CARBON 4 SOIL QUALITY | Interreg Euro-MED | Co-funded by the European Union

June 2025

STRATEGIC ANALYSIS FOR SOIL QUALITY IMPROVEMENT IN MEDITERRANEAN CLIMATE

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Kmetijski inštitut Slovenije
Agricultural Institute of Slovenia
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ISD Institute for Sustainable Development
RINOVA agricoltura ambiente alimentazione Coltiviamo il futuro
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Deliverable ID

Project acronym	Carbon 4 Soil Quality
Project title	Capturing and Storing Atmospheric CO_2 for Improvement of Soil Quality
Project mission	Natural Heritage
Project priority	Greener MED
Specific objective	RSO2.7
Type of project	Study
Project duration	01/01/24 – 31/03/26 (27 months)

Deliverable title	Preparation of transferable carbon farming training materials
Deliverable number	2.1.1
Deliverable type	Report
Work package number	2
Work package title	Building solid foundation for testing carbon farming in Euro-MED area
Activity name	Strategic systemic approach to improve soil quality
Activity number	2.1
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Document history

Versions	*Date*	*Document status*	*Delivered by*
Version 1.0	11/06/25	Draft	KIS
Version 2.0	27/06/25	final	KIS
Version 2.1	30/06/25	final	KIS

June 2025

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EXECUTIVE SUMMARY

This paper presents a strategic analysis of the potential of carbon management and soil quality improvement in Mediterranean agricultural systems, developed in the framework of the Carbon4SoilQuality project (C4SQ). It summarizes cross-country findings from six Mediterranean partner countries — Greece, Italy, Montenegro, North Macedonia, Slovenia and Spain — using a harmonized Political, Economic, Social, Technological (PEST) framework and a stakeholder mapping approach.

The results emphasize a broad alignment with EU-level strategies (e.g. European Green Deal, CRCF Regulation, CAP strategic plans), but also reveal significant implementation gaps. Common challenges include the lack of legal definitions for carbon management, the lack of certified protocols for monitoring, reporting and verification (MRV), fragmented institutional coordination and the lack of functioning carbon markets.

Economic barriers persist in all countries: high upfront costs, limited monetization mechanisms and an underdeveloped private investment landscape hinder uptake, especially among smallholder farmers. Social awareness of carbon farming remains low, although interest is growing among younger farmers, non-governmental organizations and research institutions. Technological capacity varies, with advanced monitoring tools and innovation centers concentrated in countries such as Italy and Spain, while access to farms remains limited due to costs and knowledge gaps.

The stakeholder analysis confirms that ministries, research organizations and advisory services play a central role, but more coordination and engagement with farmers, consumers and the private sector is needed to enable system-wide change. A complementary impact assessment emphasizes the wider environmental and agronomic benefits of carbon farming, especially in terms of soil resilience, biodiversity and long-term productivity.

To scale up carbon farming across the Mediterranean, the report recommends the development of localized MRV systems, tailored economic incentives, expanded training and extension services and better integration of scientific innovations into farmer-friendly tools.

1 INTRODUCTION

The Carbon 4 Soil Quality project (C4SQ) aims to research and accelerate the implementation of high-carbon farming practices in the Mediterranean regions, with the dual objective of mitigating climate change and improving soil quality. This report is part of project WP 2, which focuses on a strategic, multidimensional analysis of the enabling and constraining factors for carbon management in six partner countries.

Agricultural systems in the Mediterranean region face acute challenges from climate change, including drought, soil degradation and declining productivity. At the same time, they offer untapped opportunities for climate-friendly solutions, such as carbon management, which can contribute to carbon sequestration, improved water retention and increased soil resilience.

To assess the feasibility and conditions for scaling carbon farming in different national contexts, this work combines a comparative PEST analysis— that considers political, economic, social and technological factors with detailed stakeholder mapping. The approach is based on standardized country questionnaires, participatory data collection and a synthesis of existing policy and scientific literature.

This report also includes an assessment of the environmental, economic, social and technological impacts of carbon farming methods and identifies knowledge gaps, capacity needs and key intervention points to promote uptake. The findings form the basis for the next phase of the project, including pilot site planning, MRV development and targeted policy engagement.

2 METHODOLOGICAL APPROACH

This chapter describes the methodological framework used to strategically analyze the improvement of soil quality and the potential of the carbon economy in the Mediterranean region. The approach combined a structured data collection from national partners, a synthesis of scientific literature and a policy review. It followed a participatory, comparative and multidisciplinary logic to ensure that the diversity of national contexts could be analyzed within a coherent regional perspective.

2.1 PEST framework

A core element of the analysis was the application of the PEST framework - political, economic, social and technological factors - to assess the favourable environment for carbon farming in each of the six C4SQ partner countries. A standardised questionnaire was developed and distributed to the national partners, who coordinated the input of experts from relevant stakeholders and institutions. The questionnaire covered topics such as policy alignment with the EU framework, availability of economic incentives, stakeholder awareness, barriers to technology uptake and monitoring capacities.

2.2 Stakeholder mapping

To complement the PEST analysis, a stakeholder mapping exercise was carried out to identify the main actors involved in the governance, research, implementation and advocacy of carbon farming. Stakeholders were categorised according to their role (public sector, research, farmers, NGOs, private sector) and analysed for their influence and engagement using a qualitative assessment matrix. This process helped to identify coordination gaps, the need for empowerment and opportunities for multi-stakeholder collaboration.

2.3 Data integration and validation

To complement the PEST analysis, a stakeholder mapping exercise was carried out to identify the main actors involved in the governance, research, implementation and advocacy of carbon farming. Stakeholders were categorised according to their role (public sector, research, farmers, NGOs, private sector) and analysed for their influence and engagement using a qualitative assessment matrix. This process helped to identify coordination gaps, the need for empowerment and opportunities for multi-stakeholder collaboration.

2.4 Limitations

Although the methodology provides a solid comparative overview, certain limitations must be acknowledged. These include the qualitative nature of many responses, the variability of national data availability and the evolving state of carbon regulation. Future findings will build on this foundation with quantitative field testing and stakeholder engagement.

3 MEDITERRANEAN SOILS AND CLIMATE: CHALLENGES AND OPPORTUNITIES FOR CARBON FARMING

3.1 Agriculture in the mediterranean in a changing climate

Agriculture in the Mediterranean is increasingly characterised by the realities of climate change. The region, characterised by hot, dry summers and mild, wet winters, is particularly vulnerable to rising temperatures, changing precipitation patterns and major interannual climate variability. Droughts have become more frequent and intense, while rainfall, when it does occur, tends to be shorter and more extreme. These conditions are already having an impact on agricultural productivity, water availability and the resilience of soil systems.

The Mediterranean region has been identified by the IPCC as a climate change hotspot (Shukla et al., 2019), and projections indicate increasing risks of desertification, fires and biodiversity loss. These climatic stresses are compounded by structural issues such as land abandonment, ageing rural populations and farm fragmentation, all of which affect the adaptive capacity of agriculture. In this context, carbon farming is seen not only as a strategy to mitigate climate change, but also as a potential co-benefit for soil and water conservation, erosion control and long-term productivity (Lal, 2018).

3.2 Limits of soil for carbon sequestration

Despite the clear need for soil-based carbon solutions, many Mediterranean soils have inherent limitations for long-term carbon sequestration. Soils in the region tend to be shallow (e.g. Leptosols), carbonate-rich (e.g. Calcisols) or coarse-grained with low clay content, which limits their ability to stabilise organic matter (Cotrufo et al., 2019; Bünemann et al., 2018). Seasonal biomass production is generally low, which limits carbon input, and the warm and dry climate accelerates the decomposition of organic matter.

Furthermore, several Mediterranean soils are already approaching their SOC saturation point (Stewart et al., 2007), especially where clay content or protection by aggregates is limited. This means that while organic inputs may improve fertility or structure, their contribution to stable carbon pools may be modest. The implication is clear: not all Mediterranean soils are equally suitable for long-term carbon storage and expectations of sequestration need to be calibrated accordingly.

3.3 Land management under stress: drought, fire, abandonment

Soil health and carbon dynamics are closely linked to the type of land management. In the Mediterranean context, increasing climate stress leads to

more extreme pressure on land management systems. Prolonged droughts reduce vegetation cover, leaving soils unprotected and vulnerable to erosion. Forest fires, a growing threat in warmer and drier conditions, not only destroy biomass but can also drastically alter soil structure and biology.

At the same time, economic pressures and demographic changes are leading to land abandonment in marginal areas. This leads to uncontrolled vegetation, less maintenance of terraces and erosion control and often to deterioration in soil quality. In the more intensively farmed areas, mechanisation and irrigation have enabled continued productivity, but often at the cost of soil compaction, salinization and a decline in organic matter.

In both cases — abandonment or intensification — soils are under increasing stress and their ability to serve as carbon sinks is jeopardised if land management is not adapted with climate resilience in mind (Lugato et al., 2014; Poeplau et al., 2023).

3.4 Adaptation gaps and farmers' needs

Carbon farming in the Mediterranean region will only be successful if it is orientated towards the actual capacities and limitations of farmers. Many producers are already struggling with climate variability, unstable markets and fragmented extension services. Knowledge about soil health and carbon sequestration is inconsistent and there is often a lack of incentives for long-term practises.

Adaptation gaps are particularly evident in water management, organic matter sequestration and access to tools that support sustainable intensification. Smallholder farmers, especially in the southern and eastern Mediterranean countries, often lack capital or technical support to implement practises such as composting, cover cropping or agroforestry. Policy frameworks, including the CAP, have taken some steps to integrate soil quality and climate change mitigation, but implementation remains uneven (Paustian et al., 2016).

3.5 Feasibility of carbon farming in different soil-climate zones

The feasibility of carbon farming in the Mediterranean must be viewed through a zone-specific lens. Some areas - such as northern Italy or the Slovenian coast - benefit from higher rainfall, deeper soils and established infrastructure, making them more suitable for measurable carbon sequestration. In contrast, semi-arid or mountainous areas (southern Spain, Greece, southern Portugal) may offer more potential through avoided degradation or soil conservation than through a significant increase in SOC.

Practises such as agroforestry, reduced tillage, residue management and strategic grazing can bring benefits even where the potential for carbon sequestration is limited. The key is to tailor interventions to local pedoclimatic conditions and recognise that in many cases the value of carbon farming lies not only in stored carbon, but also in improved water retention, erosion control and system resilience

(Bastida et al., 2008; Lozano-García et al., 2013).

One model that fits all will not work. Site-specific planning based on soil type, climate regime, land use history and socio-economic context is essential for meaningful progress.

4 PEST ANALYSIS

PEST analysis is a strategic tool for assessing the political, economic, social and technological factors that shape a particular context or influence the feasibility of policy or market interventions (Gupta, 2013). In the Carbon4SoilQuality (C4SQ) project, the PEST framework was applied to analyze the enabling or constraining conditions for carbon management and soil quality improvement in the participating partner countries.

This chapter provides a structured summary of the findings at national level, based on a standardized PEST questionnaire developed by the project team. The questionnaire was designed to obtain targeted reflections from partners on key sectoral trends, barriers, opportunities and stakeholder dynamics relevant to the carbon economy. Each country report provides a brief summary of responses across the four PEST categories, providing a comparative overview of regional diversity and cross-cutting issues.

Appendix 1 of this report contains the blank version of the national questionnaire. The completed questionnaires were collected by the project partners but are kept for internal communication purposes and are not included in this report. The summaries presented in this chapter are based on the information provided by these completed questionnaires.

4.1 Political factors

In the Mediterranean partner countries, alignment with EU carbon management targets is progressing but remains uneven. While most countries refer to key EU policies such as the Green Deal, the CRCF and the CAP strategic plans, national legislation and institutional frameworks often lack the clarity, coordination or enforcement capacity to implement them effectively. Italy and Spain show the most advanced integration, especially at regional level, while countries such as Montenegro and North Macedonia are still in the process of developing basic legislation. A common shortcoming is the lack of MRV systems and legal recognition of carbon management; although the CRCF is seen as a crucial opportunity to close these gaps and catalyzes national reforms.

4.1.1 GREECE

In Greece, carbon farming is not yet integrated into the national or regional policy

framework. While the concept is being explored through research and trial, there are currently no structured policies or incentives to support its introduction. Nonetheless, Greece is showing partial alignment with EU-level strategies, particularly through the implementation of the Common Agricultural Policy (CAP) 2023–2027, which includes organic schemes to improve soil quality. National efforts also reflect broader EU goals, such as transitioning to a circular economy and achieving zero waste targets, although these are not specifically tailored to carbon farming.

Key regulatory challenges include the lack of a dedicated carbon farming policy and the absence of a functioning voluntary carbon market. Soil degradation and carbon sequestration are monitored by the Hellenic Agricultural Organization, but the level of coordination between local, regional and national authorities remains unclear. Stakeholder involvement is limited to a few government agencies and research organizations. Looking ahead, the EU Carbon Removal Certification Framework (CRCF) Regulation (EU 2024/3012) could serve as a catalyst for national policy development. International engagement is limited to co-operation at the research level. To move forward, Greece should align its policies with the CRCF targets and develop mechanisms that facilitate the adoption and certification of carbon farming practices.

4.1.2 ITALY

Italy does not yet have a specific national policy for carbon farming, but numerous measures under the Common Agricultural Policy (CAP) and regional programmes support soil carbon sequestration and quality improvement. Both the Veneto region and the Emilia-Romagna region are implementing eco-programmes and rural development measures (e.g. SRA03, SRA04, SRA07, SRA08) that improve soil organic matter, support sustainable grassland management and promote afforestation. These regional measures are in line with the European Green Deal and the Biodiversity Strategy. Italy actively contributes to EU and global soil health objectives through the Soil Mission, the 4p1000 initiative and the UNCCD.

National coordination remains limited as most CAP Pillar 2 measures are managed regionally, resulting in uneven uptake in Italy. For example, cover cropping (SRA06) is only funded in a subset of regions. Soil monitoring is carried out by regional authorities (e.g. ARPAV, ARPAE, Emilia Romagna Region) through mapping, field data and laboratory analyses. Recent legislation - including the National Plan for Ecological Conversion and agri—voltaic - signals an evolving approach to integrating soil and carbon management. A public registry for voluntary carbon credits, managed by CREA and compliant with the CRCF regulation, is being established and could become a turning point for national certification and incentive mechanisms. Furthermore, several Italian representatives participate in international projects and research networks such as EJP Soil, Interreg, Horizon and LIFE, which provide platforms for methodological testing and innovation.

4.1.3 MONTENEGRO

Montenegro has taken initial policy steps towards sustainable agriculture in line with EU environmental objectives, but a specific policy for low- carbon agriculture remains underdeveloped. The Agriculture and Rural Development Strategy 2023–2028 emphasises low-carbon agriculture and biodiversity, while more comprehensive laws regulate land use and environmental protection. However, a specific law on soil protection is still missing. The absence of a clear legal framework and enforcement mechanisms remains a major obstacle to the implementation of low- carbon agriculture on a large scale. Soil and carbon issues are mentioned in national strategies, but implementation is weak and monitoring is sporadic.

Although Montenegro aims to align with EU strategies such as the Green Deal and the Biodiversity Strategy 2030, there are still gaps between policy intent and practise. In particular, the country has not yet introduced a carbon crediting system or ecosystem. Soil monitoring systems are underdeveloped and capacity is limited both at institutional and field level. Coordination between ministries and authorities is inconsistent, which hinders integrated land management. On a positive note, Montenegro is involved in several international and regional initiatives, such as the UNCCD Land Degradation Neutrality Programme and EU-funded projects, which provide both technical support and a framework for future action.

4.1.4 NORTH MACEDONIA

North Macedonia has made progress in recognizing the role of sustainable land use and soil protection within its national policy framework. The Ministry of Agriculture and Water Economy (MAFWE) has included adaptation and mitigation measures in its National Strategy for Agriculture and Rural Development (NARDS), while the IPARD 3 program supports agri-environmental and organic farming measures. However, the policy landscape lacks specific legislation for soil conservation and carbon farming. The current Law on agricultural land and the Law on organic farming only partially address soil quality, and the long-awaited law on soil protection is still under revision.

Although the country is aligned with the EU's Green Agenda for the Western Balkans and participates in regional climate and soil initiatives, legal obstacles remain. The absence of a carbon farming strategy, lack of financial incentives and weak institutional coordination hinder systematic implementation. Monitoring of soil degradation and carbon sequestration is limited to individual projects or ad-hock monitoring campaigns. Important ministries and institutions are involved, but their coordination is insufficient. The upcoming adoption of a specific soil law offers a promising way to integrate carbon management into national policy.

4.1.5 SLOVENIA

Slovenia shows a strong alignment with EU climate targets, in particular through its CAP Strategic Plan (2023–2027), the long-term climate strategy (ReDPS50) and the national LULUCF plan. These policy instruments recognise the importance of soil as a carbon sink and support sustainable practises such as reduced tillage, cover cropping and permanent grassland management. While Slovenia actively supports ecological and agro-ecological measures, it has not yet developed a formal definition or legal framework for carbon management. The absence of certified MRV (Monitoring, Reporting and Verification) protocols, a national carbon register or legal recognition of carbon removal from soils remains a major obstacle.

Stakeholders involved include the Ministry of Agriculture (MKGP), ARSO, KIS and UL-BF, but coordination between these institutions remains limited and is largely restricted to project-based collaboration. Monitoring of soil carbon at the farm level is sporadic and not systematically enforced, although the ARSO tracks LULUCF data and climate indicators at the national level. Future developments such as the EU Carbon Removal Certification Framework (CRCF) are likely to influence national policy and could stimulate investment in MRV systems and the integration of soil indicators into CAP performance monitoring. Slovenia also participates in international projects and research networks such as EJP Soil, Interreg and LIFE, which provide platforms for methodological testing and innovation.

4.1.6 SPAIN

Spain is actively aligning its agricultural and environmental policies with the European Green Deal and the 2030 Biodiversity Strategy. The Spanish CAP Strategic Plan includes measures to promote soil health and carbon sequestration, and both national and regional governments are engaged through overlapping actions. However, the decentralized nature of governance (with autonomous communities) leads to variations in implementation and coordination problems at different levels. The main ministries involved include MITECO and MAPA, while regional agencies, co-operatives and NGOs also play an important role.

The regulatory environment is still under development. One of the main obstacles to widespread adoption of carbon farming is the absence of a standardized national definition or certification system. The lack of clear MRV protocols and a functioning registry for carbon credits hinders the monetization of soil carbon gains. Land degradation is monitored by public institutions, but enforcement is inconsistent. Spain is expected to further adapt its legislation in response to the EU CRCF regulation and to advance strategies that integrate climate, soil health and circular economy objectives within the PNIEC and RTRP. At international level, Spain is very active — it hosts events such as the European Mission Soil Week and participates in research networks such as the Soil Carbon IRC and Horizon Europe projects.

4.2 Economic factors

Economic support for carbon management remains limited and highly dependent on CAP measures; with little direct monetisation of soil carbon in the region. Italy and Spain have taken initial steps to establish markets and registries for carbon credits, while countries such as Montenegro and North Macedonia are more reliant on IPARD and donor funding. High costs for monitoring, equipment and certification are a major obstacle - especially for small farms - while public-private partnerships and consumer demand for sustainable products are still emerging. Harmonised MRV systems, targeted subsidies and accessible financing instruments are seen as crucial prerequisites for the economic expansion of carbon farming.

4.2.1 GREECE

Greece offers only limited economic support for carbon farming. Current funding mechanisms consist mainly of subsidies under the CAP eco-scheme, which include soil improvement measures but do not explicitly support carbon farming. A national market for carbon credits has been announced for 2025, but is still under development. Several obstacles hinder monetisation, including the difficulties in measuring and verifying carbon sequestration, the volatility of carbon credit prices and regulatory uncertainty. The high costs associated with carbon management - particularly verification and monitoring - may further discourage farmers from participating, especially in the absence of strong financial incentives.

Information on implementation costs, affordability for farmers and the level of public or private investment is not currently available. Similarly, there is no data on market demand or the economic impact of land degradation on agricultural productivity. Recommendations to address these gaps include developing robust markets for carbon credits, offering targeted subsidies, grants and tax incentives and building public-private partnerships. Other support measures could include low-interest loans, insurance products and long-term payments for ecosystem services (PES), as well as financial support for training, technical assistance and the development of a carbon market.

4.2.2 ITALY

Funding for soil improvement and carbon sequestration is primarily provided through the mechanisms of the CAP, such as the eco-schemes and regional rural development programmes. Public investments include support for the restoration of damaged land (e.g. after flooding in Emilia-Romagna) and soil mapping, while private actors such as the food industry Barilla are starting to invest in sustainable practises. However, there is no fully operational national carbon market as of 2025. There are some pilot projects (e.g. the Alberami project), and a national voluntary registry for carbon credits is under development. The main obstacles include high costs for MRV processes, limited access to certification instruments, lack of price

stability for carbon credits and unclear market structures.

Cost is a particular challenge for smallholders, who often cannot afford specialised equipment and rely on contractors instead. Large farms are better placed to adopt sustainable practises, but they too face operational constraints. Soil degradation - particularly due to poor organic matter content as well as erosion, compaction and salinisation - has led to productivity losses in regions such as Emilia-Romagna. Consumer demand for climate-friendly products is growing, but is still underdeveloped. The recommendations focus on price stability, upfront support, subsidised loans and training, and the creation of clear, trustworthy carbon credit schemes with co-benefits that are integrated into CAP funding systems.

4.2.3 MONTENEGRO

Montenegro's support for carbon farming practices is mostly indirect. Through its Agrobudget and IPARD funds, farmers can access grants for practices like organic farming, pasture improvement, or planting perennials - activities that improve soil quality and sequester carbon incidentally. However, targeted financial instruments for carbon farming - such as tax breaks or carbon payments - are not yet in place. The carbon credit market is also undeveloped, and farmers lack access to brokers or verification systems that would enable monetization of carbon sequestration.

Costs remain a major barrier, especially for the smallholders who dominate Montenegrin agriculture. Implementing even low-tech practices like cover cropping or rotational grazing can be prohibitively expensive without cost-sharing or communal equipment schemes. Larger farms, which are better positioned to absorb investments, are rare. There is limited public or private investment in soil-specific initiatives, with most infrastructure projects supported by international donors. To address these gaps, Montenegro could introduce dedicated subsidies for soil carbon practices, offer grants or loans for equipment, and pilot internal offset schemes to support on-farm carbon sequestration. Public-private partnerships - especially involving the tourism or food processing sectors - could also stimulate market-driven interest in sustainable farming.

4.2.4 NORTH MACEDONIA

Economic support for carbon farming in North Macedonia is mainly available through direct payments, IPARD funds and the National Programme for Rural Development. These mechanisms provide limited support for agro-ecological practices like green cover, crop rotation and organic farming. However, there are no incentives directly linked to verified carbon sequestration or penalties for land degradation. There is no market for carbon credits and the current legal framework does not include mechanisms to monetise soil carbon, although the draft Law on Climate Action proposes future carbon fee structures.

The costs of implementing carbon management techniques vary widely. While some low-cost practises such as cover cropping are more accessible, others - such

as mulching, composting or mechanical manure spreading - require investments that are prohibitively expensive for smallholders. Many fruits and wine growers resort to burning pruning residues because mulchers are prohibitively expensive. Limited public and private investment, low farm incomes and limited access to equipment or credit are major economic barriers. Organic farming, which is relatively well supported, is expanding and could provide an indirect model for promoting carbon-friendly practises. Expanded IPARD measures, more targeted subsidies and raising awareness of the long-term economic benefits are needed to expand carbon farming.

4.2.5 SLOVENIA

Funding for soil quality and carbon-friendly practises in Slovenia is primarily channelled through CAP mechanisms, including eco-schemes and agri-environmental and climate measures. These include the promotion of permanent grassland, green cover, the use of compost and organic fertilisers. However, these subsidies are not currently linked to measured or verified carbon sequestration outcomes. Beyond the CAP, EU projects such as Carbon Farming MED and Horizon initiatives provide additional funding for innovation and pilot testing, but these are not accessible to all farmers.

In Slovenia, there is currently no functioning carbon market and farmers cannot monetise carbon sequestration as there are no MRV standards, aggregation platforms or certification infrastructure. The implementation costs of carbon management - such as buying no-till equipment or conducting SOC tests - are a major challenge, especially for the many smallholders in Slovenia (average farm size ~6.9 ha). Economic barriers also include the low profitability of primary production, uncertainty about future regulation and carbon prices and the lack of risk-sharing instruments. While public investment flows through the CAP and EU research, there is virtually no private investment in carbon farming and opportunities for public-private partnerships remain untapped. Consumer awareness of and demand for carbon-labelled products is also negligible, although interest in organic and local food is growing.

4.2.6 SPAIN

Spanish carbon farming is primarily based on CAP-funded agri-environmental programmes that support practises such as cover cropping, reduced tillage and organic farming. Additional support comes from regionally tailored programmes and Horizon Europe projects. While these subsidies improve soil management, they are not directly linked to carbon removal. In Spain, there is no fully functioning market for carbon credits, although pilot initiatives (e.g. ClimateTrade, Azolla Projects) are trialling commercial models. The challenge remains the standardisation of verification methods and the establishment of a trustworthy system for issuing and trading credits.

Economic barriers include high upfront costs for equipment and training -

particularly burdensome for smallholder farmers - limited access to finance, market volatility and uncertainty about long-term yields. Although large farms and co-operatives are better placed to invest, small farms struggle with affordability and risk. Public investment remains focussed on CAP instruments, while private sector investment is increasing, particularly in the areas of agricultural technology, carbon detection and biopesticide development. Public-private partnerships have potential but are still being developed. Soil degradation, especially in arid and semi-arid regions, is a growing problem that reduces productivity and increases production costs. To achieve broad acceptance, Spain needs performance-based payments, accessible credit and mechanisms to reduce the risk of investing in the carbon economy.

4.3 Social factors

Awareness and acceptance of carbon farming among stakeholders is generally low, but growing, especially where pilot projects and demonstration farms are active. Traditional agricultural practises and socio-economic challenges (e.g. ageing farmers, fragmented extension systems) are limiting rapid uptake. Nevertheless, younger farmers, non-governmental organisations and academic institutions are important actors for change. Interest increases when carbon management is seen in the context of productivity, soil health and co-benefits such as biodiversity. Peer learning, tailored training programmes and regional success stories are essential to change perceptions and build a better informed and motivated farming community.

4.3.1 GREECE

Awareness of carbon farming among Greek farmers and communities is limited, mainly due to the novelty of the concept and insufficient access to information and services. Nevertheless, interest is growing - especially among younger, better educated farmers who are more open to modern, sustainable practises. Traditional farming methods such as intensive tillage and monocultures are still widespread and are often at odds with soil conservation objectives. However, resistance to carbon management is primarily economic rather than cultural or historical.

Some non-governmental organisations and extension services are working to promote soil quality and some agricultural advisors are supporting pilot projects, such as integrated land management in olive groves. Although there are no formal training programmes, there is a great willingness among stakeholders to participate in capacity building activities, especially among younger farmers. There are significant knowledge gaps among both farmers and policy makers regarding carbon sequestration mechanisms, MRV systems, economic benefits of carbon credits and the integration of carbon management into existing practises. Given the visible impacts of climate change, community support for carbon farming is likely to be high and previous soil remediation projects have received public support. To improve uptake, Greece would benefit from targeted awareness

campaigns, education programmes, community engagement and greater collaboration between policy makers, NGOs and corporate partners.

4.3.2 ITALY

Awareness of carbon farming among farmers and communities is still low throughout Italy. Where awareness exists, interest is growing - especially among younger or better-informed stakeholders. However, scepticism and resistance remain due to uncertainty about economic returns, lack of short-term benefits and mistrust of carbon markets. Cultural factors play a role: ageing rural populations and knowledge systems based on tradition are less open to adopting unfamiliar techniques. Some practises supported by the CAP (such as cover cropping and reduced tillage) are more easily adopted due to their economic orientation, while agroforestry or advanced conservation agriculture face more resistance.

Interest groups such as non-governmental organisations (Re Soil Foundation, Legambiente), universities, cooperatives and producer organisations are actively promoting soil quality. Training is available locally and is being expanded through EU projects such as LILA4SOILS, but national coordination is limited. Stakeholder engagement is improving, especially where demonstration plots, roundtables and pilot projects are utilised. Community support is possible but depends on access to practical tools, farmer-to-farmer learning and credible data. Recommendations include setting up living labs, improving knowledge sharing, integrating carbon farming into curricula and promoting early adopters as role models.

4.3.3 MONTENEGRO

Carbon farming is a new concept for most farmers and communities in Montenegro. While terms such as "organic farming" are somewhat familiar, practises explicitly aimed at improving soil carbon levels - such as no-till, cover cropping or agroforestry - are not widely known or practised. Traditional farming practises are prevalent, particularly among the ageing rural population and resistance to change is often rooted in cultural norms and perceived economic risk. Nevertheless, there is the potential to combine tradition and innovation. Traditional mixed cropping systems, for example, already recycle nutrients and seasonal grazing can be carbon friendly.

Stakeholder interest is growing, especially among non-governmental organisations, universities and some local authorities. The Biotechnical Faculty of the University of Montenegro is playing a leading role in research and outreach. Some farmers practising organic farming are starting to adopt carbon enhancing practises and could serve as pioneers. However, a combination of public recognition, practical training and local pilot projects is needed to achieve widespread adoption. Community-based outreach, such as field schools or school programmes, could normalise carbon management while respecting traditional knowledge. Embedding carbon management in a framework that preserves the land for future generations and national identity can also improve social

acceptance.

4.3.4 NORTH MACEDONIA

Carbon farming is still an unfamiliar concept for most producers and municipalities in North Macedonia. Due to limited outreach, inadequate training infrastructure and fragmented stakeholder coordination, awareness of the issue is widely lacking. Farmers are generally open to new practises when the benefits are clear and the technologies accessible - especially when pilot projects offer training or equipment. However, resistance remains, often due to low incomes, poor access to technology and adherence to traditional practises.

Cultural attitudes are not inherently resistant, but the progressive depopulation of rural areas and the ageing agricultural population are hindering innovation. While some land improvement measures - such as drip irrigation, fertilisation and soil monitoring sensors - are on the rise, intensive monocultures and the use of mineral fertilisers remain widespread and detrimental to soil health. Scientific institutions and non-governmental organisations have initiated projects on soil, but carbon farming is not yet a priority for the government or large cooperatives. Social acceptance could be significantly increased through targeted campaigns, field demonstrations, farmer-to-farmer exchanges and incentives for early adopters. Community support is likely if carbon management is presented as a way to maintain land productivity and improve rural livelihoods.

4.3.5 SLOVENIA

Awareness of carbon farming is still low among Slovenian farmers, although the general understanding of soil conservation practises is higher. Many producers are unfamiliar with the term “carbon farming” and associate it with bureaucratic red tape or potentially restrictive requirements. Misconceptions persist, especially around the financial viability of carbon credits, and scepticism prevails as there are no local success stories. Consumer understanding of the links between soil, carbon and food is virtually non-existent and there are no products with carbon credits on the domestic market.

Traditional agricultural practises are often at odds with the goals of the carbon economy. For example, ploughing is still widespread in arable farming regions, which hinders the accumulation of carbon in the soil. In contrast, alpine and sub-alpine livestock systems with permanent grassland provide a more favourable basis for carbon-positive management. Resistance to change is partly cultural and generational. Many farmers rely on traditional practises and are cautious about introducing innovations without peer endorsement. Non-governmental organisations such as SACA, research institutions such as UL-BF and KIS, and municipalities involved in EU soil projects are among the most active proponents of soil quality.

Training programmes are increasing but remain fragmented. EU projects and

NGOs occasionally offer workshops, but there is no structured national training programme or consultative integration of the carbon economy. Farmers are willing to participate in pilot projects if they are locally relevant and incentivised. There are still gaps in knowledge about how carbon farming works, how soil carbon is measured and what policy or market opportunities (e.g. CRCF) exist. Community support is possible, especially if carbon management is presented as a co-benefit for water retention, biodiversity or food resilience. Demonstration farms and open days, such as those organised as part of the LIFE Grasslands and Carbon Farming MED projects, have shown that they can generate interest.

4.3.6 SPAIN

Awareness of carbon farming is increasing in Spain, but there are still gaps in knowledge and misconceptions - especially around the complexity, costs and long-term benefits. Many farmers still rely on traditional practises that may conflict with sustainable land management, and some are resistant to change due to cultural conservatism and uncertainty. Nevertheless, there is strong public and institutional support for agroecological, organic and regenerative agriculture that intersect with carbon farming principles.

Community-led restoration projects, initiatives for sustainable viticulture and olive groves, and soil conservation programmes in erosion-prone regions such as Andalusia and Murcia show a growing social commitment. Non-governmental organisations, cooperatives and research centres are committed to soil health and consumers are beginning to appreciate eco-labelled products, even if demand for products with the carbon label is still low. Stakeholders - especially younger and innovation-oriented farmers- are showing interest in pilot programmes, especially if they involve equipment, training or financial support. However, formal training systems are fragmented and not generally accessible, especially for smallholder farmers. Social measures such as awareness-raising campaigns, peer learning and the integration of carbon issues into agricultural education are essential to increase community acceptance and uptake.

4.4 Technological factors

A technological capacity for soil monitoring and carbon sequestration varies widely across the region. Advanced tools such as GIS, remote sensing and laboratory-based SOC analysis exist mainly in Italy, Spain and Slovenia, but they are not yet sufficiently used due to high costs, lack of standardisation and limited user-friendliness. Most countries lack a national MRV protocol and data systems are often fragmented. Pilot initiatives and EU-funded research projects are filling some gaps, but wider adoption requires accessible tools for farmers, training and better integration into national platforms. Affordable, locally adapted technologies and advisory support are crucial for scaling up effective carbon farming practises.

4.4.1 GREECE

In terms of technology, the use of carbon-intensive farming methods such as agroforestry and crop residue management has been limited and inconsistent in Greece. The available tools - primarily direct soil sampling and analyses - are technically accessible but financially prohibitive for many farmers, which limit their widespread use. Some pilot initiatives, such as the SOILL start-up project and the development of living labs, are testing new approaches. Research institutes and private companies are actively involved in research and development. Notable projects such as MRV4SOC and ai4soilhealth are contributing to the development of soil quality technologies.

Data management is still fragmented. Commercial Farm Management Information Systems (FMIS) contain soil and carbon data, but there is no integration at national level. Challenges include poor data quality, lack of interoperability, data silos and concerns about privacy, accessibility and governance. Metrics for soil carbon monitoring are not clearly defined and are not commonly used. However, future opportunities lay in the use of precision agriculture technologies, AI-driven tools, blockchain-based carbon verification and smart irrigation systems. Cross-border cooperation, especially through Interreg projects, can support technology transfer. To strengthen the technological framework, Greece should invest in precision agriculture, improve MRV infrastructure and ensure affordable access to monitoring technologies.

4.4.2 ITALY

Italy uses a range of carbon farming techniques, including cover crops, organic amendments, reduced tillage and permanent pastures. Soil monitoring technologies include in-situ sampling, laboratory analyses, GIS-based mapping and new tools such as remote sensing and visual soil assessment (VSA). Some platforms such as the Climate-Smart Agriculture Simulator and the C-FARMs demo support data management, while blockchain solutions such as Trusty and Agri-Food Track improve the traceability of carbon-related products.

Nevertheless, the adoption of advanced technologies is hampered by cost, complexity and the small size of many Italian farms. There are several research and innovation efforts - led by universities and institutions such as CREA, ISPRA and CNR - as well as pilot initiatives within projects such as Carbon Farming CE, LIFE Carbon Farming, Carbon4SoilQuality and Spin-Fert. Challenges remain in standardising MRV protocols, ensuring data interoperability and integrating systems at different levels. Future opportunities include AI-powered GIS, precision sensors and smart machines, but their success will depend on farmer-friendly interfaces and economic support. Technological progress must be paired with meaningful financial and political incentives to achieve broad acceptance.

4.4.3 MONTENEGRO

Technological readiness for carbon farming in Montenegro is limited but is gradually improving. While some traditional practises such as manure spreading and permanent grassland contribute to soil carbon content, advanced techniques such as biochar, no-till or precision cropping are rare. Soil monitoring is not systematic, although major institutions such as the Biotechnical Faculty and the Environmental Protection Agency have analytical capacity and use GIS tools for land use mapping. Outside of the larger producers, there is hardly any modern agricultural equipment, and even basic tools for analysing soil quality are out of reach for most smallholder farmers.

IPARD and donor programmes have supported the introduction of some new technologies, but high costs, lack of training and weak extension services are obstacles. Montenegro is in the process of digitising its national soil maps and integrating its databases (e.g. LPIS, IACS), which could support better soil and carbon tracking in the future. Research organisations are involved in international projects and can provide a basis for expansion. Opportunities include using remote sensing and drones for soil analysis, trialling small-scale biochar systems and developing digital platforms for agricultural data and carbon metrics. For this to succeed, technological improvements must go hand in hand with farmer training, accessible funding and institutional coordination.

4.4.4 NORTH MACEDONIA

The introduction of technologies in North Macedonia is progressing but is uneven. The most widespread carbon-intensive farming practises include cover cropping in orchards and vineyards, mulching with pruning residues, composting and crop rotation. These practises are generally only used in individual cases, often as part of donor-funded projects. The infrastructure for soil monitoring is available at the reference institutions, but is limited by inadequate equipment, the lack of a national monitoring system and the lack of accessibility for smallholders.

Promising initiatives include the Macedonian Soil Information System LPIS, agro-ecological zoning and digital mapping platforms. R&D projects such as CARBONICA and ECOBASE contribute to the development of new methods. However, the cost of equipment, limited training and weak interoperability of data hinder wider application. Farmers rarely use advanced tools such as sensors or satellite data, although pilot projects show potential. Soil metrics such as pH, SOC, texture and nutrient content are collected inconsistently and without a coordinated MRV system.

Future opportunities lie in the expansion of remote sensing, the integration of soil sensor networks and the promotion of cross-border cooperation within the framework of EU-funded programmes. To enable effective carbon management, North Macedonia needs to establish a national soil monitoring system, strengthen scientific capacity and improve access to technology for both researchers and

farmers. The networking of digital databases and the institutionalisation of lifelong learning for farmers and advisors will be crucial.

4.4.5 SLOVENIA

Slovenian farmers already use several carbon-enhancing practises, such as cover cropping, reduced tillage, composting and grassland management. However, the impact of these techniques on soil carbon is rarely quantified due to the lack of accessible MRV tools. Slovenia has strong institutional capacity in soil science and monitoring, with detailed datasets maintained by ARSO and KIS, GIS layers and laboratory SOC analyses. Nevertheless, these tools are not integrated into farm-level decision-making and farmers generally do not have access to localised or user-friendly digital platforms.

Official MRV methods for soil carbon have not yet been introduced, although pilot trials are underway through different national and international projects. The technological infrastructure is in place, but major bottlenecks include high testing costs, fragmented data systems and the lack of standardised protocols. Research organisations are active, but private sector involvement is minimal and there are few agri-tech startups working on SOC measurement or carbon credits. Promising technologies include AI modelling, in-field SOC sensors and blockchain systems for traceability, but these need to be adapted to Slovenian conditions.

To advance carbon management, Slovenia needs a national MRV standard, a digital soil carbon calculator in Slovenian, affordable test kits, better interoperability between databases and training of advisors. Cross-border cooperation - especially with Austria, Italy and Croatia - offers valuable models for technology transfer and implementation.

4.4.6 SPAIN

Spain is making progress in adopting low-carbon farming technologies, but access and uptake remains uneven. Practises such as no-till, composting and cover cropping are widely used in certain sectors, especially in vineyards and olive groves, where their benefits are more visible. In arid and semi-arid areas, however, uptake is limited due to water scarcity and infrastructure gaps. Soil monitoring tools - including remote sensing, soil sensors and GIS - are available but not widely used by smallholders due to cost, technical complexity and lack of support services.

Spain is an active player in the field of research and innovation. Institutions such as the CSIC and several universities are developing tools for soil carbon measurement, biochar production, AI-assisted diagnostics and precision agriculture. Private agri-tech companies are involved in software and hardware solutions, including soil sensor networks and blockchain-based carbon tracking platforms. Projects like SOILCARE and current Horizon-funded efforts support innovation, but interoperability, data standardisation and cost remain bottlenecks.

Metrics for monitoring soil health include SOC content, structure, water retention,

nutrient content and biodiversity, with a new focus on analysing the microbiome. Despite strong R&D capacity, the practical adoption of technologies remains patchy, especially among smallholders. To improve results, Spain needs to invest in cost-effective MRV tools, standardised data platforms and cross-border collaboration through Interreg and Horizon programmes. Improving digital literacy and infrastructure in rural areas is also crucial to ensure equitable access to new technologies for the carbon economy.

4.5 Summary of the results of the pest analysis

The PEST analysis identified a number of common challenges and opportunities in the partner countries as well as context-specific barriers to the uptake of carbon farming.

In all six partner countries, there is a strong rhetorical and strategic alignment with EU climate and soil policies, including the European Green Deal, the Biodiversity Strategy and the CRCF Regulation. National CAP Strategic Plans typically include eco-schemes and agri-environmental and climate measures (AECMs) that indirectly support carbon sequestration. However, none of the countries have formally defined carbon management in their national legislation, and all lack a certified MRV (Monitoring, Reporting, Verification) protocol or an operational carbon register. Soil protection laws are either weak, fragmented or under development. While research organisations and ministries participate in EU-funded projects and international soil networks, coordination between national, regional and local actors is often limited or inconsistent. This leads to a gap between policy and practise, where strategies exist but are not yet translated into enforceable or measurable carbon management frameworks.

In economic terms, all partner countries face a number of similar challenges. CAP funds provide important support for sustainable agricultural practises such as cover cropping and reduced tillage, but these payments are not performance-based and do not reward verified carbon removals. No country has an active national market for agricultural carbon credits, and farmers cannot yet monetise the results of carbon sequestration. The lack of MRV infrastructure, carbon pricing mechanisms and aggregation platforms makes it difficult for farmers - especially smallholders - to see clear financial benefits. Initial investment costs for equipment and soil analyses remain high, and access to credit or insurance for risk protection is limited. While there is some interest from the private sector, particularly in Spain and Italy, public-private partnerships are underutilised. Economic uncertainty, small farm sizes and lack of clarity on return on investment are the main barriers to widespread adoption of carbon farming methods.

Social awareness of carbon farming is developing but remains low in all six countries. Most farmers understand the basic principles of soil conservation, but the concept of "carbon farming" - especially as a climate service or market opportunity - is not yet well known. Misconceptions about the complexity,

certification effort or potential yield reductions often lead to resistance. Traditional farming methods (e.g. deep/intensive tillage, residue burning, monocultures) are still prevalent and can be incompatible with soil carbon targets. While pilot projects and EU-funded training have increased engagement in certain areas, advisory systems and educational work remain fragmented and insufficiently scaled. Consumer awareness is also very low and there is no widespread demand for carbon-labelled or renewable food. Nevertheless, the willingness of stakeholders to participate in training or pilot projects is growing, especially when it comes to tangible benefits (equipment, payments or peer learning). Greater communication, practical demonstrations and integration into vocational training could help to change attitudes.

Technological capacity for carbon farming varies widely across partner countries, but all face similar barriers to equitable access and effective implementation. Best practises such as reduced tillage, composting and cover cropping are used in parts of each country, but their application is still uneven, especially among smallholder farmers. Monitoring tools (e.g. SOC tests, GIS systems, remote sensing and laboratory infrastructure) are provided by public organisations, but are often too expensive, too complex or too fragmented to be used at farm level. There is a clear gap between research capacities - many of which are state of the art - and the practical tools available to farmers. None of the countries have a nationally recognised MRV method for soil carbon, although pilot initiatives are underway. The interoperability of data, lack of real-time tools, language barriers and lack of digital literacy further hinder technology transfer. To scale up carbon farming, countries need localised, farmer-friendly MRV tools, integrated databases and trained advisors who can bridge the technical gap.

Table 1: Political barriers overview

Issue	Common Across	Notes
No formal definition of carbon farming	All 6 countries	Carbon farming is recognized only informally or within CAP; legal frameworks are missing.
Lack of national MRV protocols	All 6	MRV (Monitoring, Reporting, Verification) systems are either absent or in the early pilot stages.
No operational carbon credit registry	All 6	Even in Spain and Italy, which are more advanced, registries are in development, not active.

Issue	Common Across	Notes
Fragmented governance	Spain, Italy, North Macedonia, Montenegro	National vs. regional authority conflicts or gaps in coordination.
EU alignment efforts in place	All 6	Most have CAP SPs and linkages to the Green Deal, CRCF and Soil Strategy.

Table 2: Economic barriers overview

Issue	Common Across	Notes
High upfront costs for adoption	All 6	Equipment, training, soil testing – all costly and burdensome for smallholders.
No access to carbon markets	All 6	Farmers cannot monetize carbon sequestration; markets are either non-existent or inaccessible.
Unclear ROI for farmers	All 6	Lack of data, support, and incentives make carbon farming risky from an economic standpoint.
Limited public-private investment	Most countries	Some EU project funding exists; national PPPs are rare.
CAP support for related practices	All 6	Existing support for eco-schemes and AECMs but not tied to carbon performance.

Table 3: Social and cultural barriers overview

Issue	Common Across	Notes
Low farmer awareness of	All 6	Basic soil conservation is known, but "carbon farming" remains a

carbon farming		new concept.
Resistance from traditional practices	Greece, Spain, Montenegro, North Macedonia	Deep-rooted/intensive tillage or monoculture habits limit transition readiness.
Limited training and advisory services	All 6	Training is project-based, inconsistent or not integrated nationally.
Low consumer awareness	All 6	No demand for carbon-labeled food; little understanding of soil-climate links.
NGOs and research support growing	All 6	Active in pilots, public education, and EU projects but still small-scale.

Table 4: Technological barriers overview

Issue	Common Across	Notes
Limited access to soil monitoring tech	All 6	High costs, lack of training and no MRV tools for farmers.
Poor interoperability and data sharing	Slovenia, Spain, North Macedonia, Greece	Soil data exists but is fragmented or not usable for MRV or decision-making.
Weak links between R&D and farms	All 6	Strong scientific base (e.g. CSIC, KIS, UL-BF, CREA) but low on-farm transfer.
EU projects piloting tech	All 6	Horizon and Interreg projects testing sensors, MRV, apps – but not yet scaled.

5 STAKEHOLDER ANALYSIS

This chapter presents a stakeholder analysis at country level based on data collected using the standardized PEST questionnaire. The motivation behind this analysis is to identify the main actors involved in carbon management and soil quality improvement in the C4SQ partner countries, assess their role, and understand their relative level of interest and influence. Stakeholder engagement is a key element for the successful implementation of soil-related climate and environmental measures, especially in the context of the EU Green Deal, the CRCF Regulation and the national CAP Strategic Plans.

Stakeholder insights were obtained from responses to specific questions in the PEST questionnaire, in particular the "social factors" section, which includes questions on stakeholder engagement, education, awareness, cultural practices and willingness to participate in carbon farming activities. Based on this information, the most important stakeholder groups of each country were identified and positioned in an influence-interest matrix. This approach provides a practical overview of stakeholder dynamics and identifies potential starting points for improving communication, coordination, and policy design.

5.1 C4SQ countries stakeholder analyses - summary

Across all participating C4SQ countries, stakeholder landscapes exhibit several common characteristics, though they differ by country in terms of capacity, commitment and institutional maturity National ministries of agriculture and environment are consistently the most influential actors in shaping carbon farming and land policy. However, their interest in or prioritization of carbon farming varies. In countries such as Spain, Slovenia and Italy, ministries are more committed to aligning with EU climate targets, while in other countries such as Montenegro or North Macedonia, implementation is still at an early stage and the policy framework is evolving as part of the EU accession processes.

Public bodies responsible for environmental monitoring or agricultural development (e.g. ARSO in Slovenia, MITECO in Spain) usually play a strong technical or regulatory role, although coordination with ministries and regional authorities is not always smooth. Their influence is often strong, but interest in carbon farming as such depends on national priorities, regulatory willingness, and the ability to implement or enforce monitoring.

Research organizations (such as KIS, CSIC, CREA and universities) are highly interested and engaged actors in all countries. They lead or support EU-funded projects, develop MRV methods, and often form the technical backbone of policy development and advisory systems. However, their influence on direct policy making or subsidy design is usually more limited unless strong science-policy links are established.

Farmers, especially smallholders, play a central role in implementing practices, but face consistent barriers across countries. These include low profitability, lack of technical knowledge, and limited access to carbon markets or customized support. While interest in soil health is often high, familiarity with carbon farming as a concept remains low, and uptake depends heavily on trust in advisors, financial support, and the practicality of proposed measures. Larger farms and co-operatives are better placed to adopt new practices and pilot projects.

Agricultural advisors and co-operatives act as important intermediaries. Their engagement is growing, especially in countries where they are supported by EU projects or have access to up-to-date training. However, carbon farming is not yet fully integrated into mainstream extension curricula in most countries.

NGOs and civil society organizations are most active in Spain, Italy and Slovenia, where they promote regenerative agriculture, agroecology and biodiversity. Although their influence is generally less than that of institutional actors, they play a crucial role in awareness-raising and local pilot projects. In other regions, their presence is more limited or project-dependent.

Consumers show the least influence and interest overall. While awareness of organic and sustainable products is increasing in some countries, carbon-labelled products or carbon farming concepts have not reached public awareness in any of the C4SQ countries. Nevertheless, the indirect demand for sustainably produced food could become a driver in the future.

Overall, the influence-interest analysis shows that better coordination between influential institutional actors and interested but underfunded stakeholders such as researchers, consultants and farmers is needed to scale up carbon farming. Targeted training, alignment of incentives and functioning MRV systems will be key to enabling broader engagement and bridging the gaps between policy ambition and action on the ground.

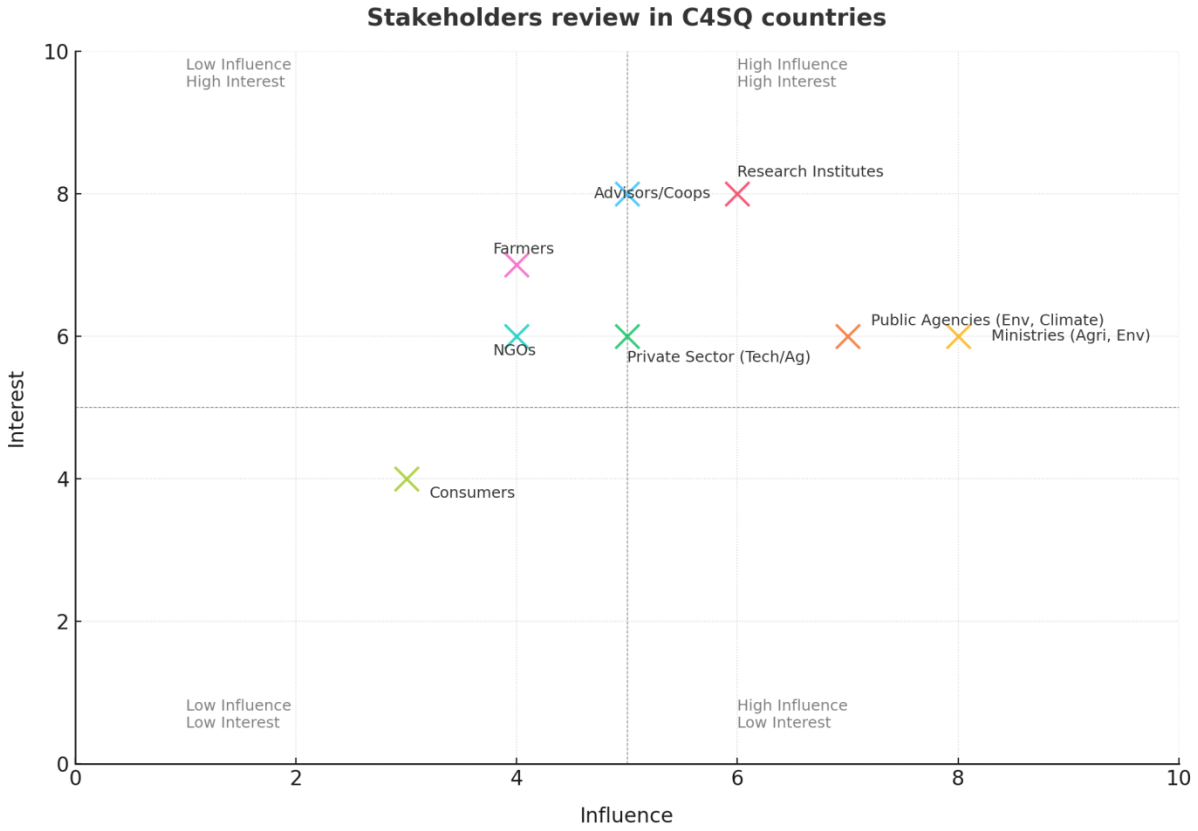

Figure 1: Influence-Interest Matrix "Stakeholders review in C4SQ countries"

5.2 Country by country stakeholder analyses

The following section provides a country-specific overview of the key stakeholders relevant to carbon management and soil quality in each C4SQ partner country. Based on the responses to the questionnaires, each profile summarizes the main stakeholder categories, their role, influence and interest, as well as their general attitude towards carbon farming. An influence/interest matrix accompanies each country's summary to visualize stakeholder positioning and identify potential entry points for engagement and capacity building.

5.2.1 GREECE

In Greece, the landscape of stakeholders around carbon management is still emerging, with government agencies such as the Ministry of Agricultural Development and Food and the Hellenic Agricultural Organization being the key players in policy and monitoring. However, national policy has yet to formally incorporate carbon management, and economic incentives are largely limited to the organic schemes within the 2023–2027 CAP. While a carbon market has been announced for 2025, its accessibility and robustness remain unclear. Farmers,

especially younger and better educated farmers, show a growing interest in sustainable practices, but uptake is limited by economic uncertainty, high upfront costs, and insufficient technical knowledge. Agricultural advisors — both public and private — play a crucial role in sharing knowledge and facilitating pilot projects. Non-governmental organizations have a marginal but positive presence, particularly in the promotion of regenerative agriculture. The private sector and research organizations are actively developing technological solutions, such as monitoring systems and MRV tools, but these are not yet widespread due to cost and fragmentation. Public awareness beyond farmers is low, and traditional practices (e.g. intensive tillage, monocultures) are often at odds with the principles of carbon farming. Future success depends on coordinated policy support, better financial incentives, a stronger data infrastructure, and a broad awareness-raising campaign targeting all actors from farmers to policy makers and consumers.

5.2.2 ITALY

In Italy, the environment for carbon farming is very progressive and multi-layered, with strong coordination between regional authorities, national ministries, research organisations, farmers, cooperatives, NGOs and the private sector. While there is no national policy that specifically regulates carbon management, both the CAP pillars and the regional rural development programmes (e.g. in Veneto and Emilia-Romagna) provide targeted measures (e.g. SRA03, SRA04, SRA07, SRA08) that support soil carbon sequestration. High-level institutional actors include ministries (Ministry of Agriculture, Food Sovereignty and Forests - Masaf, Ministry of Environment and Energy Security - MASE), regional environmental protection agencies ARPAE/ARPAV, Council for Agricultural Research and Economics - CREA and National Research Council - CNR, while local governments and regional authorities are responsible for implementation and monitoring. Research institutions and universities play a key role in the further development of methods, MRV tools and digital platforms. Farmers are divided: large farms show more capacity and openness, while small farms are limited by economic barriers and lack of access to technology. Co-operatives and advisors act as important intermediaries, helping to bridge knowledge and resource gaps. NGOs such as ReSoil and Legambiente advocate for regenerative practises and policy change. Consumers are showing moderate interest in sustainable food systems, although awareness of carbon farming is still low. Successful pilot projects and growing market mechanisms such as the national registry for carbon credits and corporate initiatives (e.g. Barilla) offer new avenues for stakeholder engagement. To scale up carbon farming in Italy, stakeholders need long-term financial predictability, MRV standardisation and coordinated, multi-level education and engagement strategies.

5.2.3 MONTENEGRO

In Montenegro, carbon farming is in the early stages of recognition and adoption, with a fragmented but gradually strengthening network of stakeholders. The Ministry of Agriculture and the Ministry of Ecology lead national policy alignment with the EU Green Deal and biodiversity strategies, although the absence of a dedicated soil law and limited administrative capacity hampers regulatory effectiveness. The University of Montenegro - Biotechnical Faculty is a central research actor, offering both policy-relevant studies and technical support. Smallholder farmers dominate the agricultural sector but face significant economic and technological barriers to implementing carbon-friendly practices. Their engagement is growing, especially when linked to pilot programs and subsidies. Agricultural advisors and local NGOs play a pivotal role in community-level outreach and awareness, although broader public understanding remains limited. There is emerging interest from the private sector, particularly from agribusiness and eco-tourism supply chains, which could become valuable partners in scaling sustainable practices. However, data infrastructure, MRV capacity, and public-private collaboration mechanisms remain underdeveloped. To fully mobilize stakeholders, Montenegro will need improved legal clarity, more targeted financial incentives, better coordination across ministries, and hands-on training and demonstration initiatives to engage rural communities.

5.2.4 NORTH MACEDONIA

In North Macedonia, the landscape of stakeholders for carbon farming is gradually evolving, driven by the strategic alignment with EU policies and the Green Agenda for the Western Balkans. The Ministry of Agriculture (MAFWE) and the Ministry of Environment oversee the development of policies and regulations, but implementation is limited due to gaps in the legal framework and fragmented institutional responsibilities. Research institutions, including the Faculty of Agricultural Sciences and Nutrition and the Institute of Agriculture, play a critical role in trialling technologies and informing policy, but lack consistent funding and infrastructure for broad-based support. Smallholder farmers, who form the backbone of national agriculture, show great interest but face significant barriers — low income, limited access to equipment and low technological capacity. Extension services are key, although their knowledge of carbon farming is still underdeveloped. Non-governmental organisations and international donors are the main actors in demonstration projects and farmer training, but outside the scientific community carbon farming is still a niche topic. Despite low consumer awareness, there is an increasing demand for organic products, which has an indirect leverage effect on the market. In the future, success will depend on improving institutional coordination, strengthening links between research and extension, improving data platforms and creating concrete financial incentives and pilot projects for farmers.

5.2.5 SLOVENIA

Slovenia's stakeholder ecosystem for carbon farming reflects strong institutional expertise but fragmented implementation. The Ministry of Agriculture (MKGP) and the Slovenian Environment Agency (ARSO) lead policy and reporting frameworks under the CAP, NECP, and LULUCF plans. While research institutions such as the Agricultural Institute of Slovenia (KIS) and the Biotechnical Faculty (UL-BF) drive innovation and EU project participation, the absence of a national MRV protocol, carbon registry, or legal recognition of carbon farming hinders systematic implementation. Smallholder farmers, who dominate the Slovenian landscape, are increasingly interested in soil health practices but remain hesitant due to unfamiliarity with MRV systems and lack of financial incentives. Agricultural advisors are key intermediaries, yet carbon farming is not yet mainstreamed into their curricula. NGOs like SACA and Plan B for Slovenia play a growing role in outreach and awareness, especially through EU-funded demonstration projects. Consumers show weak awareness of carbon-labelled food products, though interest in organic and local produce is increasing. The private sector, including organic value chains, has not yet integrated carbon metrics but may become a partner in voluntary markets. To scale carbon farming, Slovenia needs coordinated MRV structures, economic signals, and robust farmer engagement through training and advisory services.

5.2.6 SPAIN

Spain presents a complex but promising stakeholder landscape for carbon farming, characterized by a multi-layered governance system and regional diversity. The Ministry of Agriculture (MAPA) and the Ministry for Ecological Transition (MITECO) set national strategies, aligned with the EU Green Deal and CAP, while regional authorities implement agri-environmental measures based on local priorities. Research institutions like CSIC and public universities are highly engaged in EU-funded projects and are leading innovation in soil health, remote sensing, and carbon sequestration methodologies. However, smallholder farmers face adoption challenges due to cost, lack of technical assistance, and limited awareness. Advisory services and cooperatives are instrumental for outreach but require improved training on carbon metrics. NGOs and environmental groups support regenerative agriculture and soil recovery projects, especially in erosion-prone regions. The private sector, including AgTech startups and carbon credit platforms, is emerging but not yet widespread. Consumer awareness of carbon farming is low, although support for organic and eco-certified products is growing. Spain’s success in scaling carbon farming will depend on standardized MRV protocols, better coordination across governance levels, expanded training, and targeted incentives for technology and practice adoption.

6 IMPACT ASSESSMENT OF CARBON FARMING PRACTICES IN THE MEDITERRANEAN

6.1 Environmental impacts

Despite significant differences in soil-climate conditions, carbon farming practises across the Mediterranean offer numerous environmental benefits. Practises such as reduced tillage, cover cropping, composting and agroforestry have been identified in all six partner countries and are known to increase soil organic matter (SOM), reduce erosion, improve water retention and promote biodiversity. However, the actual potential for carbon sequestration is limited in many areas due to shallow soils, high mineralisation rates and SOC saturation in carbonate-rich soils.

Nevertheless, ecological side effects beyond sequestration are repeatedly recognised, such as increased drought resistance, reduced soil degradation and better erosion control. In more humid or temperate Mediterranean zones (e.g. northern Italy, parts of Slovenia), the potential for a measurable increase in SOC is higher. In arid and semi-arid areas (e.g. southern Spain, northern Macedonia), carbon farming is more effective when it comes to avoiding further degradation and stabilising existing carbon stocks.

6.2 Economic impacts

From an economic perspective, the carbon economy in the Mediterranean remains financially risky and receives little support. Although CAP ecosystems and agri-environmental measures provide indirect support, there are no performance-based payments for verified carbon sequestration. None of the partner countries currently have a fully functioning carbon credit market. Italy and Spain are the most advanced in the development of registries, while other countries rely mainly on the CAP or donor support.

The implementation costs - of equipment, MRV or switching to new practises - are a significant barrier, especially for smallholder farmers who dominate the agricultural landscape in most partner countries. The lack of MRV systems, unstable or non-existent carbon prices and the lack of clear return on investment (ROI) paths contribute to farmers' reluctance. Nevertheless, pilot projects and research initiatives suggest that public-private partnerships and consumer incentives (e.g. sustainability labelling) could play a role in future market development.

6.3 Social impacts

Social awareness of carbon farming is low but increasing. Farmers generally understand the principles of soil conservation, but the term “carbon farming” is not widely used, and where it is known, it is often associated with bureaucratic complexity or uncertain benefits. Resistance is partly cultural - due to traditional practises such as deep tillage or monocultures - and partly economic.

Younger, better educated farmers are showing greater openness to sustainable practises, and non-governmental organisations, consultants and research institutions are actively promoting carbon-friendly land management. However, education remains fragmented and extension services are not yet able to mainstream support for carbon management. Public support tends to be higher where demonstration projects, EU-funded pilot projects and awareness-raising campaigns have been implemented (e.g. in Slovenia and Spain).

6.4 Technological impacts

The technological capacity to support carbon management is uneven across the region. While countries such as Greece, Italy, Spain and Slovenia have advanced scientific infrastructure, the practical tools needed by farmers - such as affordable SOC tests, standardised MRV tools and farmer-friendly digital platforms - are largely absent. This creates a gap between excellent research and applicability at farm level.

Pilot projects such as blockchain platforms, soil sensors and GIS-integrated farm management tools are underway and are often funded by Horizon or Interreg projects. However, scaling these technologies requires integration into extension systems, cost reductions and national MRV standardisation.

6.5 Yield impacts of carbon farming practices

When implementing carbon farming practises in the Mediterranean region, it is not only soil health and carbon sequestration that need to be considered, but also the impact on agricultural yields, which remains a major concern for farmers. While yields are highly dependent on local conditions and management, a growing body of research suggests that carbon management can improve the stability and resilience of yields over time, although short-term trade-offs are possible in the transition. Although yield levels were not assessed in the C4SQ PEST questionnaires, we conducted a brief literature review to highlight relevant aspects of this important topic for farmers and policy makers alike.

The main cropping systems in the six C4SQ countries include:

- Perennial systems (olives, grapes, citrus and fruit crops) in Spain, Greece, Italy and Montenegro.
- Arable farming with cereals and maize in Slovenia and northern Italy.
- Mixed vegetable, fodder and grassland systems in North Macedonia, Slovenia and Montenegro.
- Vegetable crops for fresh and industry use in Italy

Many of these systems are under climate and soil stress, especially in the southern zones where drought, shallow soils and low organic matter limit productivity.

6.5.1 SHORT-TERM VARIABILITY

During the transition phase, practices like reduced tillage or permanent cover can

sometimes lead to temporary yield reductions due to:

- Delayed soil warming in spring,
- Initial weed competition,
- Nutrient immobilisation during organic matter build-up (Pittelkow et al., 2015).

These effects are often transient and can be mitigated by locally adapted management and adequate technical support.

6.5.2 MEDIUM-TO-LONG-TERM STABILITY

Improved soil structure, water retention and microbial activity stabilise or improve yields over time, especially under stress conditions. This is particularly important for:

- Cereals and legumes under reduced tillage (Lal, 2018; Roldán et al., 2005),
- Olive and grape systems with permanent cover and compost (Fernández-Habas et al., 2022),
- Extensive grassland with rotational grazing or organic supplements (Conant et al., 2017).

6.5.3 PERENNIAL SYSTEMS AND QUALITY

For vineyards, fruit orchards and olive groves, the focus shifts from yield quantity to fruit quality and soil moisture conservation. Ground covers and organic inputs can reduce soil erosion and improve fruit characteristics (e.g. olive oil polyphenol content, grape sugar content), which increases market value (Gómez-Muñoz et al., 2014; Moreno et al., 2013).

6.5.4 RISKS IN LOW-INPUT SYSTEMS

In resource-poor regions (e.g. parts of Montenegro and North Macedonia), lack of access to compost, machinery or training can lead to sub-optimal carbon farming implementation, where yield losses are possible if carbon practices are not well-adapted to farmers' circumstances or supported by incentives.

6.5.5 IMPLICATIONS FOR C4SQ TESTING ACTIVITIES

Future C4SQ pilot sites should include systematic yield monitoring in addition to carbon and soil indicators. Key recommendations include:

- Measure the quantity and quality of yields of key crops (e.g., cereals, olives, grapes, forage).
- Track stability from year to year to assess the benefits of resilience.
- Include farmer-reported performance indicators (e.g. crop health, input costs, income).
- Consider site-specific trade-offs and design packages of measures accordingly.

7 CONCLUSIONS

Carbon farming in the Mediterranean region has the potential to significantly improve the resilience and long-term productivity of agricultural systems, in particular by reducing vulnerability to drought, erosion and soil degradation. While short-term yield losses are possible - especially in cropping systems undergoing conversion - the environmental and agronomic benefits of well-designed interventions are well documented. Practices that improve soil structure, water retention and organic matter content contribute not only to climate change mitigation, but also to yield stability and resilience of agroecosystems.

However, the impact of carbon farming is highly context dependent. The potential for soil carbon sequestration is often limited by local soil characteristics (e.g. shallow, carbonate-rich or sandy soils) and climatic stress factors (e.g. drought, fire risk, erratic rainfall). Economically, the sector remains underdeveloped and confusing to many farmers, as there are no functioning MRV systems, clear economic incentives, or access to carbon markets. At a societal level, interest is growing - especially among younger and more innovative actors - but uptake is hampered by fragmented training systems and a lack of structured advisory support. Technologically, there is robust research capacity across the region, but innovations are not yet sufficiently utilized as most instruments are still in the pilot or demonstration phase.

To ensure the success of future C4SQ pilot actions and to disseminate carbon farming in the different Mediterranean countries, the following strategic actions are recommended:

- Favour locally adapted approaches that provide other benefits beyond carbon sequestration (e.g. water regulation, biodiversity, food quality).
- Accelerate the development of MRV infrastructure and ensure compatibility with the EU Carbon Removal Certification Framework (CRCF).
- Support economic instruments (e.g. subsidies, PES schemes, carbon credits) that reduce the risk and cost of adoption, especially for smallholders.
- Expand training, extension and advisory services to integrate carbon management into national agricultural education and support systems.
- Promote technology transfer by bridging the gap between research innovations and practical, accessible tools for farmers and advisors.

Achieving scalable impact depends on technical implementation being accompanied by robust data collection, stakeholder engagement and inclusive governance models that reflect the diversity of agricultural systems and institutional capacities in C4SQ partner countries.

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