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SoildiverAgro

Soil biodiversity enhancement in European agroecosystems to promote their stability and resilience by external inputs reduction and crop performance increase

D6.5 REPORT ON CROSS-CASE STUDY COMPARATIVE ANALYSIS

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D6.5 REPORT ON CROSS-CASE STUDY COMPARATIVE ANALYSIS

Summary

As part of Work Package 6 (WP6) of the SoildiverAgro project, Task 6.3.3 conducted a comparative cross-case study analysis to evaluate the environmental, economic, and social impacts of various soil management practices tested across diverse pedoclimatic regions.

The analysis revealed that several agricultural practices, such as **minimum or reduced tillage, reduced use of inorganic fertilizers, crop rotations, and organic farming**, consistently **demonstrated both environmental benefits and economic viability**. These results are broadly aligned with the preferences of farmers and stakeholders, as well as with observed trends in adoption. In contrast, practices such as biostimulants and carbon addition were found to be economically unviable or lacked sufficient environmental impact data, limiting their potential for broader implementation.

Key barriers to adoption include limited technical knowledge, inadequate advisory support, and the absence of enabling policy frameworks. Moreover, past behaviour emerged as a significant factor influencing current decision-making, highlighting the difficulty of altering entrenched agricultural practices. The study stresses the importance of shaping farmers' attitudes and perceived behavioural control through targeted information dissemination, on-farm demonstrations, and peer-to-peer learning networks.

From a policy perspective, the report highlights the need for regionally tailored incentives, including performance-based payments for ecosystem service provision, alongside increased investment in local research, extension services, and capacity building. While relatively simple and clearly beneficial practices may only require moderate support, more complex or less profitable approaches will necessitate strong institutional and financial backing to ensure successful adoption and long-term sustainability.

Deliverable Number		Work Package	
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	DEC	Websites, patents filing, press & media actions, videos	
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Dissemination Level	PU	Public	X
	CO	Confidential, only for members of the consortium	



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The main objective of SoildiverAgro is the adoption of new management practices and cropping systems that enhance soil genetic and functional biodiversity to reduce the use of external inputs while increasing crop production and quality, the delivery of ecosystem services and the EU agricultural stability and resilience. The project has tested new management practices with realistic potential for meeting end users' needs through soil biodiversity enhancement in the case studies' on-field experiments in WP5 (Figure 1).

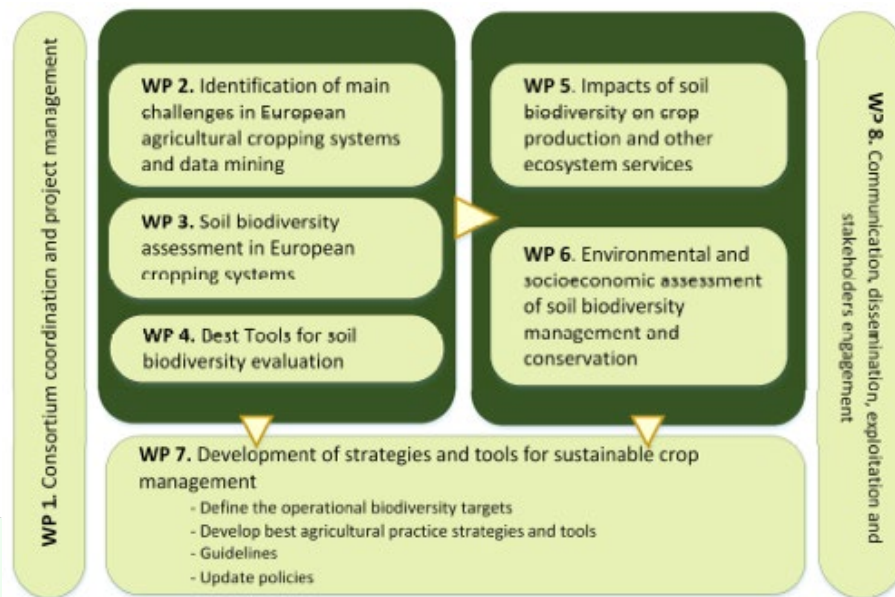


Figure 1. SoildiverAgro's Work Packages structure.

WP6 focuses on the environmental and socio-economic analysis of tested soil biodiversity management farming practices to see if they provide real benefits for farmers and society. The main aim of WP6 is therefore to assess the environmental, economic and social costs and benefits of proposed management practices and cropping systems that might positively affect soil biodiversity.

Within SoildiverAgro's WP6, sub-task 6.3.3 (Enabling environment for biodiversity enhancing management practices through comparative analysis across case studies) focuses on assessing the transferability of soil management practices across pedoclimatic regions based on a comparative cross-case study analysis. It aims to make the project's results useful for policy and decision makers, while identifying options to make practices profitable for farmers that do not pay-off in the short run.

This report presents the outcome of task 6.3.3 by comparing, on a summarised fashion, the results of the different case studies (comparative cross-case study analysis), including an assessment of critical factors affecting the adoption of the soil biodiversity enhancing management practices. The findings will be used in WP7 to develop practical guidelines and tools for sustainable crop management.

The sources used in this report for the comparative cross-case study analysis are the following SoildiverAgro deliverables:

- “Common integrated environmental-socio-economic framework and research methodology” ([Deliverable 6.1](#)): defines the approaches used for the environmental-socio-economic assessment.
- “Economic Assessment of Soil Biodiversity Enhancement at Farm, Regional, and EU Level” ([Deliverable 6.3](#)): presents the results of the assessment of the environmental and economic impact of the management practices tested in the project’s experimental activities, including:
 - On-farm financial analysis (impact of practices on crop profitability);
 - On farm environmental analysis (environmental cost-benefit analysis);
 - Economic impact at EU Member States level;
 - Economic impact at EU level.
- Farmers’ adoption of sustainable soil management practices ([Deliverable 6.4](#)): presents the results of the analysis of barriers and drivers for the adoption of different sustainable soil management practices in several of the case studies.
- Report of data compilation from discussion groups and surveys ([Deliverable 2.1](#)): presents the results from a survey to stakeholders and discussion groups with stakeholders to assess the effectiveness of practices in facing the major agro-environmental problems in each case study, as well as barriers for their practical implementation.

The soil management practices that were tested in the experimental activities of SoildiverAgro’s case studies are shown in Table 1. However, not all the assessments in WP6 were carried out for all case studies and/or for alternative management practices. More specifically:

- The on-farm financial analysis was carried out for all case studies and alternatives (see [Deliverable 6.3](#));
- The on farm environmental analysis (environmental cost-benefit analysis) was carried out for the alternatives in case studies 1, 4, 8, 9, 11 and 14 b (see [Deliverable 6.3](#));
- The adoption analysis was carried out for specific alternative practices in case studies 1 (biostimulants), 3 (crop diversification), 6 and 7 (non-inversion tillage) 10b (diversification by undersowing) 12 (no tillage) and 14a (cover crops plus minimum tillage) (see [Deliverable 6.4](#)).
- The assessment of the economic impact at both EU Member States level and EU level considered only the no tillage and organic farming as alternatives (see [Deliverable 6.3](#)).
- Additionally, the assessment in WP 2 ([Deliverable 2.1](#)) included most of the management practices tested in case studies.

The fact that not all the assessments have been carried out in all the case studies and for all the management practices restricts the extent to which a cross-case study can be performed using quantitative analysis methods. Consequently, we have opted to compare the results of the different assessments carried out considering the type of management practice as the element around which the comparative analysis is structured.

After this introductory section, we present the comparative analysis of the results obtained for each type of practice across case studies, and we end by summarising the main findings of the economic analysis, including some policy implications.

Table 1. Management alternatives analysed in SoildiverAgro's case studies.

Case study	Main crop	Pedoclimatic region	Alternatives to conventional management (control)
1	Potato-based crop rotation	Mediterranean south	Reduced fertilization
			Bioestimulants
2	Cereal-based crop rotation	Mediterranean south	Reduced fertilization
			Bioestimulants
3	Potato-based crop rotation	Lusitanian	Rotation with legumes
			Trap crops
4	Potato-based crop rotation	Lusitanian	Reduced P fertilization
			Zero P fertilization
			Bioestimulants
5	Potato-based crop rotation	Lusitanian	Pest alert system
			No fungicide application
6	Potato (rotation with barley and vegetables)	Atlantic Central	Fertilization with compost
			Fertilization with manure
			Cover crop removed (vs incorporated)
7	Potato (rotation with Broccoli and beet)	Atlantic Central	Cover crop (2-species mixture)
			Cover crop (5-species mixture)
			Cover crop (12-species mixture)
8	Rotation of vegetables	Atlantic Central	Extensive production
			Organic production
9	Organic Wheat-potato rotation	Atlantic Central	Fertilization with farmyard manure
			Fertilization with worm compost
			Fertilization with fermented org matter
10a	Wheat (rotation with potato)	Continental	Bioestimulants
			Plant adjuvant
10b	Organic potato (rotation with wheat and mustard)	Continental	Strip undersowing
			Broad undersowing
11	Winter wheat (rotated with silage)	Continental	Extensive farming
			Clover undersowing
12	Winter wheat	Nemoral	No tillage compared to reduced tillage
12	Winter rape	Nemoral	No tillage compared to reduced tillage
12a	Cereal-based crop rotation	Nemoral	No tillage
12a			Organic farming
13	Potato (without rotation)	Boreal	Carbon addition using null fibre
			Carbon addition using nutrient fibre
14 a	Wheat (rotation with pea)	Boreal	Soil cover + minimum tillage
14 b	Wheat (rotation with pea)	Boreal	Minimum tillage
15	Potato (without rotation)	Boreal	Use of catch crops (rye)
			Use of catch crops (honey flower)

2.1.1. Soil management alternatives

2.1. Soil management alternatives

Different tillage alternatives were analysed for wheat-based systems in the Finish Boreal and Estonian Nemoral study areas. Based on their results, **minimum tillage** appears as the most profitable alternative due to its lower costs compared to both conventional tillage and no tillage. In terms of the environmental costs, the analysis carried out in the Boreal study area shows similar environmental costs per unit of gross margin for both minimum tillage and conventional intensive tillage, but a slightly lower environmental cost for minimum tillage when the environmental cost per hectare is considered.

No tillage significantly increases production costs, being more profitable than conventional tillage but less than minimum tillage. Its economic impact was analysed at the EU level, concluding that a shift to no tillage would cause small reductions of food production across the EU with some environmental benefits related to decrease soil erosion, without significant reductions in chemical run-off and/or GHG emissions taking place.

This is consistent with the assessment of stakeholders' preferences for farming practices carried out in WP2. Although there was a controversy between the use of conventional tillage and less intensive tillage options in some study areas, a majority of stakeholders consider that reducing tillage intensity is the best alternative to face the agronomic and environmental challenges in their study area, with a marked preference for minimum tillage and, to a lesser extent shallow tillage. Additionally, the results of the adoption survey analysis showed that over 70% of total surveyed farmers were using or intending to plough less frequently and reduce tillage depth, compared to the 40% that expressed interest in no tillage.

The introduction of **cover crops** was only studied for potato-based systems in the Atlantic study area, where a positive effect on crop revenue and profit was found but only when multispecies covers were used. The environmental costs analysis was not carried out for this specific practice. In the assessment of stakeholders' preferences for farming practices carried out in WP2, the use of cover crops received relatively large effectiveness indexes in some study areas but not in others, differences that might be caused by the diverse ways in which cover crops can be, or are being implemented in each region and crop. Related to this, only 52% of total farmers for the adoption analysis were using or intending to introduce cover crops, with significant differences among areas, compared with the 79% of farmers expressing interest in incorporating crop residue to the soil. Additionally, cover crops and incorporating crop residues were seen by the surveyed farmers as ones of the farming practices that more contribute to improving soil quality.

2.2. Fertilisation and soil amendment alternatives

Different fertilisation and soil amendment options were analysed in several case studies, in most of them including the environmental costs analysis.

The use of **organic sources of nutrients** was analysed in two case studies (potato and organic wheat-potato rotation) in the Atlantic study area. Despite the increase in direct costs, it has a positive effect on revenue, resulting in increases in profitability for conventional production and more modest ones for organic production. The environmental costs were only analysed for the organic wheat-potato rotation. The increase in crop profitability was accompanied by an increase in environmental costs, very small for the use of compost but significantly high for the use of cattle manure. This is consistent with the assessment of stakeholders' preferences for farming practices carried out in WP2, where stakeholders in general pointed at the need for a shift towards the use of organic fertilisation sources. Stakeholders across case studies coincided in choosing the addition of solid organic matter and manures or the use of green manure as the most effective fertilisation alternative. Additionally, covering field with organic matter were seen by farmers surveyed in the adoption analysis as ones of the farming practices that more contribute to improving soil quality.

Three case studies have demonstrated the **potential for reducing fertilization**, with very positive results. In both the Mediterranean South (potato and wheat) and Lusitanian (potato) case studies, reducing the application of fertilizers allowed to maintain crop revenue and produced a significant reduction in production costs, resulting in an increase profitability. Additionally, environmental costs analysis demonstrated that reducing fertilization significantly reduces the environmental costs of production.

The opposite result was found for the **application of biostimulants/biofertilizers** in the three above cases plus the Continental area (wheat-potato rotation). Their application does not have a positive impact on crop revenue but increases production costs in all the tested cases and, therefore, based on our results, it is not a profitable alternative. Regarding the environmental costs, these increased with the use of biostimulants/biofertilizers in the Mediterranean South case study but showed some reduction in the Lusitanian one. Again, this is consistent with the assessment of stakeholders' preferences for farming practices carried out in WP2, where biostimulants, biofertilizers, mycorrhizas and new generation fertilizers are not perceived as effective alternatives (with the exception of the Mediterranean South and Continental potato cases), and with the adoption survey analysis that showed a moderate interest towards them.

Last, **carbon addition**, tested in the Boreal case study area, has a negative effect on production costs and profitability. The environmental costs analysis was not carried out for this specific practice.

2.3. Crop diversification alternatives

Four case studies tested crop diversification options. First, the **rotation of potato with legumes** in the Lusitanian study area reduced production costs and increased profitability. Second, an opposite result was obtained in the Boreal study area, where the use of **catch crops** on potato had a negative effect on crop yield, production costs and gross margin. The environmental costs analysis was not carried out for these two practices.

Last, crop diversification through **undersowing** was tested in two case studies in the Continental area, with conflicting results: a very negative effect on crop revenue and profitability for organic potato production and the opposite result in winter wheat. The environmental costs were only assessed for winter wheat, yielding that the diversification of wheat significantly reduced the environmental cost with respect to the undiversified alternative.

The results of the adoption survey analysis allow us to further delve into the issue of crop diversification. While 74% of total surveyed farmers expressed their interest in long rotation periods, only 55% expressed their interest in intercropping or undersowing, what might suggest a that farmers perceive more advantages in crop rotation than in intercropping, for which a greater degree of uncertainty seems to be perceived.

Despite the mixed empirical evidence of the economic benefits of crop diversification alternatives, crop diversification (either intercropping, rotations or multiple cropping), was the most preferred alternative for stakeholders participating in WP2's assessment, not only as an alternative for improving soil conditions but also for improving plant protection. Another related relevant result is that the vast majority of the participating stakeholders perceived that farming practices are more effective in addressing each cropping system's needs when integrated within a diversified cropping system.

2.4. Plant protection

Plant protection alternatives were only tested In the Spanish Lusitanian area (potato), yield different results depending on the specific option considered. The use of **trap crops** was found to be significantly less costly and more profitable than conventional pest management, while using **pest alerts** and **eliminating fungicides** had a very significant negative impact on yields and thus on profitability. This partly coincides with the assessment of stakeholders' preferences for farming practices carried out in WP2, where stakeholders in general pointed towards crop diversification and increasing invertebrates soil biodiversity as the best alternatives to improve plant protection, and where pest alerts and trap crops were not perceived as very effective alternatives. Even in pedoclimatic areas, such as the Atlantic, where trap crops were among the preferred alternative, they didn't receive very high effectiveness scores.

2.5. Organic farming and low-input systems

Some case studies also looked to changes in production beyond individual farming practices. A more **extensive production**, implying changes in tillage, fertilization, cover crops, and plant protection methods, was tested in both the Atlantic (vegetables) and Continental (winter wheat) areas, whose findings show a negative impact on crop yields and profitability in both cases, but also an increase in the environmental costs.

Contrarily, **organic farming**, tested in both the Atlantic (vegetables) and Nemoral (cereal-based rotation) study areas, was found to be more costly than conventional production but significantly more profitable, being in fact the option that results in greater relative increases in profitability among all those analysed in the project. Moreover, in the Atlantic case study this was accompanied by a significant reduction of the environmental costs. The environmental costs analysis was not carried out for organic farming in the nemoral study area. However, its economic impact at the EU level was analysed, concluding that a shift to organic farming would lead to a significant reduction in crop production and crop value added, with significant variations between EU countries (e.g. a significant increase in crop value added in the southern fruit and vegetables production areas), together with a reduction in chemical run-off, soil erosion and GHG emissions and an increase in soil biodiversity.

2.6. Barriers for adoption

WP6's activities included an analysis of barriers and drivers for the adoption of different sustainable soil management practices in each of the five case studies ([Deliverable 6.4](#)), which adds significant evidence to the stakeholders' assessment of preferences for farming practices in WP2 ([Deliverable 2.1](#)).

When asked about barriers that they perceive that can difficult the adoption of different more sustainable farming practices, stakeholders surveyed in WP2 pointed out similar issues with relation with different types of farming practices (soil management and tillage, soil conservation, fertilization, crop diversification, plant protection, etc.). First, most stakeholders pointed out at the lack of farmers' knowledge regarding the real effectiveness of farming practices and, to a lesser extent, the lack of tradition among farmers in the area, as very relevant barriers. Second, stakeholders emphasized the importance of relying on technical advice for an adequate and profitable implementation due to the complexity of some farming practices, especially in relation with the use of cover crops, organic fertilization and different crop diversification alternatives. Directly related to this is the perception of some stakeholders, especially farmers, that support from the government on technical issues is inadequate or insufficient. Third, the lack of enabling legislation/regulation is also highlighted by stakeholders in some case studies, especially with respect to fertilization and plant protection practices. Last, although some stakeholders point out at the relatively higher implementation cost of some farming practices, in general, a vast majority of stakeholders do not perceive sustainable farming

practices as difficult to implement, should adequate technical advice be available, or do not consider the lack of profitability as a barrier for their implementation.

Consistently with the above, the adoption analysis showed that attitudes towards farming practices were very positive and more important than perceived behavioural control or moral obligations, being social norms the less important factor. Attitudes reflect farmers' perceptions of farming practices and their capacity to improve soil quality and meet other farmer's objectives. Perceived behavioural control represents the perceived ease or difficulty of implementing farming practices. Moral obligation reflects the perceived responsibility to engage in sustainable soil management practices. Social norms represent the perceived social pressure impelling them to adopt sustainable farming practices in order to improve soil quality.

The adoption analysis also showed that the intention to adopt soil-improving farming practices was largely influenced by past behaviour, together with the attitudes towards farming practices and the perceived difficulty of implementing them (perceived behavioural control). The influence of past behaviour indicates that positive prior experiences increase the interest in applying a given practice. Attitudes emerge from farmer's behavioural beliefs regarding a specific farming practice and its capacity to lead to specific results, being the impact of farming practices in environmental and soil quality factors the most influential beliefs.

Regarding implementation difficulties, relevant control beliefs shaping perceived behavioural control are related to information and knowledge availability, implementation costs of farming practices and dependence on weather conditions, with little influence from supporting policies. In general, the different practices analysed were not perceived as neither easy nor difficult to implement. Last, social norms were influenced with the opinions of diverse groups, being experts and peer farmers emphasized as key normative groups.

The most straightforward policy implication of the importance of past behaviour is the need, and the difficulty, to break the behavioural inertias and change farmer's behaviour, something is unlikely to be achieved only through technical advice and/or payments.

Results suggest that the most promising route to behavioural change appears to be through farmer's attitudes, which are influenced by a limited selection of behavioural beliefs regarding the impact of soil management practices. Although the relative importance found for normative beliefs suggest some difficulty of influencing behaviour through advisory services and peer networks, providing information and practical evidences on the impact of sustainable farming practices, especially on soil fertility and on the environment, is of paramount importance.

Additionally, perceptions of controlling factors, which might ease or difficult practice implementation, emphasized the importance of production costs and the need for know-how and examples in the area, what can be addressed by policies supporting the technical aspects of farming practices, starting with financing sound demonstration activities within local networks, and subsidies. Last, and regarding subsidisation, the analysis of farmers

compensation needs revealed the heterogeneity in compensation expectations, highlighting the need for regionally tailored compensation schemes rather than one-size-fits-all approaches.

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Despite the evident limitations of comparing results from different case studies that focus on different farming practices, and where not all the economic assessments have been carried out, it is possible to highlight some general key findings, especially with respect to some specific practices.

First, there are a number of **farming practices that are consistently preferred** by farmers and stakeholders across case studies, as being perceived as more effective in improving soil quality and facing agro-environmental threats. These include reducing tillage intensity (frequency and depth), cover crops, incorporation of crops residues to the soil, increasing the use of organic nutrient sources, crop diversification (with a clear preference for crop rotations against intercropping) and organic farming.

Second, the economic assessment across case studies allows to identify specific soil improvement **farming practices that are both profitable for farmers and less environmentally costly**, in general, consistently with farmers' and other stakeholders expressed preferences for farming practices. These include minimum or reduced tillage, reducing inorganic fertilization and crop rotations. Similarly, organic farming combines a greater private profitability with clear environmental benefits but may pose threats for food security at EU level.

The use of trap crops for plant protection and cover crops also showed positive impacts on farm profitability but their environmental assessment was not assessed, and farmers and stakeholders did not show clear preferences for their use. Evidence is less clear for other options, such as organic fertilization, where a positive economic impact depends on the type of nutrient source, or intercropping, where a decrease in the environmental costs goes together with mixed evidence regarding its profitability.

Third, the analysis identified **unprofitable alternatives that showed positive environmental outcomes**, such as the use of biostimulants/biofertilizers, or for which the environmental analysis was not carried out (catch crops, pest alerts, carbon addition, ...).

Looking at **policies initiatives aimed at promoting sustainable agricultural practices**, our findings suggest that they should be tailored to regional edaphic, climatic conditions but also to economic and social ones. Despite the positive attitudes towards soil improving practices found, the analysis suggests the existence of important inertias in the study areas, as past behaviour significantly determines the current one, what difficults changing farmer's behaviour only through technical advice and/or payments. Attitudes towards farming practices and the perceived difficulty of their implementation were also found to influence



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the intention to adopt soil-improving farming practices, so policies influencing these could be more effective.

At this point, we can make a difference between two types of practices. On one hand, sustainable practices that are perceived as effective in conserving soils but also as relatively easier to implement and profitable (or at least, not unprofitable). These might only require more dedicated extension efforts. On the other hand, farming practices that are perceived as more risky, complex to implement, requiring significant technical support and/or less profitable or even unprofitable. Should they provide essential ecosystem services, the society could profit from targeted policy interventions.

Fostering the widespread adoption of the latter ones would require significant efforts targeted to reshaping farmers beliefs towards them, but also efforts in terms of subsidies, tax incentives for investments and technical support. Based on our results, changing farmers' beliefs would require policies supporting the technical aspects of farming practices. More specifically, practical evidences on the impact and costs of farming practices should be provided through the development of local/regional knowledge and training networks including research and innovation systems, advisory services and peer farmers.

Regarding subsidies, these should not only cover costs or yield gaps, but also finance sound regional research efforts and demonstration activities within local networks. Additionally, payments to farmers should be performance-based, retributing the real provision of ecosystem services.