Check for updates

RESEARCH ARTICLE

A comparative analysis assessment on policy, soils, and water in European countries: A pathway for sustainability

[version 1; peer review: 2 approved with reservations]

Ana Pego, Mohammad Hadad

University of Algarve CinTurs: Research Centre for Tourism Sustainability and Well-being, Faro, Faro District, 8005-139, Portugal

v1 **First published:** 29 May 2026, **6**:182
https://doi.org/10.12688/openreseurope.22272.1
Latest published: 29 May 2026, **6**:182
https://doi.org/10.12688/openreseurope.22272.1

Abstract

Although European efforts to improve water and soil management have improved over recent decades, turning policies into practical actions remains a challenge. In this study we analyze water and soil management policies, institutional arrangements, and market dynamics across 14 European countries (Albania, Cyprus, Czech Republic, Denmark, France, Greece, Italy, Netherlands, Norway, Poland, Portugal, Spain, Turkey, and Ukraine) to understand how they influence the adoption of sustainable practices and new technologies.

We used a mixed-method approach. An extensive review of European and national policies has been undertaken. Additionally, structured questionnaire responses and Excel-based national policy summaries were collected from stakeholders and integrated for cross-country comparison. The comparative analysis suggests that national strategic plans (NSPs) align well with EU frameworks such as the Common Agricultural Policy (CAP) and the Water Framework Directive (WFD), and stakeholders typically report benefits for climate resilience and pollution reduction. Yet implementation often falls short in practice.

Technology adoption appears sensitive to cost and short-term profitability. High technology costs, uncertain returns for farmers, and limited awareness within agricultural communities commonly prevent adoption. Importantly, while policies seem effective at promoting overall sustainability goals, they are less consistently linked to rapid technological adoption.

Plain Language summary

We wanted to understand how different European countries manage their soil and water to help farming become more sustainable. While there are many high-level policies in place, it is often difficult to turn these goals into real-world actions on the farm.

Open Peer Review

Approval Status ? ?

	1	2
version 1 29 May 2026	? view	? view

1. **Mohamed A.E. AbdelRahman**, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

2. **Arturo A. Keller**, University of California Santa Barbara, Santa Barbara, USA

Any reports and responses or comments on the article can be found at the end of the article.

Healthy soil and clean water are essential for our well-being, but intensive farming often damages these resources. In Europe, roughly 60–70% of soil is considered unhealthy because of human activity. We looked at 14 countries - including Spain, Portugal, Poland, and the Netherlands - to see what stops farmers from using new, greener technologies.

We reviewed European and national laws and asked experts and stakeholders for their views through a detailed survey. We then compared how well these countries' national plans align with broader European environmental goals.

Most countries have national plans that match European environmental standards very well. However, there is a clear gap between these plans and what happens on the ground. We found that farmers are often slow to adopt new technologies because of high initial costs, uncertain profits, and a lack of awareness about the tools available.

Our findings suggest that having good laws is not enough. To protect our natural resources for future generations, governments need to provide better financial support, clearer communication, and more hands-on training for farmers. This will help bridge the gap between policy design and practical farming.

Keywords
Water and Soil management, Sustainable agriculture, Environmental policy, Comparative policy analysis, Policy implementation gap

HE This article is included in the Horizon Europe gateway.

Corresponding author: Ana Pego (acpego@ualg.pt)

Author roles: Pego A: Conceptualization, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Supervision, Validation, Writing – Original Draft Preparation, Writing – Review & Editing; **Hadad M**: Data Curation, Formal Analysis, Investigation, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2026 Pego A and Hadad M. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: Pego A and Hadad M. **A comparative analysis assessment on policy, soils, and water in European countries: A pathway for sustainability [version 1; peer review: 2 approved with reservations]** Open Research Europe 2026, **6**:182 https://doi.org/10.12688/openreseurope.22272.1

First published: 29 May 2026, **6**:182 https://doi.org/10.12688/openreseurope.22272.1

1. Introduction

Water and soil play a central role in environmental health and human well-being across Europe. However, protecting them and keeping agriculture productive remains a challenging balancing act. European policy has been evolving for decades in response to growing concerns (public health, climate change, and biodiversity loss), but translating high-level goals into everyday farm practice is not straightforward.

In recent years, governments have pushed policies that try to pair productivity with sustainability. The idea is sensible, but it often runs into trade-offs in practice: measures that protect ecosystems can slow short-term yields or raise costs for farmers. In this article we review how 14 European countries (including Albania, Cyprus, Czech Republic, Denmark, France, Greece, Italy, Netherlands, Norway, Poland, Portugal, Spain, Turkey, and Ukraine), have developed and implemented water and soil management policies, and we look at the institutional and market arrangements that shape real-world outcomes. For clarity, we use "PIM" to mean policy, institutional, and market conditions.

The assessment of the strengths and constraints related to policy, institutional capacity, and market conditions is critical for understanding the feasibility of adopting sustainable agricultural technologies and practices. Analyzing these factors helps assess whether farmers have the necessary access to prerequisites required for the successful adoption of technologies. This assessment is further necessary because investigating these builds the infrastructure for the European countries to adopt technologies within the frameworks of the Common Agricultural Policy and National Strategic Plans, thereby advancing a more sustainable and competitive agricultural sector.

The threats are well known and persistent. Intensive agriculture often plays a major role: overapplication of nitrogen fertilizers and extensive pesticide use, for example, contribute to soil degradation and to the contamination of surface water and groundwater with nitrates, phosphorus, and pesticide residues. Across parts of northern and Central Europe, nitrogen surpluses remain a concern, and groundwater nitrate concentrations have shown little improvement over decades.[1] Soil quality is also being eroded through loss of organic matter, compaction, contamination, and sealing, while water scarcity and more frequent droughts, worsened by climate change, add a worrying new stress. The EU estimates that 60–70% of European soil is unhealthy due to human activities.[2]

To make sense of how policy translates (or fails to translate) into practice, we carried out a comparative assessment of PIM conditions across 14 selected countries. Our analysis draws on EU and national policy documents, structured questionnaire responses from stakeholders, and Excel-based national policy summaries. This approach lets us compare readiness for sustainable practices and technology adoption across various European countries. This comparative assessment will highlight systemic barriers and also identify existing opportunities that can inform future policy design and technology deployment plans to reach long-term environmental and economic sustainability.

2. Literature review

The European Union (EU) has acknowledged the critical role of water and soil in environmental sustainability and human well-being for years. Over recent decades, policy has gradually evolved to confront the progressive degradation of these resources, motivated by concerns that range from public health to climate change and biodiversity loss. More recently, EU policy has emphasized two objectives in responding to global pressures such as resource scarcity and climate risks: maintaining agricultural productivity and enhancing sustainability.[3] This study examines how 14 selected European countries have articulated water and soil management in policy and practice, and it highlights prevailing scientific insights and applied measures intended to foster sustainability.

2.1. Water and soil assessment

Water and soil are fundamental natural resources that are deeply interconnected and essential for human well-being and economic activity. Agricultural ecosystems, for instance, rely on several soil functions, including the production of food, fiber, and fuel, water purification and regulation, carbon sequestration and climate regulation, habitat for biodiversity, and the recycling of nutrients and agro-chemicals.[4] The physical, chemical, and biological characteristics of soil, along with natural and human influences like land use, collectively shape these vital soil functions.

However, human activities have a significant impact on these resources, often leading to degradation. Intensive agricultural practices contribute to environmental problems such as soil erosion and water eutrophication, which leads to threatening both agricultural production and soil functions.[5] Specifically, the excessive use of fertilizers or herbicides can pollute water bodies.[6] Agricultural practices throughout the EU contribute significantly to the pollution of water resources by nitrates, phosphorus, and pesticides.[1] This pollution creates a major risk to water bodies across the EU, with nitrogen surpluses remaining very high in northern and Central Europe and nitrate concentrations in groundwater showing no improvement for 30 years.[1] Similarly, pesticide use has not decreased since 2011, affecting water quality, quantity, ecology, and biodiversity.[1]

In response, the European Commission's Farm to Fork Strategy, a key part of the 2020 European Green Deal, has set ambitious targets to reduce the use and risk of chemical and more hazardous pesticides by 50%, the use of fertilizers by at least 20%, and nutrient losses by at least 50% by 2030.[1] Soil degradation manifests in various forms, including erosion, a decline in organic matter, contamination, sealing, compaction, and a reduction in biodiversity, all of which affect soil quality and its capacity to provide ecosystem services. Additionally, Europe faces increasing challenges from water scarcity and droughts, necessitating effective risk management strategies.

EU policy instruments address many of these concerns. The Water Framework Directive (WFD), together with the Nitrates Directive and the Groundwater Directive, aims to improve water quality and reduce nutrient and pesticide losses to the environment. The WFD promoted Integrated River Basin Management (IRBM) as a holistic planning approach that treats land and water as parts of the same system. Implementing IRBM requires cross-disciplinary understanding and benefits from tools that can quantify variable source pollution and erosion. Agro-hydrological models, for instance the Soil and Water Assessment Tool (SWAT+), are commonly used to estimate sediment and nutrient reductions and to inform targeted mitigation measures.

Despite increased awareness, soil is often not explicitly included in environmental policies, and a comprehensive EU-level soil protection directive is currently lacking. Although the European Commission proposed a Soil Framework Directive, it was ultimately withdrawn due to disagreements among Member States. This absence has led to varied approaches to soil protection across Member States. Ronchi et al.'s study indicates a persistent gap between the scientific understanding of soil degradation and the policy attention it receives.[7] While monitoring tools like CORINE Land Cover and LUCAS Soil provide extensive data on land use and soil properties, policies often remain disconnected from this evidence.[7] For effective soil management, there is a clear need for harmonized targets, monitoring, and evaluation methods across the EU. Enhanced coordination of data and knowledge is crucial for strengthening policy coherence and effective implementation.

2.2. The policy background

The history of European water and soil management policy reflects a long process of adaptation, shaped by shifting priorities from productivity to sustainability. Early agricultural revolutions in the 18th and 19th centuries focused on increasing yields through intensive methods, which, however, led to issues like soil erosion, biodiversity loss, and water contamination.[3] European water and soil management policies have undergone significant evolution. Early EU water policies, initiated in the mid-1970s, focused on setting standards for water uses, such as drinking and bathing, and controlling the discharge of harmful substances.[8,9]

However, these early policies were often criticized for being isolated and fragmented, leading to a recognized need for a more holistic approach.[8] These directives, while sometimes challenged, often led to broader reforms and research, effectively shaping national environmental policies. By the early 1990s, the focus expanded to include controlling diffuse pollution, particularly from urban wastewater and agricultural nitrates. The Nitrates Directive and the Water Framework Directive (WFD) are considered highly relevant for water and also soil quality due to their indirect impacts.

The Common Agricultural Policy (CAP) has undergone a parallel evolution. Once focused primarily on increasing food production, the CAP has integrated environmental dimensions. This evolution recognizing agriculture's dual role as both a source of environmental pressure and a potential contributor to ecosystem services. Reforms have introduced key mechanisms such as cross-compliance, that links funds to farmers to follow environmental standards, and rural development measures, which reward sustainable practices that go beyond legal baselines. Recent initiatives have further strengthened the link between CAP payments and sustainability objectives through "greening" requirements. Empirical work by Pulighe et al. (2025) shows that practices such as no-till farming, filter strips, crop rotation, and grassed waterways can meaningfully reduce soil erosion and improve water conservation which is aligning well with CAP's broader environmental purposes.[5]

The adoption of the Water Framework Directive (WFD) in 2000 represented a strategic revision, promoting integrated management of freshwaters by establishing the river basin as the core management unit. While this directive sets broad objectives for water quality, it also allows Member States flexibility in defining specific standards and measures, embodying the principle of subsidiarity.[8]

Turpin et al. indicate that the "embeddedness" of soil concerns within policy frameworks varies significantly across Member States. Studies show a positive correlation between higher embeddedness levels and national efforts in environmental innovation and increased farmer land ownership.[6] Countries that exhibit higher levels of embeddedness,

alongside strong trust in EU institutions and a commitment to renewable energy, tend to propose a greater number of management practices to address soil-related challenges. Conversely, a higher farm income can sometimes correlate negatively with the number of implemented practices, suggesting complex trade-offs. Overall, Ronchi et al. found that national soil protection laws often lack coordination, with each country defining its specific threats independently, and contamination thresholds vary widely across Member States, impacting human health and investment decisions. The absence of a unified EU framework for soil protection has resulted in a fragmented and inconsistent legislative landscape among Member States.[7]

Despite its progressive framework, the implementation of the WFD continues to face challenges. Variations in interpretation, ambiguity in the Common Implementation Strategy, and insufficient institutional support have hindered the consistent application of IRBM principles across Member States.[8] To advance sustainable soil and water management, there is a clear need for a coherent European framework that integrates these objectives, supported by transparent reporting and monitoring mechanisms. Establishing a comprehensive EU soil conservation policy would represent an important step toward addressing systemic gaps and reinforcing the EU's environmental commitments.

3. Methodology

This study employed a comprehensive approach to evaluate the hypothesis. The methodology was based on three types of data sources (see Table 1):

(i) Extensive literature and policy review: This included both European and national policies.

(ii) Questionnaire responses: A structured questionnaire was administered to capture participants' perceptions of CAP, NSP technologies, and related market conditions. The questionnaire consisted of 58 questions, including Likert scale, open-ended, and multiple-option questions, gathering comprehensive information on NSPs for sustainable agriculture and water management. It covered NSP details, alignment with EU policies (CAP/WFD), sustainability goals, specific national policies, their alignment with EU frameworks, contributions to Sustainable Development Goals (SDGs), enforcement strength, effectiveness in promoting sustainability and technology adoption, and challenges. It also assessed institutional capacity, stakeholder engagement, market readiness, economic incentives, policy-technology linkages, and the influence of key actors. The questionnaire was administered to stakeholders, including specialists, living lab researchers, and technology providers, across the selected countries from January 2025 to March 2025.[10]

(iii) Excel-based summaries of national policies: To synthesize the data, quantitative and descriptive analyses were conducted. The analysis also involved integrating these three sources within each country case, comparing questionnaire results with research on PIM to validate findings, and constructing a matrix to analyze input and output from the project.

The study included a comparative analysis assessment across 14 European countries: Albania, Cyprus, Czech Republic, Denmark, France, Greece, Italy, Netherlands, Norway, Poland, Portugal, Spain, Turkey, and Ukraine. These countries were selected to represent diverse agricultural and socioeconomic conditions and also as strategic locations for implementing different policies and integrated environmental solutions.

4. The pathway for sustainability results

European countries are actively advancing their sustainability in water and soil management, displaying diverse levels of readiness, institutional capacity, and implementation approaches. Much of this effort is included in National Strategic Plans (NSPs) that align with broader European frameworks such as the Common Agricultural Policy (CAP), the Water Framework Directive (WFD), and the European Green Deal.

Table 1. Methodology approach.

Data source	Focus	Use in research
Literature Review	EU/national frameworks	Legal/policy alignment, gaps
Questionnaire	Stakeholder perceptions	Implementation experience, barriers
Excel Policy Data	Specific laws/policies per country	Verification and comparison across sites

In general, these frameworks aim to promote a resilient and environmentally sustainable agricultural sector, while ensuring the long-term health of Europe's natural resources. The analysis demonstrates that most European countries exhibit a high degree of policy alignment with EU sustainability objectives. In this sense, this point reflects the most difficult challenge for the policy, but also the capacity of stakeholders to adopt the financial and regulatory national or European framework.

Questionnaire results showed overall excellent national alignment with EU policy such as the CAP and WFD and directives, clear focus on various sustainability goals, and underscored the continuing need to a technology forward approach to agricultural practices regarding efficient water use, and water and soil pollution. Areas of opportunity include addressing the lack of knowledge within the farming sector and poor message clarity within and between policies.

4.1. Results analysis

Almost all participants were able to identify their NSPs and expressed alignment with several EU policies, with the highest alignments to the CAP, WFD and Green New Deal and Farm to Fork. These were followed by seventy percent alignment with Natura 2000. Though not provided as a response, several respondents wrote in 2030 SDGs as being aligned. As respondents were not given this as an option, this suggests that perceived alignment would have been higher among respondents had this been included in the list and also indicates a relevance and awareness of SDGs within the agricultural sector. Most participants agreed that their NSPs enhance climate resilience and deliver co-benefits for sustainable water management, reduced pesticide and fertilizer use, rural development, and farmer support. Biodiversity conservation (82.4%) and organic farming (70.6%) emerged as particularly prominent objectives, while about one-third of respondents identified carbon sequestration as a key sustainability priority.

When asked to list three specific policies, their compliance requirements, monetary support and scale of vision, there were several interesting similarities and differences among participants. Most responses included a mix of voluntary and mandatory policies, all of which included significant funding through national subsidies, EU programs, and rural development funds. Often participation in voluntary programs was encouraged through access to these funds and focused on encouraging sustainable best practices.

Mandatory policies were more aimed at environmental protection, such as nitrate use and pollution. In general, policies focusing on water management, organic farming, and climate adaptation were most common. Regarding enforcement, less than 10% of policies across all participants' responses were judged to be weak with little to no enforcement. For the large part of the policies, about two thirds of respondents considered them to be moderately enforced, though some gaps may exist within these. This is in line with the fact that many policies were described as voluntary, with distribution of funds being the main driver for participation. Most policies covered long-term goals aligning with 2030 or 2050 timelines and included structural changes, like modernization of irrigation, as well as behavioral changes, like crop diversification.

Regarding sustainability and specific SDGs, only one respondent said that one of their national policies was ineffective at promoting sustainability, while over three quarters of the other policies were either considered very effective or effective. Participants were asked to list the main sustainability goals related to their national policies, and the area with the most room for improvement was the adoption of technology, followed by soil health and promotion of biodiversity. Only one policy from one respondent considered to be very effective at the promotion of technology, while the large majority of others marked that technology promotion was only moderately effective or neutral. Further details are presented in Table 2.

As shown in Table 3, these results suggest the policy has a strong environmental foundation. They are most strongly associated with climate mitigation and water use efficiency, reflecting its focus on preventing climate change and encouraging sustainable agricultural practices. Clean Water and Sanitation was selected by the majority of respondents, indicating that these policies are (Table 3).

Table 2. Effectiveness of governance policies in promoting sustainability and technology adoption.

Effectiveness of governance policies	Very effective	Effective	Neutral	Ineffective	Do not know
Sustainability	10.4%	68.8%	10.4%	2.1%	8.3%
Technology adoption	4.2%	58.3%	22.9%	2.1%	12.5%

Table 3. The main sustainability goals targeted.

	Climate mitigation	Water use efficiency	Soil health	Biodiversity	Technology adoption
Total Average	72.9%	70.8%	68.8%	64.6%	52.1%

Table 4. Contribution of SDGs.

	SDG2- zero hunger	SDG6- clean water and sanitation	SDG12- responsible consumption and production	SDG13- climate action	SDG15- life on Land	SDG14- life below water
Total Average	54.2%	83.3%	64.6%	79.2%	62.5%	6.3%

The suggestion from some participants that decent work and economic growth (SDG8) and industry innovation and infrastructure (SDG9) should have been included in sustainable goal alignment highlights areas where more emphasis could be put on stakeholder interests. Likewise, zero hunger (SDG2) was perceived as more poorly aligned to national policy as compared to life on land, clean water and sanitation (SDG6), climate action (SDG 13) and responsible consumption and production (SDG12). An overview of these SDG contributions is presented in Table 4 based on the questionnaire results.

However, the practical application often faces significant challenges, such as high initial costs for new technologies, a lack of immediate profitability for farmers, and insufficient awareness among the agricultural community. This suggests that while the vision and policy frameworks for readiness are positive, the actual applicability still requires support and adaptation to local economic realities and farmer engagement. Policies often require structural changes in land use practices, which involve initial investments, legal adjustments, and additional labor or knowledge. Farmers will face challenges without adequate financial incentives or technical support. Table 5 summarizes the challenges in the implementation of policies.

The questionnaire responses indicate that most policy implementation efforts are executed by public entities, most often at the national level (see Figure 1). While information about policies adequately reaches farmers and other users, engagement from involved stakeholders in shaping new policies is often occasional rather than consistently collaborative. This suggests a need for stronger partnerships. Furthermore, only approximately half of farmers receive necessary advisory support or training from public institutions, which highlights an opportunity to expand these services (including practical training and on-site advice) to significantly boost the adoption of sustainable practices. Reflecting a strong push for innovation, national strategies prioritize technologies that improve water efficiency and soil health, frequently mentioning advanced tools like precision irrigation systems, digital monitoring, and smart farming practices. This technological advancement is a core pathway toward a resilient agricultural sector, with targeting for digital transformation and efficient water use, and seeking to use cutting-edge solutions to optimize resource management.

As shown in Table 6, key primary actors are often government ministries, especially those focused on agriculture, as well as farmer cooperatives. These actors guide the implementation of policies and facilitate the shift towards sustainable methods. The collective effort of diverse stakeholders, from policymakers to private companies and local communities, is essential for building together an effective and long term framework for sustainability.

This assessment of policy fit, institutional capacity, and market potential across selected European countries indicates varying levels of readiness for water sustainability and soil health, as well as varied support requirements.

Table 5. The challenges in enforcement of policies.

	Lack of government funding	Weak institutional coordination	Low awareness among farmers	Conflicting policy objectives	Not profitable for farmers	Farmers can invest	High bureaucracy	No market for products
Total Average	58.3%	41.7%	64.6%	35.4%	47.9%	52.1%	56.3%	8.3%

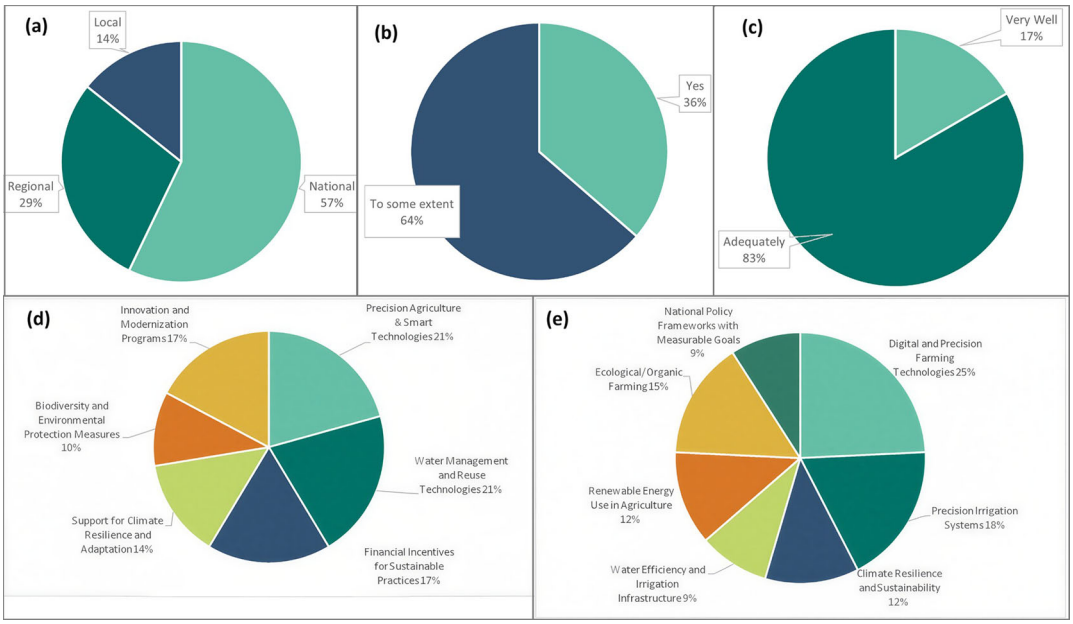


Figure 1. Overview of implementation, stakeholder involvement, communication, and top policy/technology targets. (a) Level of policy implementation, (b) Stakeholder Engagement, (c) Policy Communication, (d) Most frequently mentioned policies and technologies, (e) Most frequently mentioned targets and themes

Table 6. Stakeholders and actors overall influence average rating.

Stakeholder/actor	Overall influence rating (1 = very low, 5 = very high)
Ministry of Agriculture	4.56
Farmer Organizations	4.12
Ministry of Environment	3.86
Water Agency/Regulator	3.73
Private Sector	3.62
Research Institutions	3.50

A distinct group of countries, including the Czech Republic, Greece, and the Netherlands, generally exhibit high overall readiness to implement sustainable practices and technologies. These nations are typically highlighted by strong alignment with European frameworks, well-funded incentives, and robust institutional and engagement capacities. For these countries, suggested support often focuses on advanced solutions, such as integrated innovation for pollution reduction, location-based information platforms, and interdisciplinary and inter-agency approaches. For instance, countries demonstrating strong policy fit are suited for advanced monitoring and precision irrigation technologies.

The majority of surveyed countries, including Albania, Cyprus, Denmark, France, Italy, Poland, Portugal, Spain, Turkey, and Ukraine, are categorized by moderate readiness. These nations generally show partial alignment with European frameworks, moderate financial incentives, or some institutional and engagement capacity. The suggested support for this diverse group frequently emphasizes a combination of approaches:

- Integrated Monitoring & Modeling Platforms and Tailor-made Tools: This includes the development of platforms, farmer tools, and co-developing recommendations to enhance understanding and application.

- Financial & Technical Farmer Support: There is a significant need for financial and technical assistance, alongside the promotion of profitable and accessible solutions and effective economic models to incentivize adoption.

- Participatory Approaches and Living Labs: Many countries benefit from encouraging multi-actor engagement, establishing living labs, and creating demonstration sites to drive innovation and practical implementation.

- Capacity Building & Knowledge Sharing: Initiatives focus on training, knowledge transfer, and raising awareness among farmers to bridge existing gaps.

- Evidence-based Policy Recommendations: A clear focus is placed on strengthening governance through evidence-based monitoring tools and reliable policy recommendations.

- Targeted Interventions: Some regions require support related to specific challenges, such as addressing water quality and climate change or focusing on post-war recovery and cost-benefit solutions in particular river basins.

Ultimately, the pathway for sustainability in European agriculture depends on continuous learning, stronger collaboration, and a willingness to integrate new technologies. By addressing the current gaps in funding, coordination, and awareness, and by encouraging technology-driven approaches, European countries can ensure that their water and soil resources are protected for future generations, leading to a more competitive and cooperative agricultural landscape.

However, systemic challenges remain widespread:

- Policy and Governance Barriers: Many Member States face issues such as inadequate public funding, institutional fragmentation, weak coordination mechanisms, and overlapping or conflicting policy objectives. Countries like Albania, Turkey, Greece, and Italy report difficulties balancing economic growth with environmental objectives, while Spain and Ukraine highlight inconsistencies between national and regional governance frameworks.

- Economic and Financial Constraints: High upfront costs, limited access to credit, and low profitability of sustainable technologies continue to discourage farmer adoption. This is particularly evident in Portugal, Spain, and Turkey, where financial support mechanisms are insufficient or poorly targeted.

- Knowledge and Capacity Gaps: Despite policy alignment, many farmers remain unaware of available programs or lack the technical expertise to implement advanced technologies. The absence of advisory networks and extension services further limits technology diffusion and reduces the practical effectiveness of policy measures.

The impact of European water and soil policies on promoting best practices is multidimensional. While policies provide a solid framework, their effectiveness is heavily influenced by national-level implementation, institutional capacity, and market dynamics. The integration of advanced digital tools and real-time monitoring platforms is seen as a promising pathway to narrow the gap between policy design and practical implementation. Establishing ongoing feedback mechanisms and linking financial incentives to targeted capacity-building initiatives are crucial for strengthening institutional effectiveness and promoting adaptability.

5. The European political analysis

The research explores two main hypotheses:

H1: Readiness for the application of soil improvement and water use practices in the selected European countries is positive.

H2: European water and soil policies create a positive impact in promoting best practices.

Our research indicates that the readiness for implementing soil improvement and water use practices in European countries is generally positive from a policy and framework perspective, yet it faces notable challenges in practical application. The study found that European countries are actively developing plans for sustainability in water and soil management, often rooted in their National Strategic Plans (NSPs), which show strong alignment with broader European frameworks (like CAP, WFD, and the European Green Deal). Stakeholders usually perceive these NSPs as beneficial for enhancing climate resilience in agriculture, improving water management, and reducing the use of pesticides and fertilizers. This strong alignment and clear focus on sustainability goals suggest a positive intent and foundational readiness within the policy landscape.

However, the practical applicability of these plans is complex and varies significantly across different countries. While some nations demonstrate high overall readiness, many others indicate only moderate readiness. Significant issues remain, including the high initial costs associated with new technologies, a lack of immediate profitability for farmers, and insufficient awareness within the agricultural community. Policies often demand structural changes and investments that can burden farmers without adequate financial or technical support. Furthermore, challenges in policy enforcement, such as limited government funding, weak institutional coordination, and conflicting policy objectives, also hinder practical applicability. Therefore, while the policy intent for readiness is positive, the full applicability of soil improvement and water use practices is not uniformly positive and requires substantial support and adaptation. This research confirms that while the frameworks are in place, the path from policy to practical application still faces considerable challenges.

The results significantly confirm that European water and soil policies create a positive impact in promoting best practices, but with important exceptions. European Union policies have always attempted to address the degradation of water and soil resources, with directives like the Water Framework Directive (WFD) and the Nitrates Directive playing a critical role in improving water quality and promoting integrated management. The Common Agricultural Policy (CAP) has also evolved to encourage sustainable practices through measures like “cross-compliance” and rural development incentives.

Our findings show that stakeholders generally consider governance policies to be effective in promoting sustainability, with over three-quarters of policies rated as either very effective or effective. These policies show strong alignment with key Sustainable Development Goals (SDGs), particularly those related to Clean Water and Sanitation, Climate Action, and Responsible Consumption and Production. Many countries prioritize advanced practices such as precision irrigation, organic soil management, and water recycling. This demonstrates that the European policy framework provides a robust foundation and guidance for encouraging positive environmental actions.

Nevertheless, the pathway from policy to practice is not straightforward. While policies provide incentives and frameworks, their ability to stimulate rapid uptake of new technologies is limited by economic, institutional, and social frictions. In particular, uneven implementation, lack of coherent soil protection at the EU level, insufficient advisory services, and modest stakeholder engagement reduce the efficiency of policy instruments. Thus, H2 is broadly supported, but the support is qualified: policies create enabling conditions, yet their effectiveness in producing consistent, on-the-ground adoption of best practices is constrained by implementation barriers.

This comparative analysis could be useful because of how it highlights the uneven relationship between Policies, Institutions, and Markets (PIM) across European contexts. Pulling these strands together, it offers a baseline that future work can build on, though it would be misleading to treat it as the final word.

The key contribution appears to be the identification of a persistent gap: apparently, policy frameworks look highly coordinated. National Strategic Plans (NSPs) show strong alignment with EU priorities such as the Common Agricultural Policy (CAP) and the Water Framework Directive (WFD). Yet this apparent readiness does not consistently translate into effective adoption of technologies on the ground. Farmers and local institutions often encounter barriers that restrict the impact of well-designed strategies.

What follows, then, is less a call for more comprehensive policy design and more a reminder that research should take implementation seriously. The real question is not whether the frameworks are well-designed, but why they fail when tested in practice. Early signs suggest that digital tools and real-time monitoring platforms could help narrow this gap by making progress easier to track and policies more adaptable. But whether these tools will be widely embraced remains uncertain, particularly if institutions lack the capacity or trust to integrate them effectively. Looking ahead, the research challenge is likely to expand. Only by making sustainable practices both viable and rewarding for farmers can long-term resilience be achieved. Otherwise, the most ambitious strategies may risk remaining limited to policy documents rather than shaping daily agricultural realities.

6. Conclusion and further development

This study examined how European countries address the critical challenge of managing water and soil resources to advance sustainability. It explored the evolution of European policy frameworks, the scientific principles supporting them, and the practical mechanisms used to encourage sustainable practices across the continent. The analysis focused on how these policies influence readiness for sustainable technologies and practices, highlighting both the opportunities that drive progress and the challenges that constrain implementation.

The findings confirm two central points regarding water and soil management in Europe. First, the readiness for applying soil improvement and water use practices is generally strong at the policy and framework level but faces significant barriers in practical implementation. European countries have developed National Strategic Plans (NSPs) that align closely with overarching frameworks such as the Common Agricultural Policy (CAP), the Water Framework Directive (WFD), and the European Green Deal. Stakeholders widely recognize these NSPs as valuable tools for enhancing agricultural resilience to climate change, improving water management, and reducing reliance on pesticides and fertilizers. However, the transition from policy to practice remains uneven across countries. High initial investment costs, limited short-term profitability for farmers, and low awareness within the agricultural sector continue to hinder adoption. Furthermore, weak coordination, insufficient funding, and administrative complexity exacerbate these challenges. Thus, while the strategic intent and institutional frameworks are in place, the widespread adoption of sustainable soil and water management practices still faces notable practical obstacles.

Second, European water and soil policies generally create a positive impact in promoting best practices, but their effectiveness is influenced by how they are implemented. EU instruments such as the WFD and the Nitrates Directive have been critical in improving water quality and encouraging integrated management, while the CAP has evolved to link agricultural support more closely to environmental performance. Most stakeholders perceive these governance policies as effective in advancing sustainability, with strong alignment to key Sustainable Development Goals (SDGs) (notably Clean Water and Sanitation (SDG 6), Climate Action (SDG 13), and Responsible Consumption and Production (SDG 12)). Many countries have also embraced practices such as precision irrigation, organic soil management, and efficient resource water systems. Nevertheless, the consistency of these outcomes varies. Soil protection remains insufficiently embedded within EU-level legislation, resulting in fragmented national approaches. Moreover, while policies successfully promote broad sustainability objectives, they are less effective at accelerating technology adoption. Persistent gaps in awareness, advisory services, and stakeholder engagement limit the full realization of policy goals.

Ultimately, creating a sustainable pathway for European agriculture requires continuous learning, stronger collaboration, and a willingness to integrate new technologies. Addressing existing gaps in funding, coordination, and awareness is essential. By developing technology-driven approaches, European countries can ensure that their vital resources are protected for future generations. This includes the integration of advanced digital tools and linking financial incentives to targeted capacity-building efforts to bridge the gap between policy design and practical implementation. Expanding advisory support and promoting consistent stakeholder engagement are also key steps in this ongoing journey towards a truly sustainable future.

Ethics and consent

Ethical approval and consent were not required.

Underlying data

Repository name: Figshare. https://doi.org/10.6084/m9.figshare.30932498.[10]

The project contains the following underlying data:

1. Questionnaire.pdf (questionnaire in its original structure)
2. Questionnaire Responses.xlsx (questionnaire's responses)
3. Questions.pdf (questions in a categorized table)

Data are available under the terms of the CC BY 4.0 licence.

References

1. Platjouw FM, Nesheim I, Enge C: **Policy coherence for the protection of water resources against agricultural pollution in the EU and Norway.** *Rev. Eur. Comp. Int. Environ. Law.* 2023; **32**(3): 485–500.
Publisher Full Text

2. Panagos P, Montanarella L, Barbero M, *et al.*: **Soil priorities in the European Union.** *Geoderma Reg.* 2022; **29**: e00510.
Publisher Full Text

3. Chatzitheodoridis F, Spinthiropoulos K, Loizou E, *et al.*: **Rationale of government policies on agricultural productivity and**

sustainability. *A European perspective.* 2025; **6**(2): 605–628.
Publisher Full Text

4. Vrebos D, Bampa F, Creamer R, *et al.*: **The impact of policy instruments on soil multifunctionality in the European Union.** *Sustainability.* 2017; **9**(3): 407.
Publisher Full Text

5. Pulighe G, Belocchi A, Tani AC, *et al.*: **Impacts of agricultural management practices on water cycle, soil erosion and crop yields in a Mediterranean agroecosystem.** *Sci. Total Environ.* 2025; **995**: 180111.
PubMed Abstract | **Publisher Full Text**

6. Turpin N, Ten Berge H, Grignani C, *et al.*: **An assessment of policies affecting sustainable soil management in Europe and selected member states.** *Land Use Policy.* 2017; **66**: 241–249.
Publisher Full Text

7. Ronchi S, Salata S, Arcidiacono A, *et al.*: **Policy instruments for soil protection among the EU member states: A comparative analysis.** *Land Use Policy.* 2019; **82**: 763–780.
Publisher Full Text

8. Giakoumis DC, Voulvoulis N: **The transition of EU water policy towards the Water Framework Directive's integrated river basin management paradigm.** *Environ. Manag.* 2018; **62**: 819–831.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

9. Kallis G, Nijkamp P: *Evolution of EU water policy: A critical assessment and a hopeful perspective (Research Memorandum No. 1999-27).* FEWEB; 1999.

10. Hadad M, Pego A: **Underlying Data for: A Comparative Analysis Assessment on Policy, Soils, and Water in European Countries: A Pathway for Sustainability.** *figshare.* 2025.
Publisher Full Text

Open Peer Review

Current Peer Review Status: ? ?

Version 1

Reviewer Report 23 September 2026

https://doi.org/10.21956/openreseurope.24109.r80387

© **2026 Keller A.** This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Arturo A. Keller
University of California Santa Barbara, Santa Barbara, California, USA

The paper's central narrative — strong policy alignment, weak on-the-ground technology adoption — is plausible and consistent with the broader EU soil/water literature it cites. But as constituted, the comparative claims across 14 countries rest on an unreported, likely small sample; conflate EU and non-EU governance frameworks under a single "CAP alignment" metric; and substitute stakeholder perception for independent outcome evidence, without acknowledging any of this as a limitation. I'd treat the qualitative narrative (implementation gap, cost/awareness barriers) as reasonably credible, but the specific country rankings and percentage figures should be treated with real skepticism until sample sizes and per-country response counts are disclosed.

Sample size and transparency. Nowhere in the manuscript is n (number of respondents) stated. Percentages like 58.3%, 64.6%, 4.2% strongly suggest a very small denominator (plausibly n ≈24–48), which the authors never disclose. For a study making country-level claims ("Czech Republic, Greece, and the Netherlands... high readiness") this matters enormously — if each of 14 countries contributed only 1–3 respondents, a country's "readiness category" is really one or two people's opinion dressed up as a comparative finding. This is the single biggest weakness and it's not addressed anywhere, including in the peer review.

Non-EU countries assessed against EU instruments. The core metric is alignment with CAP and the WFD — but Turkey, Ukraine, Albania, and Norway are not EU member states and CAP does not apply to them in the same institutional sense (Norway is EEA/non-CAP; Turkey, Ukraine, Albania are candidate/non-member states with entirely different agricultural support architectures). Treating "NSP alignment with CAP" as a comparable variable across EU and non-EU states conflates fundamentally different governance systems. This is a conceptual flaw, not a wording issue, and the reviewer's line-edits never touch it.

Selection of the 14 countries is unexplained. The justification given — "diverse agricultural and socioeconomic conditions... strategic locations for implementing different policies" — is circular and reads like an artifact rather than a principled comparative sample. If so, that's a legitimate design choice but should be disclosed as convenience/consortium sampling, not implied to be a

considered comparative selection.

No low-readiness category, despite the country list. Every country land in either "high" or "moderate" readiness. Given that the list includes Ukraine (under active war-related disruption) and Albania, the absence of any country scoring poorly is suspicious and suggests either a ceiling effect in the instrument, response bias (respondents rating their own national systems favorably), or thresholds set to avoid distinguishing between very different contexts.

Self-report conflated with institutional fact. Stakeholder *perception* that a policy is "effective" (Table 2) is treated as evidence of policy alignment and impact, but perception data from people embedded in implementing these programs (ministry staff, technology providers with a stake in continued funding) is a weak proxy for actual outcomes — there's no independent outcome data (e.g., actual pesticide/fertilizer reduction trends, WFD "good status" water body counts) cited to validate the self-reports against reality. The intro even cites evidence that nitrate concentrations haven't improved in 30 years — this directly undercuts the "positive impact" conclusion of H2 but is never reconciled with it.

Hypotheses aren't falsifiable as stated. H1 ("readiness is positive") and H2 ("policies create a positive impact") are vague enough that almost any result short of total failure would confirm them. There's no pre-specified threshold for what would count as disconfirmation, and the conclusion section unsurprisingly finds "broad support, but qualified" for both — a pattern that reads as confirmation-seeking rather than hypothesis-testing.

Presentation/interpretation issues

- Table entries are occasionally unclear or apparently mislabeled — e.g., in Table 5 ("challenges in enforcement of policies"), "Farmers can invest" (52.1%) doesn't read as a challenge at all, and no table note explains it.
- The country-cluster "suggested support" lists (bullet points under the moderate-readiness group) are generic policy-toolkit boilerplate (capacity building, living labs, digital platforms) that could apply to virtually any agricultural policy context — they don't actually differentiate the ten countries in that bucket from one another, undermining the "comparative" framing in the title.
- There's no dedicated Limitations section, which is a real gap given the sampling and cross-national comparability issues above.
- The Discussion (Section 5) shifts into a more essayistic, hedging register ("apparently," "it would be misleading to treat it as the final word," "the real question is...") that sits oddly against the more clinical results section and reads like unedited reasoning-in-progress rather than a peer-reviewed research discussion.

Is the work clearly and accurately presented and does it engage with the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

Are all the source data and materials underlying the results available?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental science

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 23 June 2026

https://doi.org/10.21956/openreseurope.24109.r75343

© 2026 AbdelRahman M. This is an open access peer review report distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

?

Mohamed A.E. AbdelRahman
National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt

Abstract
- “turning policies into practical actions remains a challenge” → Revise to “translating policies into practice remains challenging.”
- “structured questionnaire responses and Excel-based national policy summaries” → Replace with “structured questionnaires and national policy summaries.”
- “stakeholders typically report benefits for climate resilience and pollution reduction” → Revise to “stakeholders reported benefits for climate resilience and reduced pollution.”
- “Technology adoption appears sensitive to cost and short-term profitability” → Replace with “Technology adoption is constrained by cost and short-term profitability.”
- Abstract is lengthy; condense by focusing on findings (policy alignment, implementation gap, cost barriers) rather than detailed methods.

Introduction
- “protecting them and keeping agriculture productive remains a challenging balancing act” → Revise to “protecting these resources while sustaining agriculture remains a challenge.”
- “measures that protect ecosystems can slow short-term yields or raise costs for farmers” → Replace with “ecosystem protection measures may reduce short-term yields or increase costs.”
- “we look at the institutional and market arrangements that shape real-world outcomes” → Revise to “we assess institutional and market arrangements shaping outcomes.”

- "The assessment of the strengths and constraints related to policy, institutional capacity, and market conditions is critical..." → Condense to "Assessing policy, institutional capacity, and market constraints is critical for technology adoption."
- "The threats are well known and persistent" → Replace with "Persistent threats remain."
- "Across parts of northern and Central Europe, nitrogen surpluses remain a concern, and groundwater nitrate concentrations have shown little improvement over decades" → Revise to "Nitrogen surpluses persist in northern and Central Europe, with groundwater nitrate concentrations showing little improvement."
- "EU estimates that 60–70% of European soil is unhealthy due to human activities" → Replace with "The EU estimates 60–70% of European soils are degraded by human activity."
- Paragraph cohesion: Several sentences repeat threats (fertilizers, pesticides, soil degradation). Condense into one unified statement highlighting nutrient surpluses, pesticide residues, and soil quality decline.

Overall Notes (Abstract + Introduction)

- Replace vague terms ("remains a challenge," "well known and persistent") with precise scientific phrasing.
- Condense repetitive descriptions of threats and policy frameworks.
- Ensure consistency in terminology (e.g., "technology adoption," "policy implementation gap").
- Emphasize novelty: cross-country comparative assessment of policy–institution–market (PIM) conditions.

Methodology

- "This study employed a comprehensive approach to evaluate the hypothesis" → Revise to "This study employed a mixed-method approach to evaluate the hypotheses."
- "three types of data sources (see Table 1)" → Replace with "three data sources (Table 1)."
- "Extensive literature and policy review: This included both European and national policies" → Condense to "Literature and policy review of European and national frameworks."
- "The questionnaire consisted of 58 questions, including Likert scale, open-ended, and multiple-option questions..." → Revise to "The questionnaire included 58 items (Likert scale, open-ended, multiple-choice)."
- "gathering comprehensive information on NSPs for sustainable agriculture and water management" → Replace with "capturing information on NSPs for sustainable agriculture and water management."
- "It covered NSP details, alignment with EU policies (CAP/WFD), sustainability goals..." → Condense to "It assessed NSP details, alignment with EU policies (CAP/WFD), sustainability goals, enforcement, and effectiveness."
- "The questionnaire was administered to stakeholders, including specialists, living lab researchers, and technology providers, across the selected countries from January 2025 to March 2025" → Revise to "Administered to specialists, living lab researchers, and technology providers in 14 countries (Jan–Mar 2025)."
- "Excel-based summaries of national policies: To synthesize the data, quantitative and descriptive analyses were conducted" → Replace with "Excel-based national policy summaries supported quantitative and descriptive analysis."
- "comparing questionnaire results with research on PIM to validate findings" → Revise to "questionnaire results were cross-validated with PIM research."
- "constructing a matrix to analyze input and output from the project" → Replace with "matrix analysis integrated inputs and outputs."

- "These countries were selected to represent diverse agricultural and socioeconomic conditions and also as strategic locations for implementing different policies and integrated environmental solutions" → Condense to "Countries were selected to represent diverse agricultural, socioeconomic, and policy contexts."

Overall Notes (Methodology)

- Replace verbose phrasing ("consisted of 58 questions, including…") with concise scientific wording.
- Ensure consistency in terminology (e.g., "candidate restoration results" → "candidate outputs"; "Excel-based summaries" → "policy summaries").
- Condense repetitive descriptions of questionnaire scope and policy alignment.
- Clarify stakeholder groups and timeframe in one sentence.
- Present selection rationale for countries more succinctly.

European Political Analysis

- "Readiness for the application of soil improvement and water use practices in the selected European countries is positive" → Revise to "Readiness for soil improvement and water use practices is generally positive."
- "yet it faces notable challenges in practical application" → Replace with "yet faces significant practical challenges."
- "Stakeholders usually perceive these NSPs as beneficial for enhancing climate resilience…" → Revise to "Stakeholders perceived NSPs as beneficial for climate resilience⋯"
- "the full applicability of soil improvement and water use practices is not uniformly positive" → Replace with "applicability is uneven across countries."
- "European Union policies have always attempted to address the degradation of water and soil resources" → Revise to "EU policies have long addressed water and soil degradation."
- "with over three-quarters of policies rated as either very effective or effective" → Replace with "over 75% of policies rated effective or very effective."
- "Nevertheless, the pathway from policy to practice is not straightforward" → Revise to "Nevertheless, translating policy into practice remains difficult."
- "Thus, H2 is broadly supported, but the support is qualified" → Replace with "Thus, H2 is supported, but with qualifications."
- Paragraph cohesion: Condense repeated points on barriers (economic, institutional, social) into one unified statement.
- "apparently, policy frameworks look highly coordinated" → Revise to "policy frameworks appear coordinated."
- "the real question is not whether the frameworks are well-designed, but why they fail when tested in practice" → Replace with "the key issue is why well-designed frameworks fail in practice."
- "Early signs suggest that digital tools and real-time monitoring platforms could help narrow this gap…" → Revise to "Digital tools and real-time monitoring may help narrow this gap."

Conclusion and Further Development

- "examined how European countries address the critical challenge of managing water and soil resources" → Revise to "examined European approaches to managing water and soil resources."
- "highlighting both the opportunities that drive progress and the challenges that constrain implementation" → Replace with "highlighting opportunities and constraints in implementation."
- "readiness for applying soil improvement and water use practices is generally strong at the

policy and framework level" → Revise to "policy-level readiness is strong."
- "High initial investment costs, limited short-term profitability for farmers, and low awareness within the agricultural sector continue to hinder adoption" → Condense to "High costs, low profitability, and limited awareness hinder adoption."
- "European water and soil policies generally create a positive impact in promoting best practices" → Replace with "EU water and soil policies positively influence best practices."
- "Most stakeholders perceive these governance policies as effective in advancing sustainability" → Revise to "Most stakeholders rated governance policies effective for sustainability."
- "Nevertheless, the consistency of these outcomes varies" → Replace with "Outcomes remain inconsistent."
- "Ultimately, creating a sustainable pathway for European agriculture requires continuous learning, stronger collaboration, and a willingness to integrate new technologies" → Revise to "Sustainable pathways require collaboration, continuous learning, and technology integration."
- "Expanding advisory support and promoting consistent stakeholder engagement are also key steps..." → Replace with "Expanded advisory services and consistent stakeholder engagement are essential."

Overall Notes (Political Analysis + Conclusion)
- Replace vague terms ("positive intent," "not straightforward," "apparent readiness") with precise scientific phrasing.
- Condense repetitive descriptions of barriers (cost, profitability, awareness, enforcement).
- Ensure consistency in terminology (NSPs, CAP, WFD, SDGs).
- Moderate claims about "always attempted" or "highly coordinated" to avoid overstating.

Recommended citations
refer 1,2

References

1. D'Antonio, P., Fiorentino, C., AbdelRahman, M. A. E., Drosos, M., & Scopa, A. (2025). Modeling climatic, terrain and soil factors using AHP in GIS for grapevines suitability assessment. Sustainable Development, 33(1), 970–991.
2. Fiorentino, C., AbdelRahman, M. A. E., D'Antonio, P., Lasaponara, R., & Masini, N. (2024). Space-to-tree: Architectural framework for real-time monitoring of pines in natural and historical park. Internet Technology Letters, 7(6), e574.

Is the work clearly and accurately presented and does it engage with the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

Are all the source data and materials underlying the results available?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: applications of RS and GIS in Soils

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.