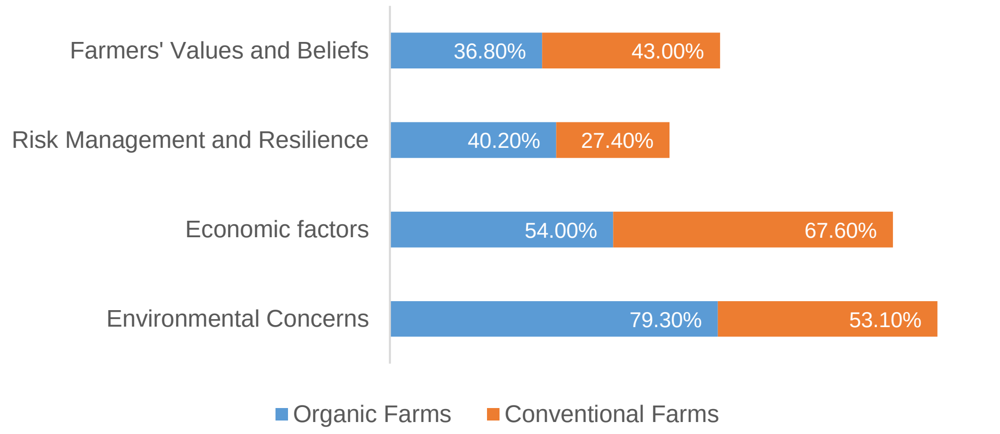

Figure 11 Drivers for sustainable practice adoption: comparison between organic and conventional farmers among survey respondents

Key insights

1. **Economic and environmental balance**: Across most countries and practices, economic factors and environmental concerns consistently rank in the top two positions, suggesting that successful sustainable soil management must address both economic viability and environmental stewardship.
2. **Regional variations**: In Western and Southern European countries (Germany, Spain, Italy), environmental concerns often outrank economic factors. In Eastern European countries (Bulgaria, Hungary, Poland), economic factors tend to be the primary driver. Slovak Republic is unique with farmers' values and beliefs as the top driver (74.2%).

Consistently low-ranked drivers: Market demand and consumer preferences rarely serve as a primary motivator. Community and social networks have minimal influence across most countries.

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Benefits from sustainable soil management practices (Q14)

Similar to the drivers, we have asked the participating farmers about their benefits of applying the reported practice(s) among surveyed respondents. Multiple answers were possible.

The benefits analysis examines what outcomes participating farmers actually experience after implementing sustainable soil management practices. The high frequency of environmental benefits among participants, particularly improved soil health (85.7%), suggests that sustainable practices consistently deliver ecological improvements regardless of farmers' initial motivations among surveyed respondents.

We have identified the most common and least mentioned benefits at both EU and country levels.

Top 5 benefits at EU level among participants (266 responses)

- Improved soil health: 228 mentions (85.7%)
- Reduced soil erosion: 178 mentions (66.9%)
- Biodiversity conservation: 158 mentions (59.4%)
- Water conservation: 149 mentions (56.0%)
- Climate change mitigation: 124 mentions (46.6%)

3 Least chosen benefits at EU level

- Enhanced crop yields and increased profitability: 1 mention (0.4%)
- Social advantages: 17 mentions (6.4%)
- Better market position: 19 mentions (7.1%)

Country	#1 Benefit	#2 Benefit	#3 Benefit
Austria	Improved Soil Health (92.3%)	Reduced Soil Erosion (92.3%)	Biodiversity Conservation (92.3%)
Bulgaria	Reduced Soil Erosion (80.0%)	Improved Soil Health (66.7%)	Biodiversity Conservation (66.7%)
Germany	Improved Soil Health (83.3%)	Reduced Soil Erosion (69.4%)	Resilient Agriculture Systems (69.4%)
Hungary	Improved Soil Health (85.7%)	Biodiversity Conservation (47.6%)	Increased Profitability (45.2%)
Italy	Improved Soil Health (95.5%)	Water Conservation (63.6%)	Economic Benefits (59.1%)
Poland	Improved Soil Health (85.7%)	Reduced Soil Erosion (75.0%)	Economic Benefits (64.3%)
Slovak Republic	Improved Soil Health (87.1%)	Water Conservation (67.7%)	Reduced Soil Erosion (64.5%)
Slovenia	Improved Soil Health (80.0%)	Climate Change Mitigation (72.0%)	Water Conservation (68.0%)
Spain	Improved Soil Health (87.0%)	Reduced Soil Erosion (78.3%)	Biodiversity Conservation (65.2%)

Table 21 Top three reported benefits of sustainable practice implementation by country among survey respondents

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Benefits by practice type

Minimum tillage - Top 5 benefits

1. Improved soil health: 79 mentions
2. Reduced soil erosion: 67 mentions
3. Water conservation: 52 mentions
4. Biodiversity conservation: 49 mentions
5. Increased profitability: 48 mentions

Cover crops - Top 5 benefits

1. Improved soil health: 66 mentions
2. Reduced soil erosion: 57 mentions
3. Biodiversity conservation: 44 mentions
4. Water conservation: 42 mentions
5. Climate change mitigation: 32 mentions

Precision agriculture - Top 5 benefits

1. Improved soil health: 28 mentions
2. Reduced environmental pollution: 24 mentions
3. Biodiversity conservation: 19 mentions
4. Water conservation: 18 mentions (tied with Enhanced Crop Yields)
5. Enhanced crop yields: 18 mentions

Key insights from the benefits analysis

Environmental benefits dominate: Participating farmers across represented EU countries primarily perceive environmental benefits as the most valuable outcomes from sustainable soil management practices. The top five benefits are all environmental in nature, with improved soil health being universally recognized (85.7% of farmers).

Consistency across countries: Improved soil health ranks as the #1 benefit in 8 of 9 countries (only Bulgaria differs). All countries have at least 2 environmental benefits in their top 3, showing remarkable consistency across different European contexts.

Practice-specific benefit profiles: Different practices show distinct benefit profiles - minimum tillage shows stronger association with water conservation and profitability, cover crops link more strongly to climate change mitigation, and precision agriculture uniquely emphasizes reduced environmental pollution and enhanced crop yields.

Limited economic emphasis: Economic benefits like "Increased Profitability" (44.4%) and "Economic Benefits" (41.4%) were reported less frequently than environmental benefits, suggesting participating farmers may value ecological sustainability over immediate economic returns, though economic considerations appear among the top expected benefits in countries like Germany, Poland and Spain.

Conclusion

This analysis highlights the complex motivations behind sustainable soil management and the diverse benefits participating farmers experience. While economic and environmental factors drive adoption among participants, environmental benefits are the most frequently reported across all farm types and regions among surveyed respondents. The consistent recognition of economic benefits supports their financial viability, particularly for larger farms among participants. For policymakers, these findings suggest that integrating both economic and environmental considerations into outreach and support programs will likely maximize adoption rates among similar farming

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communities. Recognizing regional differences and farm-specific characteristics will further enhance the effectiveness of sustainable agriculture initiatives among participants.

Cost-benefit analysis of sustainable soil management practices (Q15)

We surveyed participating farmers to evaluate how the benefits of their chosen soil management practices compare with the associated costs. Farmers assessed ecological benefits (soil health, preservation, quality) and economic benefits (cost savings, increased yields) against direct costs (financial investments) and indirect costs (labour, time commitment). Farmers rated their experiences on a 3-point scale: 1-Negative, 2-Neutral, 3-Positive.

Overall rating analysis

Our analysis (based on 206 valid answers) reveals that participating farmers generally perceive sustainable soil management practices positively, with ecological benefits consistently rated more favourably than economic returns.

Aspect	Average Rating	Positive Ratings	Neutral Ratings	Negative Ratings
Direct costs vs. Ecological benefits	2.51	61.8%	27.5%	10.7%
Direct costs vs. Economic benefits	2.33	48.9%	35.1%	16.0%
Indirect costs vs. Ecological benefits	2.28	48.7%	30.8%	20.5%
Indirect costs vs. Economic benefits	2.25	45.0%	34.8%	20.2%

Table 22 Cost-benefit assessment of sustainable practices among survey participants (rating of ecological and economic benefits relative to direct and indirect costs)

Key findings:

- Nearly 62% of farmers report positive ecological outcomes relative to their financial investments
- Economic returns show more mixed perceptions, with less than half (48.9%) reporting positive outcomes
- When considering labour and time investments, satisfaction levels decrease further
- Ecological benefits are consistently rated more favourably than economic benefits

Practice-specific patterns

Different sustainable soil practices show distinct patterns in their perceived benefits relative to costs:

Practice Type	Direct Costs vs. Ecological benefits	Direct Costs vs. Economic benefits	Indirect Costs vs. Ecological benefits	Indirect Costs vs. Economic benefits
Minimum Tillage	2.64	2.41	2.23	2.18

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Practice Type	Direct Costs vs. Ecological benefits	Direct Costs vs. Economic benefits	Indirect Costs vs. Ecological benefits	Indirect Costs vs. Economic benefits
Cover Crops	2.58	2.31	2.27	2.08
Precision Agriculture	2.36	2.47	2.14	2.31

Table 23 Cost-benefit ratings for the three most commonly implemented sustainable practices among survey participants

Key observations:

- Minimum tillage provides the strongest ecological benefits relative to financial investment (2.64)
- Precision agriculture is unique in delivering better economic (2.47) than ecological (2.36) returns on financial investment
- Cover crops face challenges in economic returns relative to labour inputs (2.08)

Regional and structural variations

Regional patterns:

- Southern European countries demonstrate particularly strong ecological benefits: Spain (2.85) and Italy (2.75) report high ecological returns relative to financial investments
- Germany shows the strongest economic returns on financial investment (2.56)
- Slovenia consistently reports the lowest ratings across multiple categories

Farm size patterns:

- Small farms (<5 ha) report exceptionally strong ecological benefits relative to both financial (2.60) and labour inputs (2.45)
- Medium-large farms (251-500 ha) are unique in rating economic benefits (2.46) higher than ecological benefits (2.37) relative to financial investment
- Mid-sized farms (51-100 ha) show the most balanced and consistently positive ratings across all aspects

Farming method differences:

- Organic farms demonstrate significantly stronger ecological benefits (2.66) than conventional farms (2.46)
- Conventional farms show slightly better economic returns relative to labour inputs (2.26 vs. 2.18)

Key insights and implications

1. **Positive overall assessment**: Participating farmers generally perceive that the benefits of sustainable soil management practices outweigh their costs, with consistently positive ratings across different segments.
2. **Ecological-economic gap**: Environmental benefits are consistently rated more favourably than economic returns, suggesting that ecological improvements are more readily observed or valued than financial gains.
3. **Indirect cost challenges**: Benefits relative to direct costs (financial investments) are consistently rated more favourably than benefits relative to indirect costs (labour, time),

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identifying time and labour requirements as more significant adoption barriers than financial investment.
4. **Context-specific effectiveness**: Significant differences exist across countries, farm sizes and farming methods, indicating that context matters substantially in the success of sustainable soil management practices.

This analysis provides evidence that sustainable soil management practices are generally viewed as worthwhile investments among the surveyed population, though specific circumstances significantly influence outcomes. The findings highlight the importance of addressing labour and time requirements as key barriers to adoption and suggest that different practices offer distinct advantages that can be leveraged in targeted promotion efforts.

Effectiveness and impacts of sustainable management practices (Q16-17-18)

With below questions, we aimed to explore participating farmers' perceptions of the effectiveness of their implemented soil management practices, the specific positive effects they have experienced and any negative consequences they have encountered among surveyed respondents.

Effectiveness Assessment (Q16): How effective is/are the practice(s) you used regarding soil health? (Not effective, Neutral, Effective, I do not know)

Positive Effects (Q17): Please explain the positive effect of the chosen applied practice(s) you experienced on soil health. (Free text response)

Negative Consequences (Q18): Have you identified any negative consequences in general and regarding soil health of applying such practice(s)? Please explain the negative effects you experienced. (Free text response for both general negative consequences and soil-specific negative consequences)

The analysis employed a mixed-methods approach combining quantitative assessment of effectiveness ratings with qualitative thematic analysis of farmers' descriptions of positive and negative effects among participants. For the effectiveness ratings (Q16), we calculated simple frequency distributions for the entire sample and across different farming contexts (farming method, farm size, region) among participants. For the qualitative free text responses regarding positive effects (Q17), we employed a systematic thematic analysis approach:

1. Text pre-processing to standardize and clean farmer responses
2. Theme dictionary creation based on recurring concepts in the responses among participants
3. Automated theme extraction using keyword identification
4. Theme frequency analysis to quantify prevalence of different benefits among participants
5. Benefit clustering to identify patterns of co-occurring benefits among participants
6. Cross-correlation analysis to examine relationships between benefits and farming contexts among participants

For the negative consequences responses (Q18), we employed a similar thematic approach, identifying recurring challenges and categorizing them into distinct types of negative impacts among participants.

Effectiveness of sustainable practices on soil health

The vast majority of participating farmers (82%) reported that their sustainable practices were effective for improving soil health among surveyed respondents. Only one respondent rated their practice as "Not effective," indicating that farmers are generally selecting and implementing practices that deliver positive outcomes among participants.

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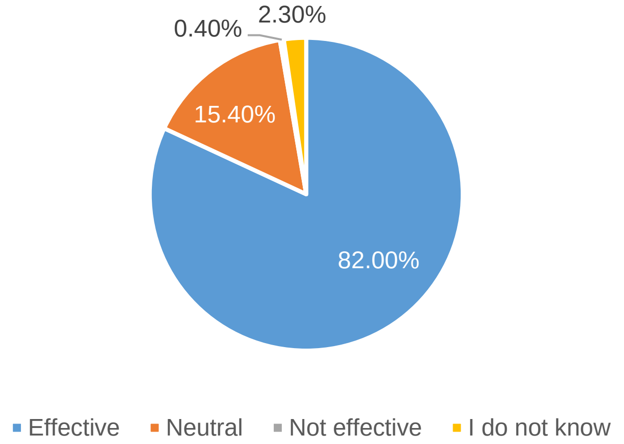

Figure 12 Farmer-reported effectiveness of sustainable practices for improving soil health among survey participants

When examining effectiveness ratings across different farming contexts among participants, we observed consistent patterns of high satisfaction:

Farming Method	Effective	Neutral	Not Effective	Don't Know
Organic	82.8%	14.9%	0.0%	2.3%
Conventional	81.6%	15.7%	0.5%	2.2%

Table 24 Effectiveness ratings of sustainable practices for soil health by farming method among survey participants

Both organic and conventional farmers among participants reported similarly high effectiveness rates, with organic farmers showing a slightly higher proportion of "Effective" ratings (82.8% vs. 81.6% for conventional) among surveyed respondents. This suggests that sustainable soil management practices can be successfully implemented within both farming systems among participants.

Farm Size	Effective	Neutral	Not Effective	Don't Know
<5 ha	88.2%	8.8%	0.0%	2.9%
6-50 ha	79.3%	17.2%	0.0%	3.4%
51-100 ha	84.0%	12.0%	0.0%	4.0%
101-250 ha	82.5%	15.0%	0.0%	2.5%
251-500 ha	76.9%	23.1%	0.0%	0.0%
>500 ha	82.1%	15.4%	2.6%	0.0%

Table 25 Effectiveness ratings of sustainable practices for soil health by farm size among survey participants

Small farms (less than 5 ha) among participants reported the highest effectiveness ratings (88.2%), while medium-large farms (251-500 ha) showed the lowest proportion of "Effective" ratings (76.9%) among participants, though this is still a strong majority. The only "Not effective" rating came from a

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farm in the largest size category (more than 500 ha) among participants, potentially reflecting implementation challenges at very large scales.

Country-level effectiveness analysis

Analysis of effectiveness ratings at the country level reveals variations while maintaining consistently high satisfaction rates across most countries among participants:

Country	Effective (%)	Neutral (%)	Not Effective (%)	Don't Know (%)
Germany	88.9%	11.1%	0.0%	0.0%
Spain	87.0%	8.7%	0.0%	4.3%
Slovenia	84.0%	16.0%	0.0%	0.0%
Hungary	83.3%	14.3%	0.0%	2.4%
Austria	82.1%	15.4%	0.0%	2.6%
Italy	81.8%	13.6%	0.0%	4.5%
Bulgaria	80.0%	13.3%	0.0%	6.7%
Slovak Republic	77.4%	19.4%	0.0%	3.2%
Poland	75.0%	21.4%	0.0%	3.6%

Table 26 Effectiveness ratings of sustainable practices for soil health by country among survey participants

Observations from the country-level analysis among participants:

Germany shows the highest effectiveness rating among countries (88.9% "Effective") among participants, followed by Spain (87.0%) and Slovenia (84.0%). Poland shows the lowest proportion of "Effective" ratings (75.0%) among participants, though this still represents a strong majority of respondents finding their practices effective. No country (with substantial sample size) reported practices as "Not effective" among participants, suggesting that sustainable soil management approaches are broadly successful across different European contexts represented in our sample.

Positive effects of soil management practices

Thematic analysis of participating farmers' descriptions of positive effects revealed a diverse range of benefits across multiple dimensions of soil health among surveyed respondents. Below table presents the frequency of each identified benefit theme:

Benefit Theme	Mention Frequency	Percentage of Responses
Overall Soil Health Improvement	73	38.2%
Water Management Benefits	56	29.3%
Soil Biology Enhancement	45	23.6%
Soil Structure Improvements	40	20.9%
Organic Matter Increases	39	20.4%
Erosion Prevention	37	19.4%
Yield Improvements	24	12.6%

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Benefit Theme	Mention Frequency	Percentage of Responses
Soil Fertility Enhancement	23	12.0%
Pest Management Benefits	22	11.5%

Table 27 Frequency of reported positive effects of sustainable practices on soil health among survey participants

The most frequently mentioned positive effects among participants focused on general soil health improvements (38.2%), enhanced water management (29.3%) and increased biological activity (23.6%). These core benefits represent fundamental soil health improvements that farmers appear to value most highly among participants. In contrast, more production-focused benefits such as yield improvements (12.6%) and pest management (11.5%) were mentioned less frequently among participants, suggesting that farmers may prioritize soil system health over immediate productivity gains.

Country-specific positive effects analysis

Analysis of reported positive effects at the country level reveals distinctive patterns in what farmers value most across different European contexts among participants:

Country	Primary Benefit	Secondary Benefit	Tertiary Benefit
Austria	Soil Biology (34.4%)	Soil Health (31.3%)	Water Management (28.1%)
Germany	Soil Health (42.9%)	Erosion Prevention (32.1%)	Soil Structure (28.6%)
Hungary	Soil Health (40.7%)	Water Management (33.3%)	Soil Structure (22.2%)
Italy	Soil Health (46.2%)	Water Management (30.8%)	Organic Matter (23.1%)
Poland	Water Management (36.8%)	Soil Health (31.6%)	Soil Biology (21.1%)
Slovak Republic	Soil Health (35.7%)	Erosion Prevention (28.6%)	Organic Matter (25.0%)
Slovenia	Soil Health 38.9%)	Water Management (33.3%)	Soil Structure (27.8%)
Spain	Water Management (44.4%)	Soil Health (38.9%)	Erosion Prevention (27.8%)
Bulgaria	Soil Fertility (37.5%)	Soil Health (25.0%)	Water Management (25.0%)

Table 28 Top three reported positive effects of sustainable practices on soil health by country among survey participants

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This country-level analysis reveals several distinctive patterns among participants:

- Soil health appears as either the primary or secondary benefit in all countries among participants, indicating its universal importance.
- Water management is particularly emphasized in Spain and Poland among participants, possibly reflecting specific water scarcity or management challenges in these regions.
- Soil biology is uniquely emphasized in Austria among participants, where it ranks as the top benefit.
- Soil fertility stands out as the primary benefit in Bulgaria among participants, unlike other countries where it typically ranks lower.

These country-specific patterns likely reflect different agricultural challenges, soil types, climatic conditions and policy environments across Europe among participants.

Negative consequences of soil management practices

While most participating farmers reported positive outcomes, our analysis also identified several challenges and negative consequences associated with implementing sustainable practices among surveyed respondents. Thematic analysis of responses to Q18 revealed five main categories of negative consequences:

Negative Consequence Category	Mention Frequency	Percentage of Responses
Implementation Challenges	42	21.9%
Short-term Yield Impacts	35	18.2%
Financial Constraints	28	14.6%
Technical Limitations	19	9.9%
Unintended Ecological Effects	15	7.8%
No Negative Consequences	53	27.6%

Table 29 Frequency of reported negative consequences of sustainable practice implementation among survey participants

Notably, more than a quarter of participating farmers (27.6%) explicitly reported experiencing no negative consequences from their implemented practices among surveyed respondents. Among those who did report challenges among participants, implementation difficulties were most common (21.9%), followed by short-term negative impacts on yield (18.2%) and financial constraints (14.6%).

Country-level analysis of negative consequences

The distribution of negative consequences varies across countries among participants, reflecting different implementation challenges in various agricultural contexts:

Country	Primary Challenge	Secondary Challenge	% reporting No Negatives*
Austria	Implementation (28.6%)	Short-term Yield (21.4%)	33.3%
Germany	Short-term Yield (25.0%)	Implementation (16.7%)	30.6%
Hungary	Implementation (25.6%)	Financial (20.9%)	25.6%
Italy	Technical Limitations (20.0%)	Implementation (15.0%)	30.0%

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Country	Primary Challenge	Secondary Challenge	% reporting No Negatives*
Poland	Financial (25.0%)	Implementation (18.8%)	21.9%
Slovak Republic	Implementation (21.7%)	Short-term Yield (19.6%)	26.1%
Slovenia	Financial (24.1%)	Implementation (17.2%)	27.6%
Spain	Implementation (20.0%)	Ecological Effects (15.0%)	30.0%
Bulgaria	Financial (33.3%)	Implementation (25.0%)	16.7%

**Percentages are calculated based on the total negative consequences reported per country.*

Table 30 Most frequently reported negative consequences of sustainable practice implementation by country among survey participants

This country-level analysis reveals several distinctive patterns among participants:

- Implementation challenges appear as either the primary or secondary challenge in all countries among participants, suggesting universal practical hurdles regardless of context.
- Financial constraints are particularly prominent in Bulgaria, Poland and Slovenia among participants, possibly reflecting economic considerations in these regions.
- Technical limitations stand out in Italy among participants, unlike other countries where they typically rank lower.
- Austria shows the highest percentage of farmers reporting no negative consequences (33.3%) among participants.
- Bulgaria shows the lowest percentage of farmers reporting no negative consequences (16.7%) among participants.

These country-specific patterns likely reflect different resource availability, technological access, economic conditions and agricultural systems across Europe among participants.

Key findings

High overall effectiveness: The overwhelming majority of participating farmers (82%) find their sustainable soil management practices effective among surveyed respondents, indicating strong real-world validation of these approaches across diverse European countries represented in our sample.

Benefit clusters: Benefits typically manifest in interconnected clusters rather than as isolated improvements among participants, with soil health, structure and biological activity forming the strongest benefit clusters. This suggests that successful practices deliver multiple synergistic advantages among participants.

Country-specific patterns: Clear country-level patterns emerge in both benefits and challenges among participants. Austrian farmers uniquely emphasize soil biology benefits among participants; Spanish farmers focus primarily on water management among participants; Bulgarian farmers uniquely emphasize soil fertility and face more financial constraints than farmers in other countries among participants.

Implementation challenges: The most common negative consequences relate to implementation difficulties (21.9%) among participants, particularly increased labor requirements and equipment limitations. These practical challenges represent important barriers to wider adoption among participants.

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Transition period issues: Many reported negative consequences are described as temporary among participants, particularly yield decreases during initial implementation years. This highlights the importance of supporting farmers through transition periods among participants.

Practical implications

These findings among participants suggest several important considerations for promoting sustainable soil management practices among similar farming communities:

Country-specific approach: Support programs should be tailored to address the specific challenges and leverage the particular benefits most valued in each country among participants, rather than applying uniform approaches across Europe.

Expectation management: Farmers should be prepared for potential short-term yield impacts and implementation challenges during transition periods. Support programs should address these temporary issues to improve adoption rates among participants.

Benefit communication: When promoting sustainable soil practices, communication should emphasize the multiple interconnected benefits that farmers can expect among participants, particularly the fundamental soil improvements that form the strongest benefit clusters.

Long-term perspective: The relatively lower reporting of economic benefits (5.0% cluster strength) despite high effectiveness ratings among participants suggests that many valuable soil health benefits take time to translate into economic returns. Policy support should therefore encourage long-term commitment to sustainable practices among participants.

Conclusion

This country-level analysis of participating farmers' experiences with sustainable soil management practices reveals a positive overall assessment, with the vast majority finding their practices effective for improving soil health among surveyed respondents. The rich diversity of reported benefits among participants, clustered around soil health, structure and biological activity, demonstrates the multidimensional value of these practices. While challenges exist among participants, particularly related to implementation and transition periods, they are generally outweighed by the positive outcomes. The distinct country-specific patterns identified in both benefits and challenges among participants highlight the importance of tailored approaches to supporting sustainable soil management. These findings provide valuable guidance for agricultural advisors, policymakers and farmers themselves in selecting, implementing and supporting practices that deliver the most relevant benefits while minimizing challenges for specific farming contexts in different European countries represented in our sample. By understanding these real-world experiences among participants, we can better facilitate the wider adoption of sustainable soil management practices across European agriculture represented in our sample.

Practice abandonment: patterns, duration and reasons (Q19-21)

This section analyses responses to three key questions regarding practice abandonment:

1. Practice Identification (Q19): "Which practice(s) did you apply but decided to quit?"
2. Usage Duration (Q20): "How long did you use this/these practice(s)?"
3. Abandonment Reasons (Q21): "What was your main reason to quit?"

These questions help identify not only which practices pose the greatest implementation challenges among participants, but also how long farmers typically persevere before abandonment and the specific factors that drive their decisions to discontinue among surveyed respondents. This analysis

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provides valuable insights for improving practice design, implementation support and policy interventions to enhance sustainable soil management adoption among participants.

Our analysis employed a multi-step approach to understand abandonment patterns among participants:

1. **Abandonment rate calculation**: For each practice, we calculated the percentage of farmers who tried but subsequently abandoned the practice relative to all farmers who ever tried it among participants.
2. **Duration classification**: We categorized abandonment timeframes into four groups among participants: Very Short: Less than 1 year; Short: 1-2 years; Medium: 2-5 years; Long: More than 5 years
3. **Reason categorization**: We classified abandonment reasons into five primary categories among participants: 1) Environmental/Results Issues: Practice failed to deliver expected outcomes or created new problems; 2) Economic Factors: Cost concerns, labour demands, or insufficient economic returns; 3) Technical Challenges: Difficulties implementing or managing the practice; 4) Resource Limitations: Lack of time, knowledge, or support; 5) Other/Unknown: Miscellaneous or unspecified reasons

Overall abandonment patterns

Among the 266 participating farmers who reported having experience with sustainable practices, 95 (35.7%) indicated they had abandoned at least one practice among surveyed respondents. This substantial rate highlights the significant challenges farmers encounter in maintaining certain soil health approaches over time among participants.

Practice	Abandonment Instances	Percentage of Experienced Farmers
Minimum Tillage	19	7.1%
Microbiological Applications	8	3.0%
Cover Crops	7	2.6%
Direct Seeding	6	2.3%
Mulching	5	1.9%
Intercropping	3	1.1%

Table 31 Most frequently abandoned sustainable practices among survey participants (number of farmers who discontinued each practice)

Minimum tillage stands out as particularly challenging to maintain among participants, with abandonment rates more than twice as high as any other practice. This suggests that reduced tillage systems present specific implementation challenges that merit closer attention among participants. Microbiological applications and cover crops also show notable abandonment rates among participants, indicating areas where farmers may need additional support for successful long-term implementation.

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Duration analysis: How long before abandonment?

The duration analysis provides valuable insights into the timeframes during which participating farmers typically abandon practices among surveyed respondents. Among practices with clearly categorized durations (53 instances), surveyed farmers most frequently abandoned practices after specific time periods, as shown in below table:

Duration Category	Frequency	Percentage
Medium (2-5 years)	24	45.3%
Short (1-2 years)	18	34.0%
Long (>5 years)	10	18.9%
Very Short (<1 year)	1	1.9%

Table 32 Duration of practice use before abandonment among survey participants

This distribution reveals important patterns among the surveyed population:

1. The relatively low abandonment rate in the first year (1.9%) indicates most surveyed farmers persist through initial implementation challenges among participants.
2. The concentration of abandonments in the medium-term period (2-5 years, 45.3%) suggests that many challenges among he surveyed population emerge only after several growing seasons of experience among participants.
3. The substantial percentage of long-term abandonments (>5 years, 18.9%) indicates that even well-established practices may eventually be discontinued as circumstances change or cumulative limitations become apparent among participants.

Different practices showed distinct duration patterns before abandonment among participants, as illustrated in below table:

Practice	Most Common Abandonment Timeframe	Percentage Within This Duration
Minimum Tillage	Medium (2-5 years)	52.6%
Cover Crops	Short (1-2 years)	57.1%
Direct Seeding	Medium (2-5 years)	50.0%
Microbiological Applications	Variable	No clear pattern
Mulching	Long (>5 years)	60.0%

Table 33 Typical duration before abandonment for specific sustainable practices among survey participants

These patterns suggest that different challenges emerge at different stages for various practices among participants:

- Minimum tillage: Problems typically emerge after several growing seasons among participants, suggesting cumulative effects such as soil compaction or weed pressure that build over time.

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- Cover crops: Early abandonment indicates more immediate challenges among participants, possibly related to establishment difficulties, competition with main crops or initial cost-benefit considerations.
- Mulching: Long-term use before abandonment suggests that either circumstances change over time (e.g., labour availability, economic factors) or that benefits diminish relative to costs after extended periods among participants.

Reasons for abandonment

Analysis of participating farmers' stated reasons for abandoning practices revealed several primary drivers among surveyed respondents, as shown below:

Reason Category	Frequency	Percentage
Environmental/Results Issues	44	27.6%
Economic Factors	31	19.4%
Technical Challenges	11	6.1%
Resource Limitations	3	2.0%
Other/Miscellaneous	47	29.6%
Unknown	24	15.3%

Table 34 Primary reasons for abandoning sustainable practices among survey participants

The predominance of environmental/results issues (27.6%) indicates that many practices are abandoned not primarily due to cost or technical difficulties among participants, but because they fail to deliver expected outcomes or create new problems in farmers' specific contexts. Economic factors (19.4%) represent the second most common reason among participants, highlighting the importance of financial viability for long-term adoption.

Further analysis revealed distinct patterns in why specific practices were abandoned among participants:

Practice	Primary Reason	Percentage	Secondary Reason	Percentage
Minimum Tillage	Environmental/Results	52.6%	Technical Challenges	21.1%
Microbiological Applications	Effectiveness Concerns	50.0%	Economic Factors	25.0%
Cover Crops	Environmental/Results	57.1%	Economic Factors	28.6%
Direct Seeding	Environmental/Results	50.0%	Technical Challenges	33.3%
Mulching	Economic Factors	60.0%	Environmental Issues	20.0%
Intercropping	Technical Challenges	66.7%	Market Barriers	33.3%

Table 35 Main reasons for abandoning specific sustainable practices among survey participants

A deeper examination of the specific reasons within these categories reveals challenges for each practice among participants:

Minimum tillage abandonment reasons

Participating farmers who abandoned minimum tillage cited diverse specific issues documented in the survey data:

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Soil structure and function problems:

- "The soil collapses if all the nutrients, lime, etc. are not balanced, so it becomes more and more compacted and the rootable space becomes less and less. WITHOUT deep loosening, the soil quickly becomes depressed."
- "Lack of air and lack of mixing of nutrients in the 15cm range"
- "Consolidation of the unworked soil layers, especially in wet years"

Weed management challenges:

- "Weed pressure"
- "Persistent weed problems"

Yield concerns:

- "50 to 80% yield loss"
- "lower yield"

Contextual limitations:

- "It is not suitable for every crop"
- "Does not work (it is location-dependent!!!)"
- "Impractical on heavy soils"

Microbiological applications abandonment reasons

Participating farmers abandoning microbiological applications primarily reported effectiveness and cost concerns documented in the survey:

Effectiveness concerns:

- "No detectable effect"
- "No scientifically supported proof of effect"
- "I have not seen its effect. Tried several different products, no difference. I found no difference compared to the control."

Cost-benefit imbalance:

- "No scientifically supported proof of effect. Scientific tests show little to no effect of this measure. The biochar is simply too expensive and the effort involved is too high."
- "No recognisable effect and too high costs"

Cover crops and other practices

For other practices, the dataset provided limited specific quotations, but documented reasons included:

Direct seeding challenges:

- "Weed infestation"
- "Difficult emergence on heavy soils"

General economic and practical concerns:

- "labour-intensive"
- "Time-consuming"
- "high operating costs"
- "insignificant results"

Environmental adaptation issues:

- "weather conditions"
- "Drought (it germinated but dried up, so it was useless)"

Implications and recommendations

The abandonment patterns identified in this analysis among participants offer valuable insights for improving soil health practice adoption and retention among similar farming communities. Strategic interventions should address both practice-specific challenges and broader systemic issues.

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Practice-specific support strategies

1. **Minimum tillage implementation:**
    - Provide targeted technical support during the critical 2-5-year period when abandonment is most common among participants
    - Develop region-specific guidelines to address soil compaction and aeration issues among participants
    - Create soil-specific management protocols to prevent structure degradation among participants
    - Implement integrated weed management strategies that reduce dependence on herbicides among participants
    - Offer transition period yield protection through complementary practices among participants
2. **Microbiological applications:**
    - Improve monitoring and evaluation protocols to better document effects among participants
    - Develop clearer standards and application guidelines among participants
    - Support more on-farm research to identify context-specific benefits among participants
    - Create evidence-based protocols with clear indicators of success among participants
    - Provide cost-benefit analysis frameworks to evaluate return on investment among participants
3. **Cover crop and other practice optimization:**
    - Focus on economic viability and species selection for different contexts among participants
    - Develop cost-sharing programs to help farmers through critical transition periods among participants
    - Create decision support tools for selecting appropriate practices based on farm conditions among participants
    - Provide specialized technical assistance for implementation challenges among participants

Duration-based support strategies

Support systems should be tailored to address challenges that emerge at different stages of practice implementation among participants:

1. **Initial Phase (0-1 year)**:
    - Intensive technical assistance during critical establishment periods among participants
    - Early problem identification protocols among participants
    - Peer-to-peer knowledge sharing networks for rapid troubleshooting among participants
2. **Transition Phase (1-2 years)**:
    - Financial risk mitigation tools during yield transition periods among participants
    - Management adjustment protocols for emerging challenges among participants
    - Performance benchmarking against realistic expectations among participants
3. **Consolidation Phase (2-5 years)**:
    - System optimization support when initial enthusiasm wanes among participants
    - Addressing cumulative challenges before they trigger abandonment among participants
    - Advanced training on managing system interactions among participants
4. **Long-term Phase (>5 years)**:
    - Practice refresh and innovation support among participants
    - Adaptation strategies for changing conditions among participants
    - Recognition and leveraging of experienced practitioners as mentors among participants

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Conclusion

This analysis reveals that practice abandonment is not simply a matter of farmer reluctance but often represents a rational response to legitimate challenges among participants. The substantial number of farmers who persisted with practices for 2-5 years before abandoning them demonstrates significant commitment to soil health approaches among participants. The predominance of environmental/results issues as abandonment drivers suggests a need for more realistic expectations and better adaptation strategies among participants.

The documented reasons from survey participants highlight the importance of addressing specific technical challenges, particularly soil compaction issues with minimum tillage, effectiveness documentation for microbiological products, and economic viability across all practices. Moving forward, support programs should focus on the critical 2-5 year implementation period when most abandonments occur, while providing practice-specific technical assistance based on the documented challenges identified in this analysis.

Recommendation analysis: Farmers' willingness to endorse sustainable practices (Q22)

Understanding whether participating farmers would recommend the sustainable soil management practices they have implemented provides crucial insights into their perceived value and transferability among surveyed respondents. This section examines responses to Question 22: "Would you suggest and recommend to other farmers to use the method(s) you applied?" Farmers could respond with "Yes" or "No" and were asked to explain their reasoning in an open text field. This analysis explores not only the overall recommendation rates but also investigates the specific reasons behind farmers' endorsements or reservations among participants, the relationship between practice types and recommendation patterns and correlations between farm characteristics and willingness to recommend among participants. These insights provide valuable guidance for promoting wider adoption of sustainable soil management practices by highlighting what existing practitioners find most valuable and what concerns might need to be addressed among surveyed respondents.

To analyse the recommendation patterns and reasons among participants, we employed a mixed-methods approach combining quantitative analysis of recommendation rates with qualitative thematic analysis of the explanatory text responses:

1. **Recommendation rate calculation**: We calculated the percentage of farmers who would recommend their practices ("Yes" responses) out of all respondents who answered this question among participants.
2. **Thematic analysis of reasons**: Free text explanations were analysed using a systematic approach explained in previous sections among participants.

Overall recommendation patterns

A total of 208 participating farmers provided clear responses to the recommendation question, with the vast majority expressing willingness to recommend their practices to other farmers among surveyed respondents: 89.4% of participating farmers indicated they would recommend their sustainable soil management practices to other farmers among surveyed respondents, while only 10.6% would not recommend them. This high endorsement rate suggests that despite implementation challenges identified in previous sections among participants, most farmers perceive substantial value in the sustainable soil management practices they have applied.

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Correlation with farm characteristics

The analysis revealed interesting relationships between farm characteristics and recommendation patterns among participants:

Farm Size	Yes	No	Recommendation Rate
<5 ha	32	4	88.9%
6-50 ha	64	8	88.9%
51-100 ha	28	4	87.5%
101-250 ha	22	0	100.0%
251-500 ha	13	1	92.9%
>500 ha	21	4	84.0%

Table 36 Willingness to recommend sustainable practices to other farmers by farm size among survey participants

This analysis reveals several interesting patterns among participants:

1. Medium-large farms (101-250 ha) show perfect recommendation rates, with 100% of respondents willing to recommend their practices among participants.
2. Large farms (>500 ha) show the lowest recommendation rate (84.0%) among participants, though this still represents strong overall endorsement.
3. Small and medium farms (less than 5 ha and 6-50 ha) both show identical recommendation rates (88.9%) among participants, suggesting consistent perceived value across these farm sizes.

The generally high recommendation rates across all farm sizes among participants indicate that sustainable soil management practices can provide value across different scales of operation, though the specific benefits may vary.

Farming Method	Yes	No	Recommendation Rate
Organic	68	6	91.9%
Conventional	118	16	88.1%

Table 37 Willingness to recommend sustainable practices by farming method among survey participants

Organic farmers show a slightly higher propensity to recommend sustainable practices (91.9%) compared to conventional farmers (88.1%) among participants. This small difference might reflect greater philosophical alignment with sustainability principles among organic farmers or possibly greater synergies between sustainable soil practices and organic farming systems among participants. However, the strong recommendation rates in both farming systems among participants indicate broad applicability across different production approaches.

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Country	Yes	No	Recommendation Rate
Spain	20	1	95.2%
Slovenia	17	1	94.4%
Germany	28	2	93.3%
Italy	15	1	93.8%
Bulgaria	13	1	92.9%
Slovak Republic	15	2	88.2%
Austria	27	4	87.1%
Hungary	29	5	85.3%
Poland	17	5	77.3%

Table 38 Willingness to recommend sustainable practices to other farmers by country among survey participants

Notable regional patterns emerge from this analysis among participants:

1. Southern European countries (Spain, Italy) show particularly strong recommendation rates among participants, possibly reflecting the importance of soil conservation in Mediterranean climates prone to erosion and drought.
2. Germany and Slovenia also demonstrate very high recommendation rates among participants.
3. Poland shows the lowest recommendation rate (77.3%) among participants, though this still represents a strong overall endorsement.

These geographic variations likely reflect differences in climate conditions, soil types, policy environments and cultural factors that influence practice effectiveness and perception among participants.

Analysis of recommendation reasons

Examination of the explanations provided for positive recommendations revealed several distinct categories of reasoning among participants:

Reason Category	Frequency	Percentage
Economic Benefits	36	27.3%
Environmental Improvements	20	15.2%
Soil Health Enhancement	17	12.9%
Long-term Sustainability	8	6.1%
Adaptability to Local Conditions	3	2.3%
Practical Implementation Advantages	1	0.8%
Other Positive Reasons	47	35.6%

Table 39 Primary reasons for recommending sustainable practices to other farmers among survey participants

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Economic benefits emerge as the most frequently cited specific reason for recommendation among participants, with farmers mentioning cost reductions, yield stability and potential market advantages. Environmental improvements represent the second most clearly identified driver among participants, with farmers specifically mentioning enhanced soil health, reduced erosion and improved biodiversity as compelling reasons to adopt sustainable practices.

Many participating farmers emphasized the future-oriented benefits of sustainable practices, noting that while short-term challenges may exist among participants, these are outweighed by long-term farm sustainability benefits. As one farmer explained: "The initial adjustment period requires patience, but after 2-3 years, the soil system begins to function better, delivering multiple benefits that continue to increase over time."

Among farmers who would not recommend their practices among participants, several distinct concerns emerged:

1. **Context limitations**: Many farmers identified specific soil types, climate conditions or farm structures that might make certain practices unsuitable rather than rejecting the practices entirely among participants. As one respondent noted: "Direct seeding is excellent in the right conditions, but I wouldn't recommend it for heavy clay soils or areas with high weed pressure without significant adaptation."
2. **Resource constraints**: Practical barriers particularly related to labor requirements, equipment needs and implementation costs represented another common reason for not recommending practices among participants. These constraints appeared more significant for smaller operations with limited resources among participants.
3. **Limited benefits**: Some farmers reported underwhelming or inconsistent results that they felt didn't justify the investment or changes required among participants.

An important pattern emerged across both positive and negative recommendations among participants: most came with specific qualifications or conditions rather than blanket endorsements or rejections. This suggests farmers recognize both the potential benefits and implementation challenges of sustainable practices among participants, leading to nuanced, context-specific recommendations rather than universal advocacy.

Key insights for practice promotion

1. **Highlight economic benefits**: The most frequently cited specific reason for recommendation is economic benefits, suggesting this aspect should be prominently featured in promotion efforts alongside environmental improvements.
2. **Address context-specific needs**: The conditional nature of many recommendations highlights the importance of context-specific guidance rather than one-size-fits-all approaches.
3. **Leverage regional success stories**: The strong geographic patterns in recommendation rates suggest utilizing success stories from high-recommendation countries could be effective in promoting adoption in regions with lower endorsement.
4. **Develop adaptive approaches**: The high recommendation rate among farmers who abandoned specific practices suggests promoting adaptable, modular sustainability approaches rather than rigid practice sets.

Conclusion

The strong overall recommendation rate (89.4%) provide compelling evidence that participating farmers who implement sustainable practices generally perceive significant value, despite the challenges identified in previous analyses. The finding that 79.1% of farmers who abandoned practices would still recommend sustainable approaches highlights the nuanced nature of sustainable agriculture implementation. Rather than viewing practice abandonment as failure, it often appears to represent an adaptive learning process within a broader commitment to sustainability principles.

4.3 FUTURE ADOPTION PLANS AND SUPPORT NEEDS

Future plans and support needs for sustainable soil management practices (Q23-26 + Q27)

In line with our methodological framework (Section 3.6), this section examines participating farmers' future-oriented knowledge, their intentions, plans and expectations regarding practices they have not yet implemented among surveyed respondents. This combines elements of both perceptual and experiential knowledge, filtered through the lens of specific implementation planning among participants. These forward-looking perspectives reveal how farmers synthesize general beliefs and specific experiences into actionable intentions among participants. The analysis focuses on responses to interconnected questions:

1. Future adoption plans (Q23): "Do you have plans to apply other/new sustainable soil and farm management practice?" (Yes/No)
2. Intended practices (Q24): "If you answered Yes to the previous question, which sustainable soil and farm management practice would you try in the future?" (Multiple selection from a list with option to add others)
3. Implementation barriers (Q25): "What were your barriers for applying this practice till now?" (Ranking from least to most important)
4. Expected benefits (Q26): "What are your expected benefits of applying this new practice?" (Multiple selection)
5. Supporting mechanisms (Q27): "Which of the following could aid you in adopting new sustainable soil management techniques?" (Multiple selection)

These questions were designed to provide a comprehensive picture of participating farmers' future plans, the obstacles they face, the benefits they anticipate and the support they need to successfully implement sustainable soil management practices among surveyed respondents.

The analysis employed a mixed-methods approach combining quantitative frequency analysis with qualitative cross-comparisons among participants:

1. **Future adoption rate calculation**: We calculated the percentage of farmers planning to implement new practices (Yes responses to Q23) across the entire sample and by country among participants.
2. **Practice popularity analysis**: For farmers indicating plans to adopt new practices (Q24), we conducted frequency counts for each intended practice, both at the EU level and by country among participants. This allowed us to identify the most desired future practices and any regional variations in preference.
3. **Barrier ranking analysis**: We analysed responses to Q25 using a weighted ranking system, where farmers ranked barriers from least to most important among participants. This allowed us to identify the primary obstacles to implementation across different contexts.
4. **Benefit expectation measurement**: We conducted frequency analysis of anticipated positive outcomes (Q26) to understand farmers' motivations and expectations regarding new practices among participants.
5. **Support need assessment**: We analysed preferences for adoption aid (Q27) to identify the most valued support channels across different farming contexts among participants. This

included categorizing support mechanisms into broader groups to identify overarching patterns.

6. **Cross-analysis**: We examined patterns by country, region and farm characteristics to identify context-specific insights among participants.

Future adoption intentions

The survey reveals strong future commitment to sustainable soil management practices among participating European farmers. More than two-thirds of surveyed respondents (68%) indicate plans to implement new sustainable practices among participants, demonstrating substantial appetite for continued agricultural innovation.

Country	Planning to Adopt (%)	Sample Size
Germany	85.0%	39
Slovak Republic	82.0%	34
Italy	79.0%	28
Poland	69.0%	42
Spain	64.0%	47
Hungary	63.0%	65
Bulgaria	60.0%	45
Austria	62.0%	42
Slovenia	58.0%	43

Table 40 Percentage of farmers planning to adopt new sustainable practices by country among survey participants

The country-level data reveals interesting patterns among participants. Germany leads with the highest adoption enthusiasm (85%) among participants, followed by the Slovak Republic (82%) and Italy (79%). Slovenia shows the lowest adoption intention (58%) among participants, though this still represents a majority of Slovenian respondents. Surveyed respondents from all major countries represented in the sample show adoption intentions above 50% among participants, indicating interest in sustainable practices across diverse agricultural contexts among survey participants.

Practice	Frequency	Percentage of Farmers Planning Adoption
Minimum Tillage	113	42.3%
Cover Crops: Summer Cover Crop	33	12.4%
Cover Crops: Intercropping	21	7.9%
Integrated Pest Management (IPM)	20	7.5%
Cover Crops: Autumn and Winter Cover Crop	19	7.1%
Microbiological Products	16	6.0%
Precision Agriculture: Site-specific Management	13	4.9%
Biochar	12	4.5%
Precision Agriculture: Soil Testing Technologies	5	1.9%

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Practice	Frequency	Percentage of Farmers Planning Adoption
Liming	4	1.5%

Table 41 Most desired sustainable practices for future implementation among survey participants planning new adoptions

Minimum tillage emerges as the most frequently cited practice in future adoption plans among participants, with over 42% of those planning new adoptions intending to implement this practice among surveyed respondents. Various forms of cover crops (summer cover crops, intercropping, autumn and winter cover crops) collectively represent another significant area of interest among participants. Integrated Pest Management and Microbiological products also show notable popularity among farmers planning new adoptions.

Country	Primary Practice	Secondary Practice	Tertiary Practice
Germany	Minimum Tillage	Precision Agriculture	Intercropping
Hungary	Minimum Tillage	Summer Cover Crops	IPM
Bulgaria	Minimum Tillage	IPM	Microbiological Products
Austria	Minimum Tillage	Intercropping	Autumn/Winter Cover Crops
Poland	Minimum Tillage	IPM	Autumn/Winter Cover Crops
Spain	Minimum Tillage	Summer Cover Crops	Microbiological Products
Slovak Republic	Minimum Tillage	Microbiological Products	Summer Cover Crops
Slovenia	Minimum Tillage	Summer Cover Crops	Intercropping
Italy	Minimum Tillage	IPM	Summer Cover Crops

Table 42 Top three desired sustainable practices for future implementation by country among survey participants

This country-level analysis reveals several key patterns among participants: Minimum tillage emerges as the most popular future practice across all major countries among participants, showing remarkable consistency. The secondary and tertiary preferences vary by country among participants, likely reflecting regional agricultural conditions, knowledge dissemination and policy environments. IPM appears particularly popular in Bulgaria, Poland, and Italy among participants and Cover crops (in various forms) show strong interest across most countries among participants.

Barrier	Frequency	Percentage of Farmers Citing
Climate and Environmental Risks	371	94.9%
Cultural and Social Factors	371	94.9%
Scaling Up Limitations	374	95.7%
Land Tenure and Property Rights	363	92.8%
Knowledge and Awareness Gaps	360	92.1%
Financial Constraints	358	91.6%
Short-Term Economic Pressures	357	91.3%

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Barrier	Frequency	Percentage of Farmers Citing
Infrastructure and Technology Limitations	359	91.8%
Policy and Institutional Barriers	358	91.6%

Table 43 Barriers to implementing new sustainable practices among survey participants planning future adoptions

The analysis reveals a complex tapestry of barriers facing participating farmers, with several obstacles cited by over 90% of surveyed respondents. While frequency counts show similar levels of concern across barrier types among participants, ranking data indicates that Climate and Environmental Risks, Cultural and Social Factors and Knowledge and Awareness Gaps are the most significant impediments to adoption among surveyed farmers.

Country	Primary Barrier	Secondary Barrier	Tertiary Barrier
Germany	Knowledge Gaps	Financial Constraints	Short-term Economic Pressures
Hungary	Knowledge Gaps	Short-term Economic Pressures	Climate Risks
Bulgaria	Climate Risks	Knowledge Gaps	Cultural Factors
Austria	Climate Risks	Cultural Factors	Knowledge Gaps
Poland	Climate Risks	Cultural Factors	Knowledge Gaps
Spain	Climate Risks	Cultural Factors	Knowledge Gaps
Slovak Republic	Scaling Up Limitations	Cultural Factors	Short-term Economic Pressures
Slovenia	Climate Risks	Cultural Factors	Scaling Up Limitations
Italy	Financial Constraints	Infrastructure/Technology Limitations	Short-term Economic Pressures

Table 44 Primary barriers to implementing new sustainable practices by country among survey participants

Country-level analysis reveals important regional variations in implementation barriers among participants:

1. Climate and environmental risks emerge as the dominant concern in Bulgaria, Austria, Poland, Spain and Slovenia among participants.
2. Knowledge gaps represent the primary barrier in Germany and Hungary among participants.
3. Scaling limitations are particularly prominent in the Slovak Republic among participants.
4. Financial constraints stand out as the primary concern for Italian farmers among participants, highlighting the economic challenges in their agricultural context.

These country-specific barrier patterns suggest the need for tailored support strategies that address the unique challenges facing farmers in different European regions among participants.

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Expected benefits

Expected Benefit	Frequency	Percentage of Planning Farmers
Improved Soil Health	318	81.3%
Reduced Soil Erosion	237	60.6%
Water Conservation	210	53.7%
Biodiversity Conservation	192	49.1%
Climate Change Mitigation	168	43.0%
Economic Benefits	134	34.3%
Reduced Environmental Pollution	124	31.7%
Resilient Agriculture Systems	116	29.7%
Enhanced Crop Yields	106	27.1%
Increased Profitability	92	23.5%
Better Market Position	76	19.4%

Table 45 Expected benefits from implementing new sustainable practices among survey participants planning future adoptions

Improved soil health emerges as the dominant expected benefit among participants, cited by over 80% of farmers planning to adopt new practices among surveyed respondents. Environmental benefits (reduced soil erosion, water conservation, biodiversity conservation) generally rank higher than direct economic benefits among participants, suggesting that farmers are primarily motivated by environmental sustainability goals rather than immediate financial returns.

Country	Primary Benefit	Secondary Benefit	Tertiary Benefit
Austria	Soil Health	Erosion Reduction	Biodiversity Conservation
Bulgaria	Soil Health	Biodiversity Enhancement	Climate Change Mitigation
Germany	Soil Health	Erosion Reduction	Enhanced Crop Yields
Hungary	Soil Health	Erosion Reduction	Biodiversity Conservation
Italy	Soil Health	Erosion Reduction	Biodiversity Conservation
Poland	Soil Health	Erosion Reduction	Increased Profitability
Slovak Republic	Soil Health	Climate Change Mitigation	Water Conservation
Slovenia	Soil Health	Water Conservation	Climate Change Mitigation
Spain	Soil Health	Erosion Reduction	Economic Benefits

Table 46 Top three expected benefits from implementing new sustainable practices by country among survey participants

Country-level benefit expectations reveal both commonalities and differences among participants. Improved soil health is consistently the primary expected benefit across all countries among participants, showing remarkable consensus. Reduced soil erosion appears as a top-three benefit

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in most countries among participants, but notably not in the Slovak Republic or Slovenia. Economic considerations (profitability, economic benefits, enhanced yields) appear in the top three expectations for Germany, Poland and Spain among participants, but are less emphasized in other countries. Climate change mitigation is particularly emphasized in Bulgaria, the Slovak Republic and Slovenia among participants.

Support mechanisms

Support Mechanism	Frequency	Percentage of Farmers
Other farmers/end users	202	51.7%
Subsidies for environmentally friendly farming	202	51.7%
Supporting financial incentives	168	43.0%
On-farm demonstration of alternative methods	134	34.3%
Advisors	130	33.3%
Collaboration with researchers	129	33.0%
Peer to peer learning and knowledge exchange	125	32.0%
Policy coherence	103	26.3%
Access to equipment	101	25.8%
Training courses for practitioners	90	23.0%

Table 47 Most valued support mechanisms for adopting new sustainable practices among survey participants

The analysis reveals a balanced demand for different types of support mechanisms among participants. Peer learning ("Other farmers/end users") and financial support ("Subsidies for environmentally friendly farming") emerge as equally important among participants, both cited by 51.7% of farmers. This suggests that both knowledge transfer and economic incentives are critical for facilitating sustainable practice adoption among participants.
When grouped into broader categories among participants, we found that Financial Support (including subsidies and financial incentives) is reported by 71.1% of farmers, Peer Learning Networks (including farmer-to-farmer learning and knowledge exchange) by 51.4% and Technical Support (including demonstrations, advisors and training) as third, by 34.3% among participants.

Farm Size	Primary Support Need	Secondary Support Need	Tertiary Support Need
<5 ha	Subsidies (50.0%)	Other farmers (44.6%)	Researcher collaboration (41.9%)
6-50 ha	Subsidies (56.1%)	Other farmers (52.5%)	Financial incentives (48.9%)
51-100 ha	Other farmers (58.8%)	Subsidies/Financial incentives (43.1%)	Subsidies/Financial incentives (43.1%)
101-250 ha	Other farmers (54.6%)	Subsidies (51.5%)	Peer learning (42.4%)

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Farm Size	Primary Support Need	Secondary Support Need	Tertiary Support Need
251-500 ha	Other farmers (60.9%)	Subsidies (47.8%)	Peer learning (34.8%)
>500 ha	Financial incentives (54.4%)	Subsidies (52.2%)	Other farmers (45.7%)

Table 48 Most valued support mechanisms for adopting sustainable practices by farm size among survey participants

Farm size analysis reveals interesting patterns among participants. While small farms (less than 5 ha and 6-50 ha) place highest priority on subsidies for environmentally friendly farming among participants, medium and medium-large farms (51-100 ha, 101-250 ha, and 251-500 ha) prioritize learning from other farmers among participants and large farms (more than 500 ha) uniquely prioritize financial incentives over subsidies and peer learning among participants. These differences likely reflect varying resource constraints and operational needs across farm sizes among participants.

Country	Primary Support	Secondary Support	Tertiary Support
Austria	Other farmers/Subsidies (69.1%)	Other farmers/Subsidies (69.1%)	Financial incentives (59.5%)
Bulgaria	Other farmers (55.6%)	Subsidies (46.7%)	Advisors (40.0%)
Germany	Other farmers (53.9%)	Financial incentives/On-farm demonstrations (41.0%)	Financial incentives/On-farm demonstrations (41.0%)
Hungary	Other farmers (50.8%)	Subsidies (43.1%)	Financial incentives 38.5%)
Italy	Researcher collaboration (67.9%)	Subsidies (53.6%)	Other farmers (46.4%)
Poland	Subsidies (59.5%)	Other farmers (54.8%)	Financial incentives (47.6%)
Slovak Republic	Policy coherence (79.4%)	Subsidies (61.8%)	On-farm demonstrations (55.9%)
Slovenia	Financial incentives (46.5%)	Other farmers/Advisors (44.2%)	Other farmers/Advisors (44.2%)
Spain	Subsidies (57.5%)	Policy coherence (51.1%)	Other farmers (48.9%)

Table 49 Most valued support mechanisms for adopting sustainable practices by country among survey participants

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Country-level analysis reveals specific national priorities among participants:
Austria shows equal highest priorities for peer learning and subsidies (69.1%) among participants, indicating a balanced approach to knowledge and financial support.
Bulgaria prioritizes peer learning (55.6%) followed by subsidies (46.7%) and advisory services (40.0%) among participants, emphasizing the importance of knowledge transfer.
Germany emphasizes learning from other farmers (53.9%) with financial incentives and on-farm demonstrations (both 41.0%) as secondary priorities among participants.
Hungary focuses primarily on peer learning (50.8%) with subsidies (43.1%) and financial incentives (38.5%) as complementary supports among participants.
Italy uniquely emphasizes researcher collaboration (67.9%) as the primary support need among participants, followed by subsidies (53.6%) and peer learning (46.4%).
Poland prioritizes subsidies (59.5%) followed by peer learning (54.8%) and financial incentives (47.6%) among participants.
Slovak Republic strongly prioritizes policy coherence (79.4%) among participants, much higher than any other support mechanism, followed by subsidies (61.8%) and on-farm demonstrations (55.9%).
Slovenia emphasizes financial incentives (46.5%) with equal emphasis on peer learning and advisory support (both 44.2%) among participants.
Spain prioritizes subsidies (57.5%) followed by policy coherence (51.1%) and peer learning (48.9%) among participants, reflecting a desire for coordinated financial and regulatory support.

Integrated analysis and key findings

Our exploratory analysis of farmers' future plans, barriers, expected benefits and support needs reveals a nuanced picture of sustainable soil management. The high percentage of surveyed farmers (68%) planning to adopt new practices demonstrates substantial momentum for agricultural transformation. This widespread interest cuts across countries, farm sizes and farming methods, suggesting that sustainable soil management has moved beyond niche applications to become a mainstream agricultural aspiration among the surveyed participants.

Among the various sustainable practices, minimum tillage emerges as the clear priority for future adoption among respondents, with 42.3% of planning farmers intending to implement this approach. The remarkable consistency of this preference across all countries indicates that minimum tillage resonates with farmers regardless of their specific agricultural context. This likely reflects its versatility, relative ease of implementation and well-documented benefits for soil structure and health. Cover crops in various forms (summer cover, intercropping and winter cover) collectively represent another significant area of interest, highlighting the growing recognition of vegetation coverage as a key soil protection strategy.

When examining the barriers to implementation, we find that surveyed farmers face a complex set of challenges that vary by regional context. Climate and environmental risks emerge as particularly significant obstacles in Southern and Eastern European countries, reflecting the heightened vulnerability of these regions to climate change impacts. Knowledge gaps represent the primary barrier in countries like Germany and Hungary, suggesting that information accessibility remains a critical issue even in well-resourced agricultural systems. Cultural and social factors exert a consistent influence across multiple countries, reminding us that sustainable practice adoption is not merely a technical challenge but also a social transition that must accommodate local norms and traditions.

The benefits that surveyed farmers expect from sustainable practices reveal a strong environmental orientation. Improved soil health stands out as the universally anticipated benefit, cited by over 80% of surveyed farmers planning new adoptions. This consistency across all countries and farm sizes indicates a fundamental recognition of soil as the foundation of agricultural sustainability.

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Environmental benefits generally rank higher than direct economic returns, suggesting that farmers take a long-term perspective on sustainability that values resource conservation alongside productivity. Nevertheless, economic considerations appear among the top expected benefits in countries like Germany, Poland and Spain, indicating that financial viability remains an essential component of sustainable agriculture.

The support mechanisms that surveyed farmers value most reveal the multidimensional nature of agricultural innovation. The equal importance placed on peer learning and subsidies (both cited by 51.7% of respondents) highlights the complementary roles of knowledge and financial support in enabling practice adoption. This dual emphasis suggests that neither approach alone will be sufficient; rather, integrated support packages that address both knowledge transfer and economic feasibility are needed.

Farm size variations in support preferences provide important insights for tailoring interventions. Smaller farms prioritize subsidies, medium farms value peer networks and larger operations emphasize sophisticated financial incentives. These variations reflect the different constraints, resources and operational contexts across European agriculture.

Recommendations

Based on our analysis, we recommend a multifaceted approach to supporting sustainable soil management across Europe, with strategies tailored to specific practices and farm contexts.

1. Practice-specific support programs

The clear prioritization of minimum tillage calls for dedicated support programs focused on this practice. These should include equipment access initiatives to overcome the capital investment barrier, transition assistance during the critical initial implementation period and technical guidance to address specific challenges like weed management and soil compaction. For cover crops, which show strong interest across multiple countries, we recommend developing regionally adapted implementation guidelines that account for climatic differences and crop rotations. These should address the timing challenges that farmers often face and provide specific recommendations for species selection in different contexts.

2. Farm size-appropriate mechanisms

Farm size represents another important dimension for tailoring support. Smaller farms would benefit most from streamlined subsidy programs with simplified application procedures and dedicated advisory support to navigate technical challenges. For medium-sized operations, peer learning networks and knowledge exchange platforms should be developed that address their specific operational contexts and challenges. Larger farms would benefit from sophisticated financial incentive programs that account for the scale of their operations, alongside specialized technical support for large-scale implementation.

3. Barrier-specific interventions

Addressing the most significant barriers requires targeted interventions. For climate and environmental risks, which particularly concern surveyed Southern and Eastern European farmers, region-specific adaptation strategies and risk management tools should be developed. These might include insurance mechanisms, drought-resistant practice adaptations and contingency planning support. To reduce knowledge gaps, especially prominent in Germany and Hungary, strengthening advisory services and facilitating farmer-to-farmer learning will be essential. Cultural barriers, present across multiple countries, require sensitively designed communication and education campaigns that respect local traditions while illustrating the benefits of innovation.

4. Comprehensive support ecosystem

Ultimately, sustainable soil management requires a comprehensive support ecosystem that integrates multiple dimensions. Financially, this means combining initial adoption subsidies with longer-term incentives that reward continued implementation and measured outcomes. In the

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knowledge dimension, formal advisory services should be linked with peer learning networks and researcher collaborations to create a continuous learning environment. Technical support should span from practical demonstrations to equipment access and innovation support, creating a progression pathway for farmers at different adoption stages. And all of these efforts should be underpinned by coherent policies that align agricultural, environmental, and economic objectives.

5. Communication strategies

Communication strategies should be carefully aligned with farmers' primary motivations as revealed in our analysis. With improved soil health universally valued across all countries, this benefit should anchor promotional messaging. Communications should be regionally tailored, emphasizing environmental outcomes in countries focused on ecological benefits, while balancing with economic messaging in countries like Germany, Poland and Spain where financial returns rank higher. The high value placed on peer learning suggests farmer testimonials and case studies should feature prominently in outreach materials, creating relatable examples of successful implementation that other farmers can identify with. This approach transforms abstract practices into tangible successes, bridging the gap between support programs and on-farm adoption.

4.4 INTEGRATIVE ANALYSIS: CROSS-SECTIONAL PATTERNS IN FARMER PERSPECTIVES ON SUSTAINABLE SOIL MANAGEMENT

This analysis examines the relationships between farmers' perceptions, experiences and future intentions regarding sustainable soil management practices within our survey sample. By analyzing the connections between different sections of our survey, we can better understand how the surveyed farmers conceptualize, implement and plan for sustainability.

Shifting frameworks: from perception to experience to planning

One notable finding from this analysis is how survey participants' prioritization of different factors shifts across conceptual frameworks. When asked about theoretical motivations for sustainable practice adoption (Section 4.1), respondents emphasize environmental factors as the dominant concern. However, when reporting on actual implementation drivers (Section 4.2), economic factors (63.2%) emerge nearly equal to environmental concerns (61.7%). This pattern reflects the distinction between values and practical decision-making among our surveyed farmers.

The analysis shows that farmers experience environmental benefits more frequently than economic benefits from their implemented practices. When looking toward future adoption (Section 4.3), farmers anticipate primarily environmental benefits (81.3% expect improved soil health) from planned implementations. This pattern demonstrates how environmental values align with expected outcomes, despite the economic considerations evident in implementation decisions.

Evolving barrier recognition: from general to specific

Analysis across survey sections reveals changes in how surveyed farmers conceptualize implementation barriers. Economic constraints dominate general perceptions of barriers (80.1% among farmers providing valid rankings in Section 4.1), but more diverse challenges emerge when farmers discuss their future plans (Section 4.3). Climate and environmental risks, which rank relatively low in general perceptions (23.5% in Section 4.1), emerge as primary concerns for future implementation. This shift likely reflects the progression from general sector perceptions to specific implementation planning among our survey participants.

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Regional and structural patterns

Regional and structural patterns remain consistent across survey sections among our respondents. Eastern European countries consistently emphasize economic factors more than their Western European counterparts, who demonstrate greater environmental orientation. This regional consistency persists whether discussing general perceptions, personal experiences, or future plans among survey participants.

Similarly, farm size effects remain stable across all sections. Larger operations consistently place greater emphasis on economic factors and technological solutions, while smaller farms report more knowledge-related barriers and emphasize social factors. The persistence of these patterns across different question framings suggests these structural differences are significant among our survey participants.

The awareness-implementation relationship

Our analysis reveals patterns in how knowledge relates to sustainable practice implementation among survey respondents. In general perceptions (Section 4.1), knowledge gaps appear as moderately important barriers (43.5%). However, in future planning (Section 4.3), they emerge as primary barriers in several countries, particularly Germany and Hungary.

Analysis of information sources (Section 4.1) and support needs (Section 4.3) shows consistent emphasis on peer learning networks among our respondents, with "Other farmers/end users" ranking as both the top information source (69.8%) and a primary desired support mechanism (51.7%, tied with subsidies).

This pattern suggests that among our survey participants, knowledge barriers aren't simply about information availability but about context-specific, practical implementation knowledge that is most effectively transmitted through peer networks.

Implementation patterns across practices

Our analysis revealed patterns regarding sustainable practice adoption among survey participants:

- **Most widely adopted practices**: Cover crops (45.5%) and minimum tillage (43.2%) show the highest current implementation rates and also feature prominently in future adoption plans.
- **Awareness-implementation gaps**: Many practices show substantially more farmers who have heard about them than are currently using them. The largest gaps appear for:
    - Terraces (72.9% heard about vs. 6.6% implementing)
    - Agroforestry (70.8% heard about vs. 9.5% implementing)
    - Rotational grazing (68.5% heard about vs. 11.8% implementing)
- **Abandonment patterns**: While minimum tillage shows high adoption rates, it also shows notable abandonment rates (5.6%), primarily due to environmental/results issues that typically emerge after 2-5 years of implementation.
- **Future priorities**: Minimum tillage emerges as the most desired future practice (42.3% of farmers planning new adoptions) across all surveyed countries, despite known implementation challenges.

Integration of economic and environmental considerations

The analysis challenges simple economic-environmental dichotomies in understanding farmer decision-making among our respondents. While these dimensions are useful analytical categories,

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our data shows that survey participants integrate these considerations within complex decision frameworks.

Economic factors (63.2%) and environmental concerns (61.7%) nearly equally drive adoption decisions among participants. However, environmental benefits are more widely recognized in farmers' experiences (85.7% report improved soil health). This suggests that while economic considerations influence adoption decisions, the realized benefits are predominantly environmental. The balanced support preferences expressed in Section 4.3, where peer learning networks and financial subsidies receive equal prioritization (both 51.7%) among survey participants, indicates that farmers recognize both knowledge and economic dimensions as essential components of sustainable transitions.

Key insights for supporting sustainable agriculture

This analysis among our survey participants offers several insights:

1. **Beyond awareness campaigns**: The substantial gaps between awareness and implementation for many practices suggest that the primary challenge lies not in knowledge dissemination but in supporting the transition from knowledge to action.
2. **Economic viability is crucial**: Despite strong environmental motivations, economic factors play a critical role in actual implementation decisions. Support programs must address both environmental benefits and economic viability.
3. **Peer learning is central**: The consistent emphasis on farmer-to-farmer knowledge exchange across all survey sections indicates this should be a cornerstone of knowledge transfer strategies.
4. **Context matters**: Regional and farm size differences persist across all aspects of sustainable practice adoption, suggesting the need for tailored rather than uniform approaches.
5. **Long-term perspective needed**: The patterns of practice abandonment and the timeline for challenges to emerge (often 2-5 years) suggest that support systems need to provide sustained assistance beyond initial adoption.

Implications for understanding farmer decision-making

This analysis among our survey participants highlights the importance of recognizing that farmer decision-making involves complex interactions between values, practical constraints and contextual factors. The shifts between general perceptions, personal experiences and future plans demonstrate that different types of knowledge and different decision-making contexts produce different priorities and outcomes.

Rather than viewing farmers as having fixed preferences or barriers, this analysis suggests that supporting sustainable agriculture requires understanding and working with the dynamic, context-dependent nature of agricultural decision-making among farming communities similar to our survey participants.

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5. Conclusion and recommendation

Key findings from the survey
The following key patterns emerge from analysis of responses from our survey participants:
1. Implementation gap beyond knowledge
Among survey participants, while knowledge of sustainable soil management practices is high across countries (over 90% awareness for most practices), implementation rates remain lower (between 4% and 45% depending on the practice). This suggests that the primary challenge lies not in awareness building but in supporting the transition from knowledge to action among the surveyed farmers.
The gap is particularly pronounced for certain practices such as agroforestry (70.8% awareness but only 12.8% implementation) and terracing (72.9% awareness but only 11.3% implementation) among survey participants. These practices may face specific barriers related to labor requirements, upfront costs or compatibility with existing farming systems. The smaller implementation gaps for practices like cover crops, minimum tillage and liming suggest these approaches have achieved greater acceptance among our respondents.
2. Economic and environmental integration in decision-making
Among survey participants, while respondents cite environmental factors as theoretical motivators, their actual implementation decisions are influenced nearly equally by economic factors (63.2%) and environmental concerns (61.7%). Economic constraints consistently emerge as the primary barrier to adoption across all demographic groups among survey participants (cited by 80.1% of farmers providing valid rankings).
The analysis shows that farmers experience environmental benefits more frequently than economic benefits relative to their initial motivations. This indicates that sustainable practices deliver stronger ecological than financial returns among our respondents, yet farmers continue to implement them despite this imbalance.
3. Peer knowledge networks
Both the information source analysis and support mechanism preferences highlight the importance of farmer-to-farmer knowledge exchange among survey participants. Other farmers/end users represent both the top information source (69.8%) and a primary desired support mechanism (51.7%, tied with subsidies) among our respondents. This peer learning preference strengthens with farm size, with 91.3% of large farms citing other farmers as their primary information source.
4. Practice adoption patterns by farm structure
The analysis reveals systematic differences in practice adoption based on farm characteristics among survey participants:

- **Farm size effect**: Larger operations implement more practices on average (7.5 practices for 251-500 ha farms vs. 3.7 practices for farms under 5 ha), likely reflecting greater financial capacity and technical resources.
- **Farming method differences**: Among survey participants, organic farmers implement nearly twice as many sustainable practices as conventional farmers (6.1 vs. 3.7 practices per farmer).
- **Age-related patterns**: Within our sample, middle-aged farmers (40-64 years) implement the most practices (4.6 per farmer), compared to both younger farmers (3.7 practices) and older farmers (3.4 practices).

5. Practice-specific implementation patterns
Different sustainable practices show distinct adoption and continuation patterns among survey participants:

- **Cover crops**: Show strong adoption (45.5%) with moderate abandonment rates

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- **Minimum tillage**: While widely adopted (43.2%), it also shows notable abandonment rates (5.6%), primarily due to environmental/results issues after 2-5 years of use
- **Biochar**: Remains the least familiar practice (28.4% never heard of it) with minimal implementation (4.3%) among survey participants

6. Future adoption intentions

The analysis reveals substantial interest in continued sustainable practice adoption, with 68.0% of survey participants planning to implement new practices. The consistent prioritization of minimum tillage for future adoption (42.3% of planning farmers) across all surveyed countries indicates broad interest in reduced soil disturbance approaches.

Recommendations for stakeholders

Based on these patterns observed among survey participants, we offer the following recommendations for different stakeholder groups:

For policy makers

1. **Develop integrated support packages**: Design programs that address both knowledge transfer and economic viability, recognizing that survey participants value peer learning networks and financial subsidies equally.
2. **Implement practice-specific policies**: Tailor support mechanisms to address the unique challenges of different sustainable practices identified in our analysis.
3. **Design regionally adapted programs**: Recognize the geographic variations in practice preferences, motivations and barriers observed among survey participants.
4. **Support farming system transitions**: Acknowledge the differences between organic and conventional farming approaches observed in our data.
5. **Develop farm size-appropriate mechanisms**: Tailor support to address the specific needs and constraints of different farm sizes identified among survey participants.

For research and extension services

1. **Strengthen peer learning networks**: Given the preference for farmer-to-farmer knowledge exchange among survey participants, extension services should identify and support farmer innovation leaders.
2. **Address the implementation gap**: Focus efforts on implementation support rather than awareness-building, given the patterns observed in our survey data.
3. **Enhance economic monitoring and communication**: Improve documentation and communication of the economic impacts of sustainable practices.
4. **Target critical abandonment periods**: Focus support interventions on the specific timeframes when farmers are most likely to abandon practices, as identified in our analysis.
5. **Develop context-appropriate knowledge transfer**: Tailor communication and training approaches based on patterns observed among survey participants.

For farmers and agricultural organizations

1. **Embrace diversified practice portfolios**: Rather than focusing on single practices, develop integrated approaches that combine complementary techniques.
2. **Establish collaborative learning groups**: Given the high value placed on peer learning among survey participants.
3. **Adopt phased implementation approaches**: Recognize the challenges of transition periods by implementing changes gradually.
4. **Leverage multiple information sources**: While prioritizing peer learning, recognize the value of diverse information channels as shown in our analysis.
5. **Engage in monitoring**: Develop systems to track changes in soil health and economic impacts.

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For supply chain and market actors

1. **Develop market recognition for sustainable practices**: Create mechanisms to reward sustainable soil management through the marketplace.
2. **Support the transition period**: Recognize that the first 2-5 years of practice implementation often present the greatest challenges, as observed in our abandonment analysis.
3. **Engage input suppliers in knowledge transfer**: Leverage the influence of input suppliers, particularly for larger farms as shown in our data.
4. **Facilitate technology access**: Address the infrastructure and technology limitations identified as barriers among survey participants.

Study limitations and future research

This analysis is based on responses from 391 farmers across 13 European countries who participated in our survey. The findings reflect the experiences and perspectives of these specific participants and should be interpreted within this context. The non-probability sampling approach, while appropriate for this exploratory study, means that results cannot be statistically generalized to all European agriculture.

Future research could build on these findings by:

- Expanding sample sizes and employing probability-based sampling where feasible
- Conducting longitudinal studies to track practice adoption over time
- Investigating the effectiveness of different support mechanisms identified in this analysis
- Exploring regional variations in greater depth

Next steps

The results of the farmer survey will be systematically shared with national node members across all participating countries. This dissemination serves as the foundation for a structured validation process that will engage key stakeholders in the agricultural sector. Consortium partners will schedule dedicated meetings and interactive workshops to facilitate in-depth discussions of the findings. These collaborative sessions aim to accomplish two primary objectives: gain deeper insights into country-specific data and contextual information that may influence interpretation of the results, and validate survey findings through stakeholder feedback, ensuring that the data accurately reflects on-ground realities faced by farmers. The participatory approach will enable triangulation of the survey data with expert knowledge and practical experience, strengthening the reliability and applicability of the conclusions drawn.

The enriched understanding derived from stakeholder consultations will be consolidated in Deliverable D3.3, alongside other relevant research outcomes. This deliverable will synthesize multiple data streams to formulate evidence-based policy recommendations focused on sustainable soil management practices. The integration of validated survey results with complementary research findings will ensure that policy recommendations are grounded in farmers' practical experiences and constraints, responsive to regional and national contexts, technically sound and implementable, and aligned with sustainability goals.

To maximize the impact of the survey findings, key results and insights will be strategically disseminated through multiple channels. Fact sheets will provide concise, accessible summaries highlighting key findings for specific stakeholder groups. Practice abstracts will offer practical applications of survey insights for agricultural advisors and farmers. The consortium will also organize webinars as interactive online sessions to present findings and engage with broader audiences. Additionally, digital platforms including project websites and social media will be utilized to reach diverse stakeholders. This multi-channel dissemination strategy ensures that valuable

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insights from the farmer survey reach relevant audiences in formats tailored to their specific needs and preferences, ultimately supporting the adoption of sustainable soil management practices across European agricultural systems.

6. References

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7. Annex

1. Soil-X-Change Farmer Survey Template

Soil-X-Change

Soil-X-Change Survey 2024

Fields marked with * are mandatory.

Soil-X-Change

INTRODUCTION

Dear participant, welcome to the Soil-X-Change survey of adaptation of sustainable soil management methods and technology!

Soil-X-Change is an acronym of an EU funded Horizon Europe project "Fostering cross-border knowledge exchange and co-creation on sustainable soil and farm management" with a mission to facilitate connections among farmers, stakeholders, policy makers, projects, and initiatives, accelerating innovation in sustainable soil and farm management.

The aim of this survey is to collect constraints and barriers affecting technology adaptation, drivers and preferences, needs and possible gaps of sustainable soil and farm management strategies. The collected information will be used to create solutions that are more closely aligned with farmers' needs, ultimately improving the adoption of beneficial agricultural technologies and practices. The survey lasts maximum 20 minutes. There are no right or wrong answers, we are curious about your views.

Your input is instrumental in shaping sustainable soil and farm management strategies that are better tailored to practitioner's' needs. By participating in the survey, you may influence the development of policies and practices that will affect daily operations. Respondents will gain access to a comprehensive source of best practices and innovative solutions that have been vetted and proven effective. This will help to improve soil health, increase crop yield, and enhance overall farm sustainability.

We offer selected farmers who take part in the survey and the subsequent focus group discussions the opportunity to share their experiences and highlight shortcomings so that recommendations for action can be derived for policy makers. In Soil-X-Change, we are also developing an information platform on which farmers can expand their knowledge of sustainable soil management and its economic benefits. In addition, the exchange between farmers is promoted in practical workshops and discussion rounds.

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The survey data will be analyzed to compare differences in the adoption of soil and crop management practices across different regions, that can help identify specific factors that influence technology adoption. Advanced statistical techniques will highlight which factors (e.g., financial incentives, access to information, training) are most important in influencing farmers' decisions. By comparing farmers' needs and barriers with available solutions and practices, gaps will be identified. This will help in developing targeted interventions to address unmet needs and remove obstacles to technology adoption. Based on the survey findings, policy briefs and recommendations will be developed to guide policymakers in creating supportive frameworks that encourage the adoption of sustainable agricultural practices.

Do you have any questions or comments? You can contact us: info@soil-x-change.eu or Survey Studies Leader: Discovery Center Nonprofit Ltd. (tgyarmati@drdc.eu).

CONSENT STATEMENT

Rest assured that this study will not disseminate any personal information. The data collected will be presented in an aggregated format and through simple statistical indicators. We ensure anonymity and compliance with current privacy and personal data protection laws (Regulation EU no. 679/2016, known as the "European Regulation on the Protection of Personal Data" - GDPR).

By selecting the consent box below:

- I am voluntarily participating in this activity.
- I understand that my participation involves providing responses to a survey, where I will be asked to share my views and experiences on the barriers and needs of farmers to apply methods of sustainable soil management.
- I have the right to seek clarification about my participation in the survey and receive clear answers before making any decisions by contacting the Survey Studies Leader: Discovery Center Nonprofit Ltd. (tgyarmati@drdc.eu) or the project responsible at info@soil-x-change.eu.
- I reserve the right to decline answering any questions I do not wish to discuss. I am free to discontinue my participation at any time.
- My survey responses will be recorded, and digital copies will be securely stored. Any physical copies made of my responses will be safely maintained by the Soil-X-Change team and will be disposed of when they are no longer necessary, or within five years after the project's conclusion (whichever occurs sooner).

☐ I consent

SECTION 1: ABOUT YOU

*** 1. I am giving my contribution as a(n)...**

○ a farmer/farm manager

○ non-farmer

If you are non-farmer, please specify:

[ ]

2

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* 2. In which country is your farm or organization/company located?

- AT - Austria
- BE - Belgium
- BG - Bulgaria
- HR - Croatia
- CY - Cyprus
- CZ - Czechia
- DK - Denmark
- EE - Estonia
- FI - Finland
- FR - France
- DE - Germany
- EL - Greece
- HU - Hungary
- IE - Ireland
- IT - Italy
- LV - Latvia
- LT - Lithuania
- LU - Luxembourg
- MT - Malta
- NL - Netherlands
- PL - Poland
- PT - Portugal
- RO - Romania
- SK - Slovak Republic
- SI - Slovenia
- ES - Spain
- SE - Sweden

* 3. What farming methods do you employ?

- Organic
- Conventional

* 4. In which of the following sector are you active?

Multiple answer is possible.

- Arable farming
- Animal farming
- Mixed farming (crops and animals)
- Horticulture without green house
- Horticulture with green house
- Viticulture
- Fruit farming
- Olive
- Agroforestry
- Forestry
- Other

If Other, please specify:

* 5. What is your farm size? How much land do you farm in total?

- Less than 5 ha
- 6-50 ha
- 51-100 ha
- 101-250 ha
- 251-500 ha
- More than 500 ha
- No land

* 6. What is your age range?

- Below 30
- From 30-39
- From 40-49
- From 50-64
- 65 or over

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SECTION 2: GENERAL KNOWLEDGE/VIEW ON SUSTAINABLE SOIL MANAGEMENT PRACTICES

In this section we would like to know what farmers, practitioners or other stakeholders know and think about Sustainable Soil and Farm Management Practices in GENERAL.

7. Please indicate to what extent you are familiar with the below listed sustainable soil and farm management practices.

	Heard of (but never used it)	Have practical experience	Did not hear about
* Minimum tillage *A soil-conserving system with the aim of reducing soil cultivation to a minimum, e.g. direct sowing, no-till, strip-till, ridge-till, and mulch-till systems.*	○	○	○
* Cover crops: summer/ autumn and winter cover crop, undersawn crops *Cover crops are grown between the main crops, undersown crops with the main crop. In most cases, the above-ground biomass is left on the field.*	○	○	○
* Intercropping: mixed cultivation or strip cropping *Planting or growing two or more crops together at the same time and on the same arable land in a beneficial manner.*	○	○	○
* Integrated Pest Management (IPM) *Combination of strategies to effectively control pests' populations, while minimizing the risk for people and environment.*	○	○	○
* Microbiological products *Products including beneficial bacteria, fungi and other microorganisms that interact with plants and soil in beneficial ways.*	○	○	○
* Biochar *Application of charcoal as a soil amendment.*	○	○	○
* Mulching *A covering of the soil, usually made of organic materials such as plants or straw. The soil is completely covered with this.*	○	○	○
* Liming *Applying neutralizing agents, such as limestone, basic slag, hydrated lime, or quick lime, to soil or water for the purpose of increasing its basicity (pH and alkalinity).*	○	○	○
* Precision agriculture: site-specific management *Site-specific adaptation of inputs and practices for optimal crop production and resource efficiency.*	○	○	○
*			

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Precision agriculture: Use of digital soil mapping technologies *High-resolution soil property analysis through technology to guide precise application of inputs, e.g. soil sensors, drones, variable rate application equipment.*	○	○	○
* Terraces *The soil of arable land or grassland is laid out in stages.*	○	○	○
* Contour farming *Practice that involves growing crops parallel to the land's contours, creating natural barriers, ridges and furrows.*	○	○	○
* Water harvesting and conservation *Collecting and storing rainwater through the construction or use of physical structures (e.g. terraces, check dams, ponds, tanks).*	○	○	○
* Drainage systems *Process of directing excess water to or away from root zones by natural or artificial means.*	○	○	○
* Livestock integration *Practice of combining crop and livestock production systems.*	○	○	○
* Rotational grazing *Practice where livestock is moved between different pasture sections in a planned sequence.*	○	○	○
* Non-rotational grazing *Involves continuous grazing in a single pasture without being moved to different sections.*	○	○	○
* Agroforestry *Practice that involves integrating woody vegetation (trees or shrubs) with crop and/or animal systems on the same land.*	○	○	○
* Bush and tree fallows *Practice where fields are left uncultivated for a period, allowing natural vegetation regrowth, before replanting crops.*	○	○	○
* Buffer strips with woody species *Conservation buffers are small areas or strips of land in permanent vegetation, designed to intercept pollutants and manage other environmental concerns.*	○	○	○

Other, please specify:

*** 8. Where do you get information about sustainable soil and farm management practices?**

Multiple answer is possible.

- ☐ Other farmers / end users
- ☐ Journals
- ☐ Exhibitions, fairs, expo
- ☐ Advisors
- ☐ Innovation brokers

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- ☐ Officials at regional / national authorities
- ☐ Input dealers / technology suppliers
- ☐ Researchers
- ☐ My own experience, testing
- ☐ Other

If Other, please specify:

9. What are, in your opinion, the top 3 reasons in general of applying any sustainable soil and farm management practices?
Please rank the main 3 reasons.

(only the top 3 reasons should be chosen, so only 3 rows should be filled)

at most 3 answered row(s)

	1 Most important reason	2 Second most important reason	3 Third most important reason
Improving soil properties	○	○	○
Adaptation to climate change	○	○	○
Increasing agricultural productivity	○	○	○
Reducing effect on the environment	○	○	○
Increasing food security	○	○	○
Adhering to EU agricultural policies and subsidies	○	○	○
Adaptation to consumer demand	○	○	○
Demonstration of success from other farmers / comparison with other farmers	○	○	○
Strategic market position	○	○	○
Increasing profitability	○	○	○
Enhancing welfare	○	○	○

10. What are, in general the barriers of applying sustainable practices in your country?
Please rank by importance, most important barrier on the top, least important barrier at the end.

Use drag&drop or the up/down buttons to change the order or accept the initial order.

- ⠿ Economic constraints
- ⠿ Infrastructure and technology limitations
- ⠿ Policy frameworks

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- Knowledge gaps
- Social dynamics
- Climate and environmental risks

SECTION 3: EXPERIENCE WITH SUSTAINABLE SOIL MANAGEMENT PRACTICES

In this section we are interested in YOUR OWN experience in regard of sustainable soil and farm management practices.

* Do you have experience with such practices?

- Yes - please answer below questions
- No - please proceed to section 4

11. Which of the below listed sustainable soil and farm management practices have you applied? Please indicate to what extent.

	Tested it	Use it	Used it (and quit using it)
Minimum tillage *A soil-conserving system with the aim of reducing soil cultivation to a minimum, e.g. direct sowing, no-till, strip-till, ridge-till, and mulch-till systems.*	○	○	○
Cover crops: summer/ autumn and winter cover crop, undersawn crops *Cover crops are grown between the main crops, undersown crops with the main crop. In most cases, the above-ground biomass is left on the field.*	○	○	○
Intercropping: mixed cultivation or strip cropping *Planting or growing two or more crops together at the same time and on the same arable land in a beneficial manner.*	○	○	○
Integrated Pest Management (IPM) *Combination of strategies to effectively control pests' populations, while minimizing the risk for people and environment.*	○	○	○
Microbiological products *Products including beneficial bacteria, fungi and other microorganisms that interact with plants and soil in beneficial ways.*	○	○	○
Biochar *Application of charcoal as a soil amendment.*	○	○	○

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Mulching *A covering of the soil, usually made of organic materials such as plants or straw. The soil is completely covered with this.*			
Liming *Applying neutralizing agents, such as limestone, basic slag, hydrated lime, or quick lime, to soil or water for the purpose of increasing its basicity (pH and alkalinity).*			
Precision agriculture: site-specific management *Site-specific adaptation of inputs and practices for optimal crop production and resource efficiency.*			
Precision agriculture: Use of digital soil mapping technologies *High-resolution soil property analysis through technology to guide precise application of inputs, e.g. soil sensors, drones, variable rate application equipment.*			
Terraces *The soil of arable land or grassland is laid out in stages.*			
Contour farming *Practice that involves growing crops parallel to the land's contours, creating natural barriers, ridges and furrows.*			
Water harvesting and conservation *Collecting and storing rainwater through the construction or use of physical structures (e.g. terraces, check dams, ponds, tanks).*			
Drainage systems *Process of directing excess water to or away from root zones by natural or artificial means.*			
Livestock integration *Practice of combining crop and livestock production systems.*			
Rotational grazing *Practice where livestock is moved between different pasture sections in a planned sequence.*			
Non-rotational grazing *Involves continuous grazing in a single pasture without being moved to different sections.*			
Agroforestry *Practice that involves integrating woody vegetation (trees or shrubs) with crop and/or animal systems on the same land.*			
Bush and tree fallows *Practice where fields are left uncultivated for a period, allowing natural vegetation regrowth, before replanting crops.*			
Buffer strips with woody species *Conservation buffers are small areas or strips of land in permanent vegetation, designed to intercept pollutants and manage other environmental concerns.*			

Other, please specify:

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* **12. We would like you to choose a sustainable soil management practice or a combination of some (holistic approach), you have applied and have the most experience with and answer the questions considering the chosen method.**
Please name the practice you will refer to in this section of the survey. Use the definitions from the previous question.
Applied practice or combination of practices (holistic approach):

* **13. Which of the following drivers impacted your adoption of the applied sustainable soil management practice(s)?**
Multiple answer is possible.
(Applied practice means your chosen practice you have defined in question 12)

- ☐ Economic factors
- ☐ Market Demand and Consumer Preferences
- ☐ Environmental Concerns
- ☐ Policy and Regulatory Support
- ☐ Access to Knowledge and Extension Services
- ☐ Farmers' Values and Beliefs
- ☐ Risk Management and Resilience
- ☐ Community and Social Networks

Other, please specify:

* **14. What are your benefits of applying this/these practice(s)?**
Multiple answer is possible.
(Applied practice means your chosen practice you have defined in question 12)

- ☐ Improved Soil Health
- ☐ Reduced Soil Erosion
- ☐ Water Conservation
- ☐ Climate Change Mitigation
- ☐ Biodiversity Conservation
- ☐ Reduced Environmental Pollution
- ☐ Resilient Agriculture Systems
- ☐ Enhanced Crop Yields
- ☐ Increased profitability
- ☐ Economic Benefits
- ☐ Better market position
- ☐ Social advantages

Other, please specify:

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15. How do benefits of the chosen applied practice(s) compare with the establishment cost?
Please indicate your answer by adding ratings as 1-Negative; 2- Neutral; 3-Positive.

	Ecological benefits (in terms of soil health, soil preservation, increase soil quality)	Economic benefits (cost savings, increased yields)
Direct costs (financial investment)		
Indirect costs (labor, time)		

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* **16. How effective is/are the practice(s) you used regarding soil health?**

- Not effective
- Neutral
- Effective
- I do not know

17. Please explain the positive effect of the chosen applied practice(s) you experienced on soil health!

18. Have you identified any negative consequences in general and regarding soil health of applying such practice(s)? Please explain the negative effects you experienced!

Negative consequence in general:

Negative consequence regarding soil health:

If you have used different sustainable soil management practices but stopped, please answer below questions:

19. Which practice(s) did you apply but decided to quit?

20. How long did you use this/these practice(s)?

21. What was your main reason to quit?

22. Would you suggest and recommend to other farmers to use the method(s) you applied?

- Yes
- No

Please explain why:

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SECTION 4: FUTURE PLANS WITH SUSTAINABLE SOIL MANAGEMENT PRACTICES

In this section we are interested in your view on future application of sustainable soil and farm management practices.

* **23. Do you have plans to apply other/new sustainable soil and farm management practice?**

- No
- Yes, please complete following questions

24. If you answered Yes to the previous question, which sustainable soil and farm management practice would you try in the future?
You can use the list as a reference or add other.

- Minimum tillage
- Cover crops: summer cover crop
- Cover crops: autumn and winter cover crop
- Cover crops: intercropping
- Integrated Pest Management (IPM)
- Microbiological products
- Biochar
- Mulching
- Liming
- Precision agriculture: site-specific management
- Precision agriculture: Use of soil testing technologies
- Terraces
- Contour farming
- Water harvesting and conservation
- Drainage systems
- Livestock integration
- Rotational grazing
- Non-rotational grazing
- Agroforestry
- Bush and tree fallows
- Buffer strips with woody species

Other, please specify:

* **25. What were your barriers for applying this practice till now?**
Please rank from least to most important.

Use drag&drop or the up/down buttons to change the order or accept the initial order.

- Financial Constraints
- Short-Term Economic Pressures

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- Infrastructure and Technology Limitations
- Scaling up limitations
- Land Tenure and Property Rights
- Policy and Institutional Barriers: Inadequate policy support, regulatory frameworks
- Knowledge and Awareness Gaps
- Cultural and Social Factors
- Climate and Environmental Risks

*** 26. What are your expected benefits of applying this new practice?**

Multiple answer is possible.

- ☐ Improved Soil Health
- ☐ Reduced Soil Erosion
- ☐ Water Conservation
- ☐ Climate Change Mitigation
- ☐ Biodiversity Conservation
- ☐ Reduced Environmental Pollution
- ☐ Resilient Agriculture Systems
- ☐ Enhanced Crop Yields
- ☐ Increased profitability
- ☐ Economic Benefits
- ☐ Better market position
- ☐ Social advantages

Other, please specify:

____

*** 27. Which of the following could aid you in adopting new sustainable soil management techniques?**

Multiple answer is possible.

- ☐ Other farmers/end users
- ☐ Advisors
- ☐ Innovation support service
- ☐ Regional/national authorities
- ☐ Living Labs
- ☐ Collaboration with researchers
- ☐ Subsidies for environmentally friendly farming
- ☐ Supporting financial incentives
- ☐ Policy coherence
- ☐ Access to equipment
- ☐ Targeted projects
- ☐ Publications/toolboxes (newsletters, flyers, booklets, guidelines) of results of national or European projects

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- ☐ Dedicated events organised by successful project
- ☐ On-farm demonstration of alternative methods
- ☐ Increased availability of easy to reach and understand information
- ☐ Peer to peer learning and knowledge exchange
- ☐ Personal coaching and advice
- ☐ Training courses for practitioners
- ☐ Project's digital product/app for practitioners

Other, please specify:

CLOSING QUESTION

A number of respondents to this survey might be contacted for a follow-up phone interview or focus group discussion to look in more details at their replies. Would you agree to be contacted for such a follow-up?

- ☐ No
- ☐ Yes

If Yes, please provide your email and/or phone number:

Your data will not be shared and will be safely maintained by the Soil-X-Change team. You have the right to withdraw your participation at any time and decline answering any questions you do not wish to discuss.

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