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## **Deliverable 5.2 Overview of socio-economic influences on crop and soil management systems**

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Overview of socio-economic influences on crop and soil management systems

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# Executive summary

## Introduction

This report examines results from Stakeholder Workshops, specifically looking at:

- Typical cropping systems and rotations and the associated risks to soil carbon and implementation of soil carbon management practices
- The barriers and the opportunities to implementation of cost effective soil carbon management practices (win-win)

One workshop was conducted in each of six case study regions across Europe: Zealand, Denmark; Central Region, Hungary; Tuscany Region, Italy; Mazovia (Mazowieckie Voivodeship), Poland; East Coast, Scotland; and Andalucía, Spain. Participants included: agricultural advisors (from public extension and commercial services), farmer representatives, leading farmers and policy makers.

These workshops follow a preliminary consultation involving interviews undertaken in 2013 and will be followed by a further set of Stakeholder Workshops in 2015. Each activity builds on analysis from the last and the results are fed back to other project WPs in an iterative process which is the core of the SmartSOIL methodology.

Five sets of management practices: planting catch (cover) crops, crop rotations, residue management, reduced tillage operations, and fertilizer and manure management provided the basis for discussion in the workshops. They were previously identified as having the potential to increase soil carbon stocks and are referred to 'soil carbon management practices'.

Preliminary analysis of the cost effectiveness of the soil carbon management practices was undertaken in each case study to provide an assessment of the methods that offer SOC most cost-effectively (win-win practices). This was done using Marginal Abatement Cost Curve (MACC) methodology. MACC figures were presented to participants in the workshops to frame the discussion around barriers and opportunities for implementation of win-win practices.

## **Cropping systems and implementation of soil carbon management practices in the case study regions**

Stakeholders were asked to consider

- Typical cropping systems and rotations in the case studies
- Risks to soil carbon associated with these systems/ practices
- Drivers of these systems/rotations
- Carbon management practices most effective in the case studies
- Current levels of implementation of soil carbon management practices
- Drivers of these soil carbon management practices

A range of cropping systems and rotations were described for the case study regions. However, heterogeneity within regions was also noted, attributed to diversity in biophysical conditions, farming systems and to farm structural conditions. Olive production with intensive tillage in Spain was highlighted as being of particular risk to soil carbon, as was the cultivation of sandy low-humus soils in Mazovia, Poland. An oversimplified crop rotation (due to profit seeking behaviour of farmers) was identified as being a risk in Central Region, Hungary, as was the scarcity of manure available to add to the soil due to reduced livestock numbers. With respect to soil factors, some case study regions had particular constraints and risks. In Tuscany, Italy the hilly landscape, with soils prone to erosion and water shortages, was identified as problematic, and in some areas (clay hilly areas mainly located in the Province of Siena and Pisa) critical soil erosion as well as soil fertility loss has been noted. Whereas in Mazovia, Poland, the poor sandy soils were described as having a significantly low humus content and at risk of degradation. Some participants pointed out the difficulty in disassociating the risks to soil carbon from risks to soil as a whole.

Although choice of crops is largely governed by biophysical factors, economic motivations are important with respect to explaining farmers' cropping and rotation decisions. In Mazovia, Poland for example, choice of crops is profit driven and the economic motivation was thought to be particularly strong for small farmers who dominate the region. In Central Region, Hungary an oversimplified crop rotation is being applied due to economic reasons (e.g. decreasing prices and unfavourable weather in recent years). Other drivers such as urbanisation, as in the example of Central Region Hungary, also influence land use and cropping decisions.

Current levels of implementation of soil carbon management practices vary across, and within, case study regions. In the most part implementation of these practices is influenced by socio economic, rather than biophysical, factors. Some soil carbon management practices are considered uneconomic. For example, in Mazovia, Poland cover crops and legumes are considered unprofitable. In Central Region, Hungary crop residues are often sold for horse bedding, especially in dry years, when the main crop has lower than average yield and there is an increased need for alternative sources of revenue. Participants also noted a shift in practices attributed to farmers' desire to reduce costs and simplify operations. In Spain, for example, advisors described a small evolution with many farmers changing from conventional systems with cereal-fallow rotations to direct seeding and reducing the use of fallow. In Tuscany, Italy, although plowing is widespread, farmers are looking at reduced tillage because they want to reduce costs.

Changing farming systems also impact opportunities for soil carbon management practices. In both Mazovia, Poland and Central Region, Hungary a reduction in livestock systems has reduced supplies of animal manure, making it unavailable or uneconomic to apply. Furthermore the mechanisation needed to spread it is costly.

Policy measures also influences farmers' decisions about soil carbon management practices. In Zealand, Denmark the use of catch crops in the cropping system is mandatory, and the N-saving benefits of catch

crops are explicitly accounted for in the total N allowance per farm. This explains the relatively high use of catch crops. However, because legumes are not accepted as legal catch crops (if the farmer wants to apply legume-based catch crops, they need to be grown in addition to the mandatory catch crops) this discourages farmers from cultivating legumes. In Central Region, Hungary nutrient management practices related to NVZs and AEMs (agri-environment measures) provide opportunities for managing carbon and nitrogen, however specifications and the administration are demanding. Some AEM agreement holders cannot meet nutrient management requirements and drop out of schemes (and therefore practices); other risk averse farmers do not apply any manure because of the risk of being penalised. In Mazovia, an indirect effect of Poland's accession to the EU and exposure to the CAP, has been reduced numbers of livestock and consequently reduced availability of manure to add to the soil.

Farm tenure plays an important role in management decisions. In Tuscany, Italy choice of practice is considered to depend on farm structure and organisation. For instance, in some areas (mainly concentrated in the province of Siena, Grosseto and Arezzo) an increasing number of farms are managed by farm-contractors, this apparently is leading to less interest in the stewardship of the soil. In Spain the agricultural cooperatives may also significantly influence management, since many farmers maintain the ownership but rent and delegate the management to the cooperative. In Central Region, Hungary land tenure is a factor influencing the effectiveness of practices; large farms are often farmed on leased lands with medium term contracts that provide limited opportunity to follow practices in the long term. In Scotland delays in legal decisions concerning the farm tenancy agreements has resulted in short term tenancies or lets becoming popular which are not compatible with long term planning needed for soil carbon management practices to be effective.

Farm size is also important in management decisions. Generally smaller farmers are thought to be less likely to implement soil carbon management practices than their larger counterparts. In Mazovia, Poland agricultural land in the region is heavily fragmented, farms covering less than 10 ha are dominant, these small farms lack expertise and equipment and strive for profit maximisation. In Tuscany, Italy farm size is one of the key drivers leading management practice choices amongst farmers. Here generally, big farm entrepreneurs are driven by economic and marketing aspects, while small farmers - representing the majority in the Region - tend to be driven more by cultural and traditional aspects. Similarly in Spain, cultural factors such as traditions are thought to be important in determining practices. Farmers in Central Region, Hungary are also distinguished as: older and conservative small scale farmers using traditional practices such as deep ploughing; so called 'land-speculators' who are also 'narrow minded' and younger more professional farmers managing larger farms who are innovative and trying out new practices such as biological replenishment. In more general terms traditional practices are preferred because they are familiar and relatively risk free, for example the Spanish winegrowers are reluctant to substitute the present system of removing weeds from between the rows of vineyards with cover crops in case of failure in dry years.

Certain general trends in some regions /countries towards greater environmental awareness and towards more benign practices were noted by workshop participants. For example, in Spain and Italy attitudes toward the environment and society are becoming more positive. This is attributed to a

generational change as younger farmers gain importance and land ownership. In Tuscany, Italy a trend of increasing organic farming was also noted.

## **Barriers and opportunities to implementation of cost effective soil carbon management practices**

In this session a presentation was made of previously prepared Marginal Abatement Cost Curve (MACC) charts for the case study regions. These figures show the cost effectiveness of measures/crop combinations in increasing soil carbon in terms of the change in gross margin for the crop (y axis units are €/tCO<sub>2</sub>e/ha). They indicate win-win practices.

It is apparent that practices assessed as cost effective (according to the MACC assessment) are subject to a number of technical/agronomic; economic/policy and social/cultural barriers suggesting that the MACC assessment needs to be refined (its limitations are acknowledged due to lack of regional data). The responses from this session of the workshops have highlighted the regional variations in the barriers and opportunities for the uptake of soil carbon management practices and the importance of understanding the context into which these practices are introduced. For example residue and manure value and availability influences management decisions.

### *Technical/agronomic barriers*

Regional climatic and environmental conditions can have an impact on the uptake of soil carbon management practices. For example, the cold climatic conditions in Denmark in general can make catch crop establishment difficult, similarly cover crops are difficult to establish in Scotland due to the late harvest and weather related limitations, whilst in Mazovia, Poland autumnal drought can impact on the sowing of catch crops. Whereas in arid conditions in Andalucia, Spain legumes, in crop rotations, do not grow well. The soil context can also influence which practices can be taken up. For example, in Scotland minimum tillage is not working well due to the soil conditions and the sandy soils of Central Region, Hungary are not suitable for growing legumes.

Another common technical barrier mentioned was the requirement for investment in new machinery for some practices, which farmers are either unwilling or unable to bear. They are often unwilling to invest in new practices where they are uncertain about the results. Also smallholdings, in particular, which are predominate in the Italian, Polish and Spanish case study regions, may not be in a financial position to invest in new machinery.

### *Economic/policy barriers*

Concerns about income uncertainties from introducing the new soil carbon management practices were identified as a barrier to uptake by some regions. Farmers, particularly those who are risk adverse, are looking for more assurances about the income potential of these practices. Another barrier mentioned was the additional costs of operation and inputs for some practices, particularly for catch crops (Denmark, Italy, Poland, Spain case studies), but also in relation to minimum tillage (Hungary, Spain case

studies), although in Zealand, Denmark it was suggested that minimum tillage can reduce costs through lower labour requirements. Other barriers included: a lack of a market to sell products, this was particularly the case for legumes in the Hungary, Poland and Spain case studies; and restrictive legislation for manure application in the case studies in Hungary, Italy and Spain. Participants from most case study regions also ranked the lack of financial incentives or subsidies highly as a barrier to the uptake of soil carbon management practices. The subtleties of economic motivations for management decisions were also revealed.

#### *Social/cultural barrier*

A clear barrier mentioned in most regions was a lack of appropriate knowledge exchange and information available to farmers to explain the benefits of soil carbon management practices and to demonstrate these benefits through real-life examples. Also participants in some regions (in particular Hungary, Poland and Spain) felt hampered by a lack of a regional advisory services to deliver these messages. A further cultural barrier for some regions and particularly those dominated by an older farmer population was a reluctance to change and move away from their more traditional management practices to alternatives. Practice-specific social barriers identified were the aesthetic value of zero and minimum tillage with fields regarded as looking “messy” (Zealand, Denmark) and odour issues with manure application, affecting farm tourism activities and local populations (case studies in Italy and Spain, Hungary ).

#### *Opportunities*

A number of opportunities to encourage the adoption of soil carbon management practices were identified. Dominant amongst these was the need to provide incentives to encourage uptake. Opportunities should also be taken to improve existing advisory provision and to establish real-life demonstrations of the practices in operation. In particular it was suggested that advice needs to focus on identifying how practices can maximise profits and gross margins as this was identified in all countries as the main driver of farmer decision-making. Maximising profit did not always equate with increasing yield. In Mazovia, Poland, for example, farmers are not striving to maximise yields for fear of experiencing difficulties in selling the product. Some of the workshops discussed the importance of profit to the farm business, with shorter term business perspectives negatively impacting sustainable soil management. It was suggested that two of the main conditions that need to be met to ensure a long-term perspective to soil management is improving the economic prospects of farms and ensuring the presence of a stable agricultural policy.

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## 1. Introduction

The SmartSOIL project aims to identify agronomic and soil management practices that can optimise crop productivity and store soil carbon. It is doing this using experimental data, scientific modelling and economic analysis to identify key cost-effective practices for managing SOC (SOC) flows and stocks for improved productivity and soil organic carbon storage. Understanding the socio-economic context is an integral part of the project and this is being done by consulting the farming community in case study regions across six European countries.

A preliminary consultation with advisors, farmers' representatives and policy makers revealed a range of region-specific barriers and incentives to the implementation of promising soil and crop management practices. Following on from this consultation, stakeholder workshops were held in case study regions with the aim of drawing on the knowledge and expertise of advisors, farmer representatives, leading farmers and policy makers to understand specifically about:

- Typical cropping systems and rotations in the region and the associated risks to soil carbon
- The soil carbon management practices most relevant to the region and current levels of implementation.
- The barriers and the opportunities to implementation of cost effective soil carbon management practices (win-win)
- A preliminary Decision Support Tool (DST) and Toolbox which is being developed to assist policy makers and advisors in identifying the most effective measures

This report examines results from these stakeholder workshops, specifically looking at:

- Typical cropping systems and rotations and the associated risks to soil carbon and implementation of soil carbon management practices
- The barriers and the opportunities to implementation of cost effective soil carbon management practices (win-win)

The structure of the Report is as follows:

Section 2 provides some context to the study. Section 3 describes the soil carbon management practices considered in this consultation. Cost effective assessment are described in Section 4. Key information about the case studies is presented in Section 5. Section 6 describes the stakeholder consultation process in the project. A summary of the previous preliminary consultation (D 5.1) is presented in Section 7. The methods employed in the workshops are described in Section 8. The analysis of the workshops is presented in Sections 9 and 10. Typical cropping systems and rotations, and the implementation of soil carbon management practices in each case study region are described in Section 9. In Section 10 estimations of the cost effectiveness of soil carbon management practices (calculated by Marginal Abatement Cost Curves) are used to frame an analysis of barriers, the opportunities and the

motivations to implement these practices. A conclusion and explanation of the next steps in the socio-economic analysis follows in Section 9.

## 2. Context of the analysis in this report

Farming practices that lead to declining returns of carbon to, and loss of carbon from, soils pose a threat to these soil functions. There is a need, therefore, to identify agronomic and soil management practices that can optimise soil carbon storage and crop productivity. This is the aim of **SmartSOIL** (**Sustainable farm Management aimed at Reducing Threats to SOILs** under climate change), an interdisciplinary project funded by EU Framework 7). The SmartSOIL project is using meta-analyses of data from European long-term experiments to model the impact of different farming practices on soil organic carbon in arable and mixed farming systems (WP1). This modelling will identify those practices that increase carbon stocks and optimise carbon use (flows). Parallel WPs identify key management practices affecting SOC flows and stocks and their applicability in various farming systems (WP2); and their cost-effectiveness (WP3). Outputs from these activities will be used to develop the SmartSOIL decision support toolbox (WP4).

Understanding the socio-economic context is an integral part of SmartSOIL and one of the main aims of WP5. As such the data collected in WPs 1, 2 and 3 are presented to stakeholders from the farming and policy community throughout the project in an iterative process for validation and comment to help refine the analysis (WP5). This consultation is being carried out in six case study regions across Europe. This process is shown in Figure 2.1.

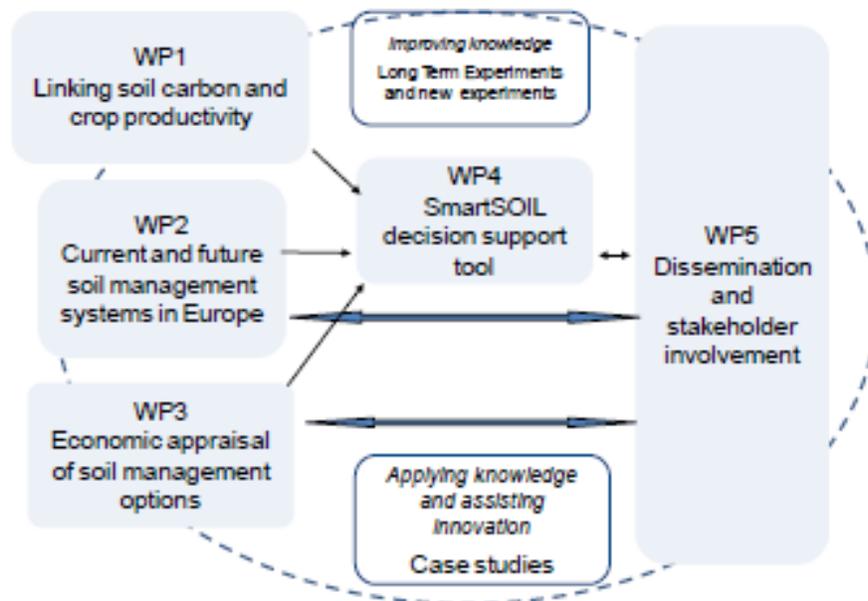


Figure 2.1 SmartSOIL project diagram

### **3. Soil carbon management practices**

Five sets of management practices were identified as having the potential to increase soil carbon stocks: planting catch (cover) crops, crop rotations, residue management, reduced tillage operations, and fertilizer and manure management. These provided the basis for discussion in the stakeholder consultation and were referred to 'soil carbon management practices'. (While these agronomic practices can be considered as soil carbon management practices, it is recognised that they also provide a range of other important functions). These were selected by drawing on analysis in WP2, project partner expertise and on an extensive review of research (Flynn *et al.*, 2007; Smith *et al.*, 2007)

There is large uncertainty with regard to the efficacy of different management practices to enhance soil carbon across different soil types and climatic conditions. Equally, the total carbon changes may be relatively small for many agricultural management practices and thus long periods may be required to measure small differences in carbon accumulation. However, there is general agreement that managing the amount and quality of organic matter inputs in soil and reducing the intensity of tillage can positively influence soil carbon stocks and flows, and thus have the potential to offset some carbon emissions. The project has identified three key sets of activities that can be done to manage organic matter (OM) on farms (and therefore organic carbon).

- put on OM from outside (e.g. animal manure)
- manage on farm OM (e.g. incorporate crop residues)
- reduce OM loss by lowering breakdown of OM in soil (e.g. non- inversion tillage)

This framework is being used by WP2 is developing and refining the list of practices and collecting further details about the effects of these practices on soil organic carbon, GHG impacts, as well as providing a qualitative assessment of the impact on farm businesses (Deliverable 2.1). An early analysis is presented in Table 1 Appendix II).

### **4. Cost effectiveness**

A preliminary analysis of the cost effectiveness of the practices described above was conducted for discussion with stakeholders in Workshop 1.

Overall SmartSOIL is undertaking a cost effectiveness analysis to:

- demonstrate the cost-effectiveness of alternative soil organic carbon (SOC) measures within European farming systems;
- provide a basic hierarchy of the methods that offer SOC most cost-effectively;
- account for additional external costs of implementing said measures (i.e. the trade-off costs in terms of other soil characteristics); and
- provide some indication of the adoption probabilities of measures.

Marginal Abatement Cost Curve (MACC) methodology is being used in this analysis (details can be found in Deliverable 3.2). This combines data on biophysical effectiveness (e.g. SOC, emissions mitigation) with cost data that can be derived from farm scale optimization models estimated with national farm accounts data. The MACC approach provides a basic hierarchy of the measures that offer SOC most cost-effectively. A preliminary analysis was conducted for discussion with stakeholders in Workshop 1 and is reported here.

MACC curves (figures) were prepared for each case study region (or country where regional data was not available) using data provided by the case study partners. MACC figures were prepared (as PowerPoint slides for use in the Workshop). The figures show the cost-effectiveness of the measure/crop combination in increasing soil carbon in terms of the change in gross margin for the crop (y axis units are €/tCO<sub>2</sub>e/ha) and the bars are ordered in decreasing cost effectiveness. Those measure/crop combinations below the x axis represent win-win options where there is a benefit to the farmer of adopting the measure. For some measures (cover crops, residue management) the impacts on gross margin can be considerable due to the high displacement costs (e.g. loss of revenue from sale of straw). In other cases such as minimum tillage for wheat the cost-effectiveness is poor due to relatively small increase in SOC. Three groups of figures were prepared (see Appendix III for explanation and the full set of figures), two MACC charts are included in the report (Section 10).

## **5. Case study regions**

To enhance overall understanding of the socio economic context in the case studies, farm structure data was collected for each region from Eurostat (the regions coincided with NUTS2 in the most part) and supplemented by case study partners with regional data. Information about the national and regional farm advisory services was also collected from document searches and case study partners. Table 5.1 presents some of this data. A summary of biophysical and farm structure data is presented in Appendix VI for each case study region.

Table 5.1 Case study description

Case study	East Coast/ Scotland	Zealand/ Denmark	Tuscany Region/ Italy	Andalucía (Jaén province)/ Spain	Mazowieckie Voivodeship/ Poland	Central Region Hungary
<b>Bio-geographical region</b>	Atlantic North	Continental	Mediterranean	Mediterranean	Continental	Pannonian
<b>Size of total area/ UAA<sup>1</sup> [ha]</b>	735,740/ 1,755,357	703,100/ 337,488	2,300,000/ 809,487	1,348,900/ 647,472	3,668,881/ 2,190,256	691,546/ 397,700
<b>Land cover on UAA</b>	41% cropland, small areas of permanent crops; remainder grassland (rough grazing excluded)	54% arable land with a large proportion of cereal crops.	65% arable lands, 19.5% of permanent crops, 15.5% pastures and grasslands	49 % arable (42% olives), 49% forested or natural area	67,9 % arable land, 23,4% grassland and permanent pasture, 4,8% multiyear culture, 3,9% fallow land	77,2% arable land, 15,6% pastures and grassland, 4,5% orchards and vineyards, 2,7% fallow land
<b>Farming systems and important crops</b>	Large-scale cereal and potato/ arable, with some mixed farming (dairy, beef pigs..) including rotational grassland	Cereal production combined with grass-seed production or cereal production combined with livestock production (primarily pig).	Large scale crops, (mainly wheat), grapevine and olive trees.	Large-scale Olives (representing 1,550,218 ha) including approximately 20% organic, 3% high input irrigated and the rest mostly low-input rainfed	small/medium scale and input crop production, medium scale and high input orchards	Dominated by medium to large-scale arable (cereal), with small to large dairy and small mixed farming (dairy, poultry and pigs.). Horticulture and orchard is also significant in the region.
<b>Land productivity</b>	Typical cereal yields are among the highest in Europe – frequently exceeding 10 t DM ha <sup>-1</sup> yr <sup>-1</sup>	Winter wheat 7.6 t DM/ha Spring barley 5.6 t DM/ha Winter oilseed rape 3.8 t DM/ha Potato 7.2 t DM/ha Sugar beet 11 t/ha Grassland in rotation 8.5 t/ha	Cereals (3.7 t/ha), Grapevine (6.8 t/ha), Olive (1.6 t/ha), Sunflower (2.2 t/ha), Grasslands (14.5 t/ha), Pastures (2.3 t/ha)	Approximately 5t/ha for olive production (primary crop in region)	Typical yields of cereals 2,8 t/ha potatoes 16,6 t/ha permanent grassland 5,6 t/ha permanent pasture 22,6 t/ha	Winter wheat 4.76 t/ha Corn/maize 7,7 t/ha Barley 4,26 t/ha Potato 23,42 t/ha Sugar beet 58,5 t/ha
<b>Soil type</b>	Lacustrine clays inland to highly sandy soils at the coast	Cambisol & Luvisol; Topsoil: 15% clay, 13% silt, 70% sand	Cambisol; Soil texture of Topsoil: Medium (18% < clay < 35% and	Cambisol (17 – 31% clay; 17-31% sand) and Regosol (14-19% clay;	Light, sandy soils. 75% of the soils are podzolic soils, in river valleys –	Physical properties: loam (34,1 %) sandy (32,9%)

<sup>1</sup> Utilised agricultural area

		Subsoil: 20% clay, 13% silt, 66% sand	>= 15% sand, or 18% <clay and 15% < sand < 65%)	45-54% sand)	alluvial soils, rest of the area brown and (small amount) black soils. Acid soils dominate	sandy clay (16,0%) clay loam (9,1%)
<b>Content of soil organic carbon</b>	Ranging from 2-5%	1 % in topsoil; 0.5% in subsoil	From 1-2% to 2-6%	1-6% according to JRC map	In mineral: 1 - 2%	Ranging from 1-12% (2nd to 4th class of JRC map)
<b>Current risks to soil carbon</b>	Alternative use of crop residues (for energy), deep tillage	A large part of the cereal straw is used for combustion in combined heat and power plants	Organic fertilization (compost or animal manure inputs) is rarely practised. Cereal straw is usually collected and sold.	soil erosion has and continues to be one of the primary soil-related threat to olive production and its long-term sustainability	Reduction of manure use, simplification of the production technologies (e.g. no inter-cropping), intensification (e.g. change of permanent grassland into arable land)	Significant decrease of livestock complemented with concentration limit for use of manure; Renewable energy use pressure threaten the use straw as a source of SOM. In addition, sustainable cultivation practices slowly gain popularity.

## **6. Stakeholder consultation**

This consultation with the farming and policy community is being carried out in six case study regions across Europe: Zealand, Denmark; Central Region, Hungary; Tuscany Region, Italy; Mazovia (Mazowieckie Voivodeship), Poland; East Coast, Scotland; and Andalucía, Spain. These case study regions have been selected in SmartSOIL to represent a range of biophysical, farming system and socio-economic contexts (Table 5.1).

Throughout the project interviews and workshops are being carried out with selected agricultural advisors (from public extension and commercial services), farmer representatives, leading farmers and policy makers in these case study regions. Advisors are being interviewed both to represent farmers and to give an informed and broad view about farming activities.

There are three phases of stakeholder consultation in the project:

- Preliminary consultation –interviews with advisors, farmers representatives, leading farmers and policy makers
- Stakeholder Workshop 1 with advisors, farmers representatives, leading farmers and policy makers
- Stakeholder Workshop 2 with advisors, farmers representatives, leading farmers and policy makers

The preliminary consultation explored the range of awareness, extent of implementation of soil carbon management practices, as well as barriers to, and incentives and advice for, the uptake of practices that can enhance soil carbon stocks (Deliverable 5.1). A summary of the preliminary consultation is presented in Section 7. Stakeholder Workshops (1), reported here, built on this consultation and extended it to include an assessment of preliminary analysis of cost effectiveness of measures (as discussed in Section 4), and the preliminary DST tool and toolbox.

## **7. Summary of preliminary consultation**

In a preliminary consultation 60 interviews were carried out with selected with advisors, farmers' representatives, leading farmers and policy makers in the six case study regions (see table 3.1). On average 10 interviews were carried out in each case study). Project partners in each case study conducted these face-to-face interviews using a semi-structured template. They identified respondents with some expertise in soil management using local contacts and a snowballing technique (a small pool of initial informants identifies, through their social networks, other participants with the specific expertise that could contribute to the study). Respondents were firstly asked about the policy context for promoting the management of soil carbon with a focus on the practices that can potentially enhance soil carbon, listed above. They were then asked about current awareness of soil carbon management and about the extent to which associated practices were implemented. Finally, they were consulted more generally about barriers to, and incentives and advice for, the uptake of practices that can

enhance soil carbon stocks. A summary of the results of this consultation are presented next together with a table (Table 7.1) of current promotion of management practices (and barriers to uptake) that potentially enhance soil carbon in the six case study regions, for full details see Deliverable 5.1.

The interviews have shown that there are no policies that specifically address soil carbon management in the case study regions. Aligned to this, advisor and farmer awareness of management practices directed towards soil carbon tends to be low. There is wide variation in how farmers understand the issue and implement practices. Although there is growing awareness of soil protection measures, the narrow focus on meeting cross compliance obligations tends to restrict interest in (and resources available for) other soil management activities. Furthermore, the quality of the advisory services in some countries has an impact on advisor awareness and competence.

A barrier common to all case studies was the perceived scientific uncertainty with respect to optimal practices and measuring soil carbon change. This leads farmers and advisors to question the credibility of scientific recommendations. The need to understand farmers' economic motivations is also clear. Farmers and many advisors remain unconvinced of the economic benefits of managing soil carbon. The difficulty in demonstrating the long-term benefits of practices that enhance soil carbon stocks is compounded by farmers' short-term outlook.

In terms of encouraging uptake of practices, the general view of respondents is that farmers will require financial incentives as increasing soil carbon stocks is regarded more as a public good than a private benefit to farmers. However, providing evidence of benefits to soil, and demonstrating cost effectiveness of practices are seen as equally important in encouraging farmers to implement practices. If private good benefits to agricultural productivity can be demonstrated this may remove or reduce the need for financial incentives. Using long-term experimental sites for this would be one option, although farmers prefer 'real life' cases studies and do have concerns about translating scientific findings to the farm scale. With respect to advice, a common message was that this needs to be delivered using simple language and integrated into existing advisory programmes.

A further key finding from this study is that, although case studies share some common issues, country specific contexts need to be considered. Barriers to uptake of practices can be diverse and related to a number of factors such as biophysical conditions, farmer knowledge and experience, land tenure and the quality of the advisory service. This needs to be taken into account in developing management recommendations, policy and advisory programmes.

These observations and views were further explored and verified in the workshops. The analysis in this report, presented in the following sections therefore validates and builds on these results, and explores further socio-economic factors that influence the implementation of soil carbon management practices.

Table 7.1 Current promotion of management practices that potentially enhance soil carbon in six case study regions

Case study region	Practices promoted and barriers
Denmark Sjælland	<p><i>Promoted:</i> Soil management is an integral part of an overall crop production strategy aimed at gaining the best economic output, and soil carbon management is a part of this. Practices, promoted as part of an overall approach to good soil management, include: planting catch crops, crop rotations, residue management, managing perennial grasses, manure and fertilizer management and reduced tillage.</p> <p><i>Barriers:</i> Lack of visual evidence that these practices benefit soil health, are cost effective and enhance crop yield in the long-term.</p>
Hungary: Közép- Magyarország	<p><i>Promoted:</i> Advice on soil management practices focuses primarily on degradation and nitrate pollution issues. There is an emphasis on reducing greenhouse gas emissions and fostering bio-energy production and use in the climate change mitigation context. Practices, promoted as part of an overall approach to good soil management, include: appropriate crop rotations, organic manure input, restricted management options on steep slopes, reduced-tillage and grass or mulch layers in orchards.</p> <p><i>Barriers:</i> Innovative practices are subsidy driven. Farmers are mostly concerned about complying with regulations. Commercial advice conflicts with advice on soil management concerned with the supply of ecological services (public goods).</p>
Italy: Tuscany	<p><i>Promoted:</i> Practices in cross compliance measures which can contribute to improving soil carbon in the soil: minimum tillage, stubble management, green manure, crop rotation, and minimum soil cover and terracing maintenance.</p> <p><i>Barriers:</i> Farmer reluctance to take up unfamiliar practices and to integrate them into consolidated farm management systems. New practices are not supported by practical evidence of effectiveness.</p>
Poland: Mazowieck	<p><i>Promoted:</i> Practices promoted relate to cross compliance requirements and include: cover crops, crop rotations and manure and fertilizer management.</p> <p><i>Barriers:</i> Farmer (and administration) awareness of environmental/climate threats is low. This, together with low profitability of the agricultural sector, impedes implementation of soil management practices. Moreover, many farmers have limited education; and the quality of (free) state advisory services is inadequate.</p>
Scotland: Eastern Scotland	<p><i>Promoted:</i> Measures are mostly focused on tackling farm efficiencies and farm productivity by reducing waste and greenhouse gas emissions. Soil carbon management is promoted within the Farming for a Better Climate initiative. Measures promoted include: nutrient planning and management of rotations as part of Nitrate Vulnerable Zones. Cover crops are not grown due to a short growing season.</p> <p><i>Barriers:</i> Markets and commercial imperatives override good intentions and practices. Regulations and agri-environment scheme prescriptions are not always compatible with beneficial soil management.</p>

Spain: Andalucía	<p><i>Promoted:</i> Practices, promoted as part of an overall approach to good soil management, include: reduced tillage, erosion safe cultivation, catch crops, fallow fields, residue management, manure and fertilizer management, crop rotations and extensive farming, pasture, and organic farming.</p> <p><i>Barriers:</i> Lack of consensus on 'best practice' in Mediterranean/semi-arid climates. Measures exist but there is no process for tailoring them to farms. The high number of tenant occupied farms is a barrier to uptake.</p>
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## 8. Stakeholder Workshop Methods

In the planning stage a pilot workshop was held in Scotland. This was used to test the content, format and structure of the workshop. A separate workshop report for this pilot is available. Based on this experience, and with further input from WP4, detailed guidelines, pre-prepared slides and a report template were prepared. These were provided to case study partners by the WP5 coordinator prior to the workshops to standardise the workshop content, format and reporting. Partners also undertook training in workshop aims, activities and participatory exercises at the SmartSOIL project meeting in November 2013. In addition Marginal Abatement Cost Curves (MACC) were prepared for each case study (see Section 4).

Project partners in each case study conducted the stakeholder workshops. Participants (advisors, farmers' representatives and policy makers) were identified by case study partners using local knowledge. Interviewees previously involved in the preliminary consultation were invited as well as new stakeholders considered to have relevant experience and understanding of farming and/or soil management in the region. The number of participants in each workshop ranged from 10-20.

The workshops all had the following main sessions:

1. Typical cropping systems, soil carbon management practices and effects on soil carbon
2. Barriers and opportunities to implementation of cost effective soil carbon management practices
3. A preliminary Decision Support Tool (DST) and Toolbox which is being developed to assist policy makers and advisors in identifying the most effective measures

Workshop guidelines provided to case study partners provide details of content of, and methods used in, the workshop (Appendix I).

For session 1 partners presented data to stakeholders on typical cropping systems, soil carbon management practices and effects on soil carbon which framed the discussions (Section 9). For session 2 Marginal Abatement Cost Curve (MACC) diagrams were presented and framed a discussion about potential win-win practices and the barriers and opportunities with respect to their implementation (Section 10).

This report presents an analysis of the first two sessions. Results from the third session will be used to develop the Decision Support Tool (DST) and Toolbox in WP4. All partners conducted case study workshops and completed workshop reports. However, the partner in Scotland, having undertaken the pilot workshop, did not complete the full workshop programme. These reports, which are available separately, have been used as the basis for analysis in this report.

## **9. Cropping systems and implementation of soil carbon management practices in the case study regions**

This section reports results from the workshop session in which stakeholders were asked to discuss the following with respect to their case study region:

- Typical cropping systems and rotations in the case studies
- Risks to soil carbon associated with these systems/ practices
- Drivers of these systems/rotations
- Carbon management practices most effective in the case studies
- Current levels of implementation of soil carbon management practices
- Drivers of these soil carbon management practices

Workshop partners approached these subjects slightly differently and some presented data to frame the discussions. In Tuscany, Italy workshop participants were presented with national figures of areas covered by crops and in Zealand, Denmark lists of farm types were used as a basis for discussion. In Spain the partner used survey data of levels of implementation of soil carbon management practices to frame the discussion. Furthermore participants responded in different ways as well, emphasising some aspects more than others, reflecting their significance in the case study region. As such not all subjects were addressed to the same extent in all workshop reports. Additionally whilst the case study region was the context for the discussion, some workshops also drew on and highlighted national level perspectives to varying extents. This session was not conducted in the pilot workshop in Scotland.

Stakeholder views about these aspects are presented below on a case study region basis, followed by a summary section drawing out common themes from all the case studies.

## 9.1. Zealand, Denmark

### 9.1.1. Typical cropping systems and rotations

In Zealand cropping systems were considered to depend on farm type. Seven relevant farm types for the region, extracted from a Danish farm typology, were used in the workshop for discussing representative cropping systems (Table 9.1).

Table 9.1 Farm types and associated rotations in Zealand, Denmark

Farmtype no.	Name	Sample rotations
2	Cash crop farm on clay soil, sugar beet	Beets; Spring barley; Winter wheat, Winter wheat +cc
3	Cash crop farm on clay soil, seed production	Example 1- Spring barley undersown with cover and meadow grass; White clover; Smooth meadow grass; Smooth meadow grass; Smooth meadow grass Example 2- Spring barley undersown with red fescue; red fescue; Red fescue; Winter OSR; Winter wheat +cc
11	Cash crop farm on clay soil, grain	Winter OSR ; Winter wheat +cc; Spring barley; Winter wheat + cc; Spring barley
30	Cash crop farm on clay soil, organic	Spring barley undersown with white cover; Grass clover for green manure; Spring oats +FYM; Faba bean
5	Dairy farm on clay soil, medium animal density	
7	Dairy farm on clay soil, organic	
9	Pig farm on clay soil, medium animal density	Winter OSR + slurry; Winter wheat + slurry, Winter wheat +slurry; Spring barley +slurry; Winter barley + slurry

Some examples of crop rotations for these farms types were identified (see Table 9.1). The sample rotations are not exhaustive for the farm type categories and the consultants were hesitant in calling the rotations ‘representative’.

With respect to risks, participants did not think that it will be possible to rank the farm types or rotations according to risks to soil carbon, since each farm typology involves a range of farmers managing their farms differently and with a varying focus on soil carbon management. No farm types or cropping systems with particular risk to soil carbon depletion were identified for the region. Some farms on clay soils focusing on sugar beet production could be at risk of depleting their soils but the consultants stressed that this would vary between farms since many farmers would apply organic inputs and grow other crops to counterbalance the impact of sugar beets. For Denmark as a whole, cropping systems with repeated silage maize were identified as systems that may be unfavorable for the soil carbon budget, depending on the organic inputs. Maize is thought to be the ‘worst’ crop in the cropping system

with respect to soil, however farmers are aware of this, as one participant said ‘With long term and frequent cropping of maize the farmer soon realizes that the soil surface is smearing’.

### 9.1.2. Current levels of implementation of soil carbon management practices and drivers

With respect to current levels of implementation of soil carbon management and the drivers of these, Table 9.2 shows that manure and fertiliser management is the most commonly implemented while catch crops/green manure; crop rotations including grass rotations, incorporating crop residues are implemented to a lesser extent; while reduced tillage is implemented the least. With respect to what is driving decisions about some of these practices, the fact that the use of catch crops in the cropping system is mandatory, and that an N-saving benefit of catch crops is explicitly accounted for in the total N allowance per farm, explains the relatively high use of catch crops. Legumes are not accepted as legal catch crops, if the farmer wants to apply legume-based catch crops, they need to be grown in addition to the mandatory catch crops.

Table 9.2 Extent of implementation of soil carbon management practices in Zealand

Management Practices	Current level of implementation
Catch crops / green manure	++
Crop rotations including grass rotations	++
Incorporating crop residues	++
Manure and fertilizer input	+++
Tillage intensity (reduced, minimum)	+

### 9.1.3. Summary

In general, there is awareness of the different practices for soil carbon management but there are a number of agronomic, economic and regulatory constraints. Among the agronomic issues, yield loss, cropping system complexity, weed infestation etc. were mentioned. Among the regulatory issues, legume crops were not accepted as a catch crop which discouraged farmers to cultivate legumes. With regard to economics, there was no clear evidence of benefits by practising carbon management practices.

## **9.2. Central Region, Hungary**

### **9.2.1. Typical cropping systems and rotations**

The Central Hungary region is dominated by arable farming. Farming is characterised by a small number of large professional farms and large number of small, subsistence and semi-subsistence farms. (Local data shows 90% of UAA has farms <5ha and 1.8% of UAA has farms > 50ha. However, the first group has only 6.1% of the UAA while the later 76.6%). The farming community also very diverse, including older generation farmers with strong insistence to “traditions” and young farmers open for new tools and approaches.

A large portion of the region is peri-urban in nature, with limited livestock and fragmented land use pattern. Arable farming and specialized cereal farming is the most dominant land use in the region, with significant grassland without grazing livestock and small-scale fruit and horticulture production due to the peri-urban of the region. Typical crops are cereals, corn and sunflower, while the horticulture is a mix of mainly outdoor fresh vegetables and berry fruits and orchards. The three most dominant arable crops – corn, wheat and sunflower represent 53% of land use, permanent grassland 12% and set aside area 3%.

The number of different crops on arable farm is decreasing, the crop rotation tends to be minimal. Canola has not been grown in less favoured areas over the last 3-4 years due to low prices. There is a low and decreasing number of livestock. Catch crops, legumes, pulse crops are not typical but are grown in areas previously used for livestock. In areas where legumes and grassland are the most promising crops, grassland is preferred.

Risks to soil carbon associated with these systems are limited crop rotation, decreasing livestock and organic matter availability, increasing competition for organic matter (bioenergy), limited knowledge to climate change mitigation and adaptation effects, and the regulatory framework - which are explored below

### **9.2.2. Drivers of these systems/rotations**

The most important drivers of the current cropping practice are those which have significant economic influence: subsidies, labor intensity, farm size, and crop profitability. Increasing importance of extreme weather events was also mentioned.

Due to economic reasons, an oversimplified crop rotation is applied. For example, canola has been unprofitable to grow in LFA over the last 3-4 years. One of the advisors pointed out that as a result of the EU ban on neonicotinoids, an increase in the soil pests (e.g. wireworms) population can be predicted which could boost the importance of crop rotation.

Urbanisation influences land use. Fruit and horticulture production is also based on the fresh product demand of the capital. Sour cherry has the largest area, but almost all fruits and fresh vegetables are produced in the area.

Small scale livestock farmers, who prefer to keep their stock close to their homestead/home, have been affected by strict regulation in the last decade. Furthermore, livestock is more time demanding and the number of full time farmers has decreased significantly. Therefore, for the small scale farmers “farming” is more likely to be a secondary activity.

In case of LFA or ANC areas, the relatively high rate of direct payments tend to increase the share of areas not cultivated with any crop, just meeting the CC requirements or having a very limited crop rotation with minimum equipment requirements.

### **9.2.3. Current levels of implementation of soil carbon management practices**

The most relevant and most promising soil carbon management practices were identified as: manure application, application of legumes in the crop rotation and residue management and conservation tillage. Green manure is less promising due to climate limitations.

Organic manure is used, but since there is not enough livestock in the vicinity, the level of application is low. Manure is only used by those farms that still keep livestock. Farms without animal husbandry have limited alternatives to apply manure, while other organic sources typically used to increase SOM and improve soil quality in general is limited. The scarcity and high value of manure (see below) limits availability, When possible, additional manure is imported from abroad (e.g. chicken and cattle manure from Italy). Smallholders prefer to use chemical fertilizers because they lack the machinery necessary to apply organic manure (furthermore it is more expensive). A lot of them do not apply any fertilizer at all; they only mow down the area and sell the hay.

Nutrient management practices are implemented as part of nitrate vulnerable zones (NVZs) and AEMs (agri-environment measures), however actual level of implementation is hard to measure as administrative requirements imposed on farmers in NVZs can lead them the denial/concealment of the actual nutrient usage.

Green manure and crop residue incorporation exists among farmers of the case study region but there is a tendency to sell it (the straw for animal bedding and some to biogas) instead of utilization in soil management. Crop residues are often sold for horse bedding (especially in dry years, when main crop has lower than average yield and there is high need for alternative revenue source). The importance of the usage of residue is recognised (among technicians/academics) as it can cover the surface and prevent transpiration and carbon loss as well as reduce fertilizer usage. Several advisors confirmed that there are farmers practicing ‘biological replenishment’ and using (exploring) crop residues by bacteria. One example was mentioned where chemical fertilizer could be reduced by 60% with the same crop yields. Legumes are rarely used in the crop rotation as it is more difficult to sell.

Deep ploughing is still dominant on arable areas, minimum and conservation tillage is rarely used, direct seeding is rarely used (because it requires 5-6 years to get established). One participant noted that most of the farmers are still devoted to the 'old school' so leave the ploughed land open for winter. However shallow tillage systems are spreading.

#### **9.2.4. Drivers of practices**

NVZs and AEMs (agri-environment measures) provide opportunities for managing nutrients. However the farmers have difficulty meeting demanding specifications and administrative requirements (soil tests<sup>2</sup>). According to participants the application of organic matter is often time limited due to the related administrative burden. A related controversial issue is the question of delimitation of nitrate vulnerable zones. Participants claim that the driver behind increasing the share of NVZs is related to RDP subsidies for livestock farms in particular. This comes with "side effects" for crop producers in the form of significant administrative burden. In response farmers either apply manure or other organic substances according to agronomic needs without meeting all administrative requirements and taking the risk of a possible fine; or, in case of risk averse farmers, do not apply manure at all. One advisor pointed out that in AEM only 10-15% of their participating clients could remain in the system, others fell out or stepped out because they failed to meet the requirements.

Land tenure is a factor influencing the effectiveness of practices. Large farms often farm on leased lands with medium range contracts that provide limited opportunity to follow practices in the long term.

Due to the low and decreasing number of livestock manure is scarce and in high demand. In case of high value crops such as horseradish, farmers even buy manure and specific compost from reliable supplier even from Italy. Partly due to the special circumstances of suburban area, manure is used for high value home garden products, so the availability of external manure in general is very limited. The cost of mechanization in organic manure application was also mentioned as a barrier.

The implication of larger share of bioenergy was also indicated, since the additional demand towards different biomass sources (e.g. straw, manure)

There are several very different soil types present in the region, which has significant consequences to soil carbon management practices and potentially applicable measures.

The farming community very diverse, including older generation farmers with strong preference for "traditions" and young farmers open for new tools and approaches. Participants also distinguished different types of farmers with different attitudes towards (and competencies for) changing practices. One type was described as 'narrow minded' "land-speculators" (who may be small or large) who are not concerned with new practices such as residue management with bacteria. The other group consists of

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<sup>2</sup> Soil tests have to be performed per 5 hectares and one test costs 10-15 thousand HUF.

farmers managing 600-700 acre, (mostly not their own property) who can pay more attention to practices like nutrient supplementation, or direct sowing. A further group of part time farmers were distinguished, who farm as an additional source of income, often producing fruits and/or vegetables on a small nearby parcel or even kitchen garden.

#### **9.2.5. Summary**

The Central Hungarian region can be described by the following:

- Arable farming and specialized cereal farming is the most dominant land use form in the region, with significant grassland without grazing livestock and small-scale fruit and horticulture production due to the peri-urban of the region.
- Certain parallel risks to soil carbon are identified: limited crop rotation, decreasing livestock and organic matter availability, increasing competition for organic matter (bioenergy), limited knowledge to climate change mitigation and adaptation effects, one sided regulatory framework
- The most important drivers of the current cropping practice are those having significant economic influence: subsidies, labor intensity, farm size, increasing importance of extreme weather events.
- Current levels of implementation of soil carbon management: limited manure application (limited availability of manure and required equipment for the application), crop residues are often sold for horse bedding (especially in dry years, when main crop has lower than average yield and there is high need for alternative revenue source), deep ploughing is still dominant on arable areas, minimum and conservation tillage is rarely used, direct seeding is rarely used (because it requires 5-6 years to get established), legumes are rarely used in the crop rotation as it is more difficult to sell.

### 9.3. Tuscany, Italy

#### 9.3.1. Typical cropping systems and rotations

Participants were represented with some data for main crops cultivated in Tuscany in the last 5 years. This shows the main arable crops cultivated (and % of area cultivated) as follows : durum wheat 51.8%, maize 10.2%, Sunflower 11%; Barley 8% (Table 9.3) , they agreed with these figures.

Table 9.3 The mains crops cultivated in Tuscany

Crop	Area cultivated (ha)	% of area cultivated	Total production (ton)
Durum wheat	101,911	51.8	335,618
Maize	20,097	10.2	153,545
Sun flower	21,658	11	43,547
Barley	15,749	8	49,688

(source: ISTAT, averages from 2007 to 2011).

Participants pointed to the high variability of Tuscan landscape, suggesting that cropping systems (and associated practices) should be identified within homogeneous agro-climatic macro zones (e.g. Coastal area, Internal plain areas, Internal hilly areas, and so on). In Tuscany about 3500 farms are devoted to organic farming systems, corresponding to about 91,000 ha (about 22,000ha are cereal crops, 23,000ha are fodder crops). The extent of organic farms in Tuscany represents the 11.8% of UAA of Tuscany (ISTAT, 2009). According to the Regional Institute Economic Planning of Tuscany – IRPET (2007), the number of Tuscan rural enterprises that have adopted the system of organic production in agriculture has been steadily increasing in recent years. The average farm size is quite high compared to regional and national averages, 35 hectares, and most of the cultivation are intended for the production of cereals (wheat flour for half, 13% of the national total), but also of grapevines, of olive and of flowers. Crop rotation is widespread in the region and mandatory in organic systems.

With respect to soil carbon management practices participants, although aware of the value of soil carbon, pointed out that it is too simplistic to focus on SOC in terms of characterizing good soils in regions like Tuscany, since, agriculture lands in Tuscany are mainly located across hilly areas. For this reason, other aspects such as soil erosion, soil nutrients components should be considered as well as soil carbon. It is therefore difficult to disassociate the risks to soil carbon from risks to soil as a whole.

#### 9.3.2. Current levels of implementation of soil carbon management practices

Participants also found it difficult to generalise on identifying routine and widespread practices across the region and general levels of implementation of soil carbon management practices. Firstly participants suggested that there needs to be a distinction according to the type of farming system (i.e. conventional or organic) as some practices are mandatory in organic farms, which constitute a high proportion of farms in Tuscany. Secondly, as mentioned above, participants pointed to the high variability of Tuscan landscape, suggesting that cropping systems and associated practices should be identified within homogeneous agro-climatic macro zones. Thirdly they agreed that choice of practice is also considered to depend on farms structure and organization. For instance, in some areas (mainly concentrated in the province of Siena, Grosseto and Arezzo) an increasing number of farms are managed by farm-contractors. A further complication in understanding implementation of practices is

the traditional use of a combination of practices rather than just one. However participants did identify the main practices implemented in the region, including soil carbon management practices which are most relevant and effective to the region and practices currently not widespread in the region - but with the possibility to be adopted. These were listed in decreasing order of implementation as follows:

- Plowing is the most widespread cultivation practice across the Region. Usually, the depth of plowing does not exceed 30 cm. In some areas (clay hilly areas mainly located in the Province of Siena and Pisa), critical soil erosion as well as soil fertility loss has been noted. In some areas it is the law to plow for water saving. There has been a slight decrease in the last decades as farmers are focused more on saving costs. Traditional deep plowing requires large machines and consequently more fuel usage. Participants considered plowing practice not to be beneficial for soil carbon. Policy makers are motivated to find alternatives to ploughing however such alternatives are not feasible in some areas due to the presence of clay hilly territories in the region. There has been an increasing trend towards adopting shallower plowing depths (less than 20 cm).
- Monoculture was widely practiced in the past but has recently shown a decreasing trend and is being substituted by crop rotation. It is still widely applied in the central-southern lands of the region (e.g. maize crop for biofuel production).
- Crop rotation is widespread in the region. Rotation is mandatory under the organic production regime.
- Residue management - straw/crop residues incorporation is widely adopted by farmers and is usually performed at the end of crop cycle by plowing before sowing the next crop. Soil organic enhancement is evident as a result of this practice.
- Hydraulic soil protection infrastructure is very important in Tuscany and contributes indirectly to soil fertility enhancement. Due to the hilly landscape of the region, with prevalence of clay texture, hydraulic soil protection infrastructures are often required in order to avoid loss of soil nutrients as well as to enhance the water regime.
- Green manure practice is usually performed by incorporating into the soil leguminous forage plants.
- Manuring is mainly adopted in organic farming systems, or mixed-farming systems (with livestock).
- Minimum tillage is not widespread but becoming more popular as farmers want to save costs.
- Exogenous biomass is not widespread.
- Ecological focus is confined to extensive farming systems.
- No tillage is rarely adopted in the region.
- Cover crops are not widespread, usually adopted in lands with high slope in order to reduce soil erosion processes. Usually, winter crops are sown.

### 9.3.3. Drivers for implementing management practices

With respect to drivers of these practices Table 9.4 lists the drivers identified by participants.

Table 9.4 Main drivers of management practice in Tuscany - in decreasing order of importance

	<b>Drivers</b>
<i>Cultural/traditional</i>	<p><i>A specific practice is adopted for traditional/cultural reasons.</i></p> <p>According to stakeholders this is the main influence on management practices for farmers of small farms (which represent the majority in Tuscany- 62% of holdings are &lt;5ha. Average farmer age is 60.</p> <p>In these contexts, farmers tend to adopt a specific practice because their forefathers used to apply it for decades or just because it is common in that area.</p>
<i>Organizational</i>	<p><i>The choice of a practice is led by organizational aspects</i></p> <p>A specific practice is adopted because it is the easiest to apply in some specific contexts or situations (in terms of machinery endowment, or of workforce organization, etc.). It is common that specific machinery is hired by farmers. Consequently, farmers tend to exploit these hired machineries as much they can, thus influencing management practice choices. Moreover, contract farming is currently increasing in Tuscany and this is leading to a reduced stewardship interest in soil. This leads agricultural entrepreneurs to give more importance to organizational/contingent aspects rather than to environmental ones.</p>
<i>Economical/marketing</i>	<p><i>Profit maximization is one of the main goals of both big entrepreneurs and small farms, driving management practice choices.</i></p> <p><i>CAP subsidies strongly drives farmer decisions.</i> This is particularly relevant in small farm enterprises. If CAP encourages no tillage practice, farmers will be incentivized to adopt it, even if not widespread or traditional in the region</p> <p><i>Marketing demands.</i> Specific management practices are driven by green procurement as requested by marketing demands. In order to comply specific sanitary and quality aspects of the final product, farmers may decide to adopt the practice that guarantees the best product as requested by the market. This aspect is quite relevant for those farms – usually big enterprises - which export their products abroad or sell to the large-scale retails.</p>
<i>Environmental</i>	<p><i>Increasing trend of organic farming</i> For decades in Tuscany soil has been seen as something to exploit rather than as a limited resource to be maintained or protected. However, in the recent years, the increasing trend of organic farming systems in Tuscany possibly indicates a higher consciousness about environmental issues (and thus soil), especially amongst youngest farmers</p> <p><i>More frequent extreme events</i> (droughts, floods, storms, etc.) that have occurred in the last decades in the region are increasingly perceived as drivers in management practices choices.</p>

The average age of farmers in Tuscany is currently very high (about 60 years old), but the younger generation has a higher sensitivity towards environmental issues. Furthermore, the importance given to environmental issues by the CAP (cross compliance, organic farming, etc.) has increased farmers awareness about the importance of maintaining soil quality.

#### **9.3.4. Summary**

- The main arable crops cultivated in the region are: durum wheat, maize, sun flower and barley.
- Tuscan agriculture lands are mainly located across hilly areas. For this reason, besides soil carbon, other aspects such as soil erosion, soil nutrients components should be considered for characterizing good soils.
- A combination of practices rather than just one is often adopted in the region.
- Increases in contract farming are leading to a less stewardship interest in soil.
- Plowing is currently the main widespread practice applied in arable lands across the Region. However, this practice has been showing a slight decrease in the last decades.
- A tendency toward minimum tillage practice as well as lower plowing depths has been recently noted in the region.
- Policy makers have a strong interest in identifying and promoting effective alternatives to deep plowing practices amongst farmers.
- Residue management, hydraulic soil protection infrastructures, green manuring, manuring, minimum tillage, exogenous biomass, ecological focus areas, no tillage, and cover crops are feasible beneficial practices evidenced by participants (in decreasing order of extent across the region).
- Farm dimension is one of the key drivers leading management practice choices amongst farmers. Generally, economical/marketing aspects lead big farms entrepreneurs, whilst small farms - representing the majority in the Region - tend to be driven more by cultural/traditional aspects.
- The increasing trend toward organic farming system observed across the region denotes a higher interest in environmental issues, and thus in soil.

## **9.4. Mazovia, Poland**

### **9.4.1. Typical cropping systems and rotations and drivers**

Mazovia is Poland's second biggest cereal producer, the top milk producer and a leading supplier of vegetables. It is a garden and plantation centre, about 30% of Poland's orchards are in the region, producing over 40% of the national fruit output.

Crops are dominated by cereals (75.7% of cultivated area) with the following proportions: Rye 21.6%, Triticale (winter) 19.6% and oats 11.9%. Cereal cropping is limited (to rye, triticale and oats) by the light, sand-based soils with low humus content which dominate characterise the Mazovian region. Farmers also select crops to grow based on profitability in the previous year, consequently crops can change frequently. One farmer, previously interviewed, explained:

*"In a given year, I plant what gave producers a good profit in previous years. If in a given year the crop is not as profitable as expected, then I change it to another next year".*

Consequently, crops change frequently. This "economic crop rotation" means that crops that should be cultivated in order to manage the soil are replaced by those promising higher rewards.

In the last 30 years, the content of humus in Polish soils decreased by as much as 40%. Thus, according to European criteria, organic carbon content in 89% of Poland's soils is low. Over 56% of Polish land contain less than 2% of humus. Mazovia has especially poor soils. As much as 10.7% of its land contains less than 1%, with 66.8% less than 2% humus content. Given the domination of light, sand-based soils in this region, such a low share of organic matter poses a serious obstacle to intensified agricultural production.

### **9.4.2. Current levels of implementation of soil carbon management practices and drivers**

With respect to soil carbon management practices, adding manure is the preferred practice to boost the content of organic carbon in the poor soils of the region. However, due to changing agricultural production, the volume of available manure has dramatically fallen since 2004. It is also costly to bring in from elsewhere.

Economic considerations are also crucial when deciding on the selection of soil carbon management practices. Cover crops are not commonly applied as they are unprofitable. As one advisor remarked:

*"... Cover crop is not applied sufficiently. The farmer analyses the costs of seeds, fertilizers and fuels necessary to carry out agrotechnical operations, and his calculation tells him that the cover crop is unprofitable. So he resigns from it".*

With respect to legumes, although farmers are aware of the benefits, they are considered uneconomic to grow. This is illustrated in a farmer’s comment from a previous interview:

*“I know that growing legumes is good for the soil and brings me benefits. But financial liquidity is my top objective. If subsidies for legumes were higher, I would apply them more extensively. At this moment I do it only when their sale as a crop is assured, or when my profit from other activities is satisfactory and I can afford it”.*

With respect to drivers of choice of practice, agricultural land in the region is heavily fragmented, farms covering less than 10 ha are dominant (80.1% of all farms of the province) (Table 9.5). This fragmentation of farms is considered to be a factor that aggravates the threat to soils, as small farms usually lack expertise of proper cultivation techniques, they do not have the necessary equipment to practice them, nor the financial means to purchase equipment. Participants argued that small farmers strive to maximise profit, even if it entails soil degradation. As one of the farmers who was interviewed in the previous consultation said, *“I cannot worry about the negative impact of what I’m doing now on the soil within 3 or 5 years. I must support my family today”.*

Table 9.5 Numbers of farms in size classes in Mazovian Province in 2010.

Farm size	No of farms	% of farms	Area of UAA in
<5ha	167,910	55.5	1,637,580
5-10ha	74,240	24.6	389,400
10-20ha	43,980	14.5	239,270
20-30 ha	10,430	3.5	64,400
30-50 ha	4,270	1.4	36,970
>50ha	1,460	0.5	23,640

Changes in animal production following Poland’s accession to the EU (progress in specialisation and associated reduction of mixed animal/plant production, new animal rearing technologies that involve discontinuation of barn rearing, and new demanding hygiene standards for milk production) has reduced the supply of manure.

### 9.4.3. Summary

The studies demonstrate that the basic factor influencing the selection of crops by Mazovian farmers, as well as of the respective technology, is economic; at which keeping financial liquidity and achieving short-term profit is more important for farmers, than following sustainable management in the longer time perspective. As a result, soils are overused and their organic carbon not replenished. The soils in the region with very low humus levels at are particular risk and opportunities for using animal manure

application are restricted due to changes in livestock production. This fragmentation of farms is considered to be a factor that aggravates the threat to soils as small farms usually lack expertise and are driven by economic motivations.

## **9.5. Andalusia, Spain**

### **9.5.1. Typical cropping systems and rotations in Spain**

At a country level the participants agree that the most common cropping systems in Spain are rainfed cereal (barley) in rotation with fallow or legume and rainfed permanent crops (olives) under conventional system. There are many different cropping systems which are undertaken to a lesser extent but with higher added value and economic importance (e.g. vineyards, fruit trees or horticulture among others) that should be also be taken into account.

In general advisors commented on a small trend of farmers changing from conventional systems with cereal-fallow rotations to direct seeding and reducing the use of fallow. The current cropping systems are strongly associated with new technologies and equipment. The risks associated with these cropping systems are erosion, runoff, leaching, organic matter and biodiversity losses, greenhouse gas emissions, diseases dispersion by stubble burning and in some cases risk of floods.

At a regional level, in Andalusia the olives production is the main farming system with approximately 1,550,218 ha, accounting for 46% out of total agricultural area. Specifically, the region of Jaen in Andalucía is divided in 49 % arable and 49% forested or natural area. In this region there are 580,000 ha of olive production (42% of total region arable land), including approximately 20% organic, 3% high input irrigated and the rest mostly low-input rainfed.

Soil erosion has and continues to be one of the primary soil-related threat to olive production and its long-term sustainability in the case study region. This problem is likely to worsen due to projected drier and warmer summers and more droughts in dry areas. The intensive olive cultivation and the use of inappropriate agricultural practices can lead to higher soil erosion, and in turn higher desertification and topsoil runoff in streams. Olive production with intensive tillage results in soil compaction, exposed soil to extreme and a decrease in organic content. Other specific problems include pollution caused by the use of mineral fertilizer and pesticides, biodiversity losses and waste generation.

### **9.5.2. Drivers of these systems/rotations in Spain**

At a country level, although farmers are more interested in the economic return and the market requirements, a change in attitude has been taking place among both farmers and consumers. Social and environmental factors are becoming more important drivers for the selection and implementation of each farming system. Scientist, advisors and farming unions are also encouraging these drivers. A generational change has been noticed as younger farmers are gaining importance and land ownership, this is accompanied by an attitudinal change. Most of the participants agree that the forthcoming changes in typical systems and rotations will not be directly associated with environmental drivers such as climate, they will be more associated to social and cultural factors such as age, education level, farmer-farmer learning and knowledge transfer.

The importance of the olive grove in the case study is recognised by farmers and the rest of society because it is of cultural significance, associated with landscape and natural heritage and its contribution to the rural population in the territory. Olive oil production is also an important economic sector in the region and is the basis of the Mediterranean gastronomy.

### **9.5.3. Soil carbon management practices most effective in Spain**

With respect to soil management practices, Table 9.10 summarizes the effectiveness according to participants' opinion of the proposed practices. Potential for mitigation of greenhouse gases is also considered.

The soil carbon management practices included in Table 9.10 are also effective for the olive production in the case study region (except for crop rotation since olives are permanent crops). So far, the widespread mitigation practice for the olive production in the case study region is the maintaining of pruning remains as soil cover between rows of the olive groves. Zero or reduced tillage are potentially very effective for the olive production for maintaining soil quality, avoiding soil erosion and improving the SOC content. However both practices are still rarely implemented. Other soil carbon management practices which are effective for the olive production are the optimized fertilization and the fertilization with animal manures since they can encourage an efficient resources use and avoid the current soil pollution and degradation derived from the application of mineral fertilizers and pesticides.

Table 9.10 Participants' opinion of the effectiveness of soil management practices

Practice proposed	Effectiveness of the practice by participants' views
Cover crop	Most of the participants believe that the cover crop practice may increase soil carbon and reduce soil erosion in the Mediterranean areas. This practice also has a high potential to reduce greenhouse gas (GHG) emissions, especially nitrous oxide (N <sub>2</sub> O). The irrigated systems seem to have the more suitable conditions to implement cover crops in Spain, since under rainfed systems some soil nitrogen reductions can be triggered and thus a decrease of the productivity. The water competition due to cover crops in rainfed systems under drought may reduce the productivity but it may be avoided with controlled management of the cultivation times.
Zero tillage	The high effectiveness of zero tillage implementation in the Spanish regions is totally accepted by all participants' consensus. This practice is recognized for its capacity to increase soil carbon content and reduce emissions of N <sub>2</sub> O.
Minimum/ conservation tillage	As the zero tillage practice does, the minimum tillage practice implementation may increase the soil carbon content. However the minimum tillage is not so effective to reduce emissions of N <sub>2</sub> O as zero tillage is. Therefore, the mitigation potential for minimum tillage would be medium when is compared with zero tillage in the participants' view.
Residue management	The residue management may be highly effective to reduce the GHG emissions if it is implemented under irrigated conditions. Most of the participants consider that residue management would have a medium mitigation potential under rainfed systems.
Fertilization with animal manures	The fertilization with animal manures highly promotes carbon sequestration, but the N <sub>2</sub> O emission will be associated with the management undertaken for the manure application. There is participants' consensus according to the high mitigation potential of this practice if the current problems associated with the manure management, treatment and transport are solved.
Optimized fertilization	There is participants' consensus according to the high mitigation potential of the optimized fertilization, but the rainfed system may undergo to lower yields than irrigated systems at the beginning of the implementation.
Crop rotations (with legumes)	The crop rotation with legumes is pointed out to have a medium mitigation potential since the increases of soil nitrogen content from the legumes, in turn may result in increased emissions of N <sub>2</sub> O. This practice is also recognized for its capacity to increase soil carbon content.

#### 9.5.4. Current levels of implementation of soil carbon management practices

The participants agreed with the figures of current levels of implementation of soil carbon management in Spain included in Figure 9.1. One advisor commented:

*“If we want to increase the suitable implementation of these practices it is necessary to take into account the farming size and structure. For example, the cover crops are limited due to the large number of sloping hectares in many regions of Spain”.*

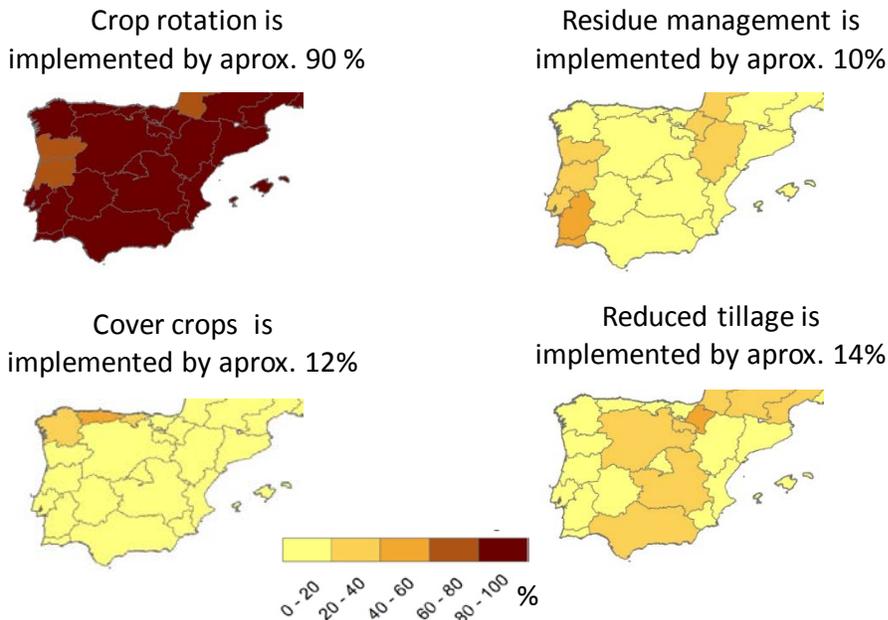


Figure 9.1 Current levels of implementation of soil carbon management in Spain (and Portugal)

In Andalusia conventional tillage remains the predominant practice implemented on around of 70% of arable land, zero tillage is implemented on approximately 5% and reduced tillage on 20%. The levels of implementation on arable land of other soil carbon management practices are as follows (approximately): crop rotation 92%, cover crop 18% and residue management 10%. In the olive production of the case study region the main practices implemented are reduced tillage and residue management, but to a limited extension. Table 9.11 shows the current spatial distribution of soil management in olive production in Spain and Andalusia per hectares

Table 9.11. Current surface distribution (ha) of soil management in olive production in Spain and Andalusia<sup>3</sup>

Soil Agricultural practice	Spain	Andalusia
Conventional tillage	295,341	107,805
Reduced tillage	1,060,989	577,347
No tillage	278,533	200,160
Spontaneous cover crops	750,421	601,725
Cultivated cover crops	8,001	4,630
Cover with pruning residue	27,749	16,882
No maintenance	160,318	41,271
Gaps	2,751	399

#### 9.5.5. Drivers for implementing management practices

The key drivers for implementing new management seem to be those related to the farmer behaviour such as cultural reasons, strong traditions or short-term view of the farming management. The agricultural cooperatives may also significantly influence the change of management, since many farmers maintain the ownership but rent and delegate the management to the cooperative. One advisor said

*“Although many farmers do not understand the scientific knowledge, they clearly see the results of the practices in the field. They usually adopt those practices which are being implemented by neighbouring farmers and those that are being promoted by the agricultural supplies companies and agricultural cooperatives. For instance, farmers usually burnt the stubble but now they are stopping to do it because they have checked that it avoids the diseases dispersion and improves soil quality. In vineyards still remain the stubble burning, but at least farmers grind the wood before burning”.*

Another advisor remarked:

*“The Spanish winegrowers do not want to have any weeds between the rows of vineyards and they make an intensive tillage (more than 5 passes) and intensive use of sprays. The alternative*

<sup>3</sup> Data derived from ESYRCE, Encuesta de superficies y rendimientos de cultivos (2013) <http://www.magrama.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/esyrce/>

*is the cover crop and it might improve the soil quality and thus the productivity, nevertheless if one year the weather is dry and the crops have problems, the farmer will not be willing to make it again”.*

The olive production sector has similar social drivers. The high percentage of farmers (over a third) more than 65 years old maintains the strong traditions associated with the management of olive groves. Furthermore, the economic driver is very relevant in the region since many of the farms (ca. 60%) are less than 5 ha and the only income received by smallholders for their livelihood are those obtained from the production.

Direct subsidies from the Common Agricultural Policy (CAP) via greening measures and rural development programs seem to be potentially the most effective drivers of the implementation of soil carbon management practices in the future, as well as promoting environmental and biodiversity certification and labelling of products. Packages which include the use of several of these practices such as ecologic/organic agriculture or conservation agriculture should be encouraged more. One advisor said *“Cross compliance is not enough but it has achieved a substantial improvement”*.

#### **9.5.6. Summary**

The more extensively cropping systems undertaken in Spain are rainfed cereal (barley) in rotation with fallow or legume and rainfed permanent crops (olives) under conventional systems but other systems such as vineyards, fruit trees or horticulture may show higher added value and economic importance. In the Andalusia case study region (Jaén), the predominant cropping system undertaken is the olives production under rainfed conventional system.

At a country level a change in the conventional management is taking place towards direct seeding and reducing the use of fallow. Changes of the management in Spain are mainly driven by economic returns, market requirements and cultural factors such as traditions and farmer-farmer learning.

The proposed soil carbon management practices were positively accepted by participants as cost effective practices in Spain and for the case study region but the participants agree that the current implementation level of these practices is very low. Measures to promote a change of the farmers’ attitude are needed to increase the implementation of these soil carbon management practices as well as economic incentives. In the case study region, strategies to identify areas at risk of soil erosion and desertification, organic matter losses, soil compaction or salinization should be in place and then targeted plans adopted to rehabilitate affected areas and reduce the risk with soil management practices.

## **9.6. Summary - cropping systems and implementation of soil carbon management practices in the case study regions**

Unsurprisingly a range of cropping systems and rotations were described for the case study regions. However, heterogeneity within regions was also noted, attributed to diversity in biophysical conditions and to farm structural conditions.

Interestingly, no particular cropping systems in any case studies were highlighted as being of particular risk to soil carbon. Although in Central Region Hungary a minimal rotation was identified as being a risk factor, as was the scarcity of manure available to add to the soil due to reduced livestock numbers. With respect to soil factors, some case study regions had particular constraints and risks. In Tuscany, Italy the hilly landscape, with soils prone to erosion and water shortages, was identified as problematic, and in some areas (clay hilly areas mainly located in the Province of Siena and Pisa) critical soil erosion as well as soil fertility loss has been noted. Whereas in Mazovia, Poland, the poor sandy soils were described as having a significantly low humus content and at risk of degradation.

Although choice of crops is largely governed by biophysical factors, economic motivations are important with respect to explaining farmers' cropping and rotation decisions. In Mazovia for example, choice of crops is profit driven and the economic motivation was thought to be particularly strong for small farmers who dominate the region. In Central Region Hungary an oversimplified crop rotation is being applied due to economic reasons (e.g. low prices for rapeseed). Other drivers such as urbanisation, as in the example of Central Region Hungary, also influence cropping decisions.

Current levels of implementation of soil carbon management varied across, and within, case study regions. Participants also found it difficult to generalise on identifying routine and widespread practices across the region and general levels of implementation of soil carbon management practices. Decisions regarding these practices are strongly influenced by socio economic factors.

Decisions about implementation of soil carbon management practices are influenced by economic factors. Some practices are considered uneconomic. For example, in Mazovia, Poland cover crops and legumes are considered uneconomic to grow. Application of manure is also described as uneconomic when it is costly due to short supplies (Hungary, Poland) or where mechanisation needed to spread it is too costly to acquire. In Central Region Hungary crop residues are often sold for horse bedding, especially in dry years, when the main crop has lower than average yield and there is high need for alternative revenue source. Participants also noted a shift towards some practices which were attributed to farmers' desire to reduce costs and simplify operations. In Spain, for example, advisors described a small evolution with many farmers changing from conventional systems with cereal-fallow rotations to direct seeding and reducing the use of fallow. Likewise, in Tuscany, Italy, although plowing is widespread, farmers are looking at reduced tillage because they want to reduce costs.

Changing farming systems also impact opportunities for soil carbon management practices. In both Mazovia, Poland and Central Region Hungary a reduction in livestock systems has reduced supplies of animal manure, making it unavailable or uneconomic to apply.

Policy also influences farmers' decisions about soil carbon management practices. In Zealand, Denmark the use of catch crops in the cropping system is mandatory, and the N-saving benefits of catch crops are explicitly accounted for in the total N allowance per farm. This explains the relatively high use of catch crops. However, because legumes are not accepted as legal catch crops (if the farmer wants to apply legume-based catch crops, they need to be grown in addition to the mandatory catch crops) this discourages farmers to cultivate legumes. In Central Region Hungary nutrient management practices related to NVZs and AEMs (agri-environment measures) provide opportunities for managing carbon and nitrogen, however specifications and administrative are demanding. Some AEM agreement holders cannot meet nutrient management requirements and drop out of schemes (and therefore practices); other risk averse farmers do not apply any manure because of the risk of being penalized. In Mazovia an indirect effect of Poland's accession to the EU and exposure to the CAP has led to reduced numbers of livestock and consequently reduced availability of manure to add to the soil.

Farm tenure plays an important role in management decisions. In Tuscany, Italy choice of practice is considered to depend on farm structure and organisation. For instance, in some areas (mainly concentrated in the province of Siena, Grosseto and Arezzo) an increasing number of farms are managed by farm-contractors, this is leading to less interest in the stewardship of the soil. In Spain the agricultural cooperatives may also significantly influence management, since many farmers maintain the ownership but rent and delegate the management to the cooperative. In Central Region Hungary land tenure is a factor influencing the effectiveness of practices; large farms are often farmed on leased lands with medium term contracts that provide limited opportunity to follow practices in the long term. In Scotland delays in legal decisions concerning the farm tenancy agreements has resulted in short term tenancies or lets becoming popular which are not compatible with long term planning needed for soil carbon management practices to be effective.

Farm size is also important in management decisions. Generally smaller farmers are thought to be less likely to implement soil carbon management practices than their larger counterparts. In Mazovia, Poland agricultural land in the region is heavily fragmented, farms covering less than 10 ha are dominant, these small farms lack expertise and equipment and strive for profit maximisation. In Tuscany, Italy farm size is one of the key driver leading management practice choices amongst farmers. Here generally, big farms entrepreneurs are driven by economic and marketing aspects, while small farms - representing the majority in the Region - tend to be driven more by cultural and traditional aspects. Similarly in Spain, cultural factors such as traditions and farmer-farmer learning are thought to be important in determining practices. Farmers in central Region Hungary are also distinguished as a) older and conservative small scale farmers using traditional practices such as deep ploughing; and younger more professional farmers managing larger farms who are innovative and trying out new practices such as biological replenishment.

In more general terms traditional practices are preferred because they are familiar and relatively risk free, for example the Spanish winegrowers are reluctant to substitute the present system of removing weeds from between the rows of vineyards with cover crops in case of failure in dry years.

Certain general trends towards greater environmental awareness and towards more benign practices were noted by workshop participants. For example, in Spain attitudes toward the environment and society are becoming more positive. This is attributed to a generational change as younger farmers gain importance and land ownership. In Tuscany, Italy a trend of increasing organic farming was also noted.

## **10. Barriers and opportunities to implementation of cost effective soil carbon management practices**

### **10.1. Introduction**

This section analyses results from workshop session (2). This session aimed to identify the barriers and opportunities to implementing soil carbon management practices assessed as being cost effective.

The cost effectiveness assessment aims to provide a hierarchy of the practices that increase SOC most cost-effectively in terms of the impact on farm businesses (win-win practices) and so provide some indication of the likelihood of adoption of these practices. The session started with a presentation of previously prepared Marginal Abatement Cost Curve (MACC) charts for the case study regions (see Section 4 and Appendix III)). These figures show the cost-effectiveness of measures/crop combinations in increasing soil carbon in terms of the change in gross margin for the crop (y axis units are €/tCO<sub>2</sub>e/ha). The bars are ordered in decreasing cost effectiveness. Those measure/crop combinations below the x axis represent win-win options where there is a benefit to the farmer of adopting the measure. Six SOC MACC charts were presented (Appendix III), two of these are included in this report for each country.

Both charts show cost effectiveness of measures using mean yield impact figures. In the first chart the SOC is captured per ha for all measures and crops. The width of the bars represent the per ha increase in SOC for each crop/measure. This chart does not have an x-axis scale as some options are mutually exclusive, i.e. you cannot simultaneously have wheat with minimum tillage and zero tillage. The second chart shows the most cost-effective measure for each crop type. Here the x-axis does have a scale.

The session proceeded with participants identifying the barriers and opportunities to implementing cost-effective soil carbon management practices (according to MACC assessment). Firstly, the participants were asked to consider a number of possible barriers to implementation, including the following:

- a. technical barriers related to specific crops or systems (e.g. rainfed vs irrigated, spring vs winter cropping)
- b. agronomic barriers (e.g. cultivations times, disease issues)
- c. environmental barriers (e.g. climate, growing season)
- d. economic (e.g. fixed costs, need for new equipment)
- e. social (e.g. land tenure patterns, social perception by other farmers, conflict with 'traditional' approaches)

Following this, the opportunities to adopt the proposed soil carbon management practices were identified by participants and related to technical, agronomic and environmental and economic and social opportunities.

Finally, participants were asked to consider the main motivations and drivers for decision-making in their region and whether these vary across crop types. Also they were asked to provide some indication of how farmers value soil in their region. The aim of this exercise was to try to understand farmers' motivations/rationale for farm level decisions as opposed to the macro drivers discussed in early sessions, by drawing out the subtleties of farm level decisions, particularly with respect to economic decisions. Outcomes of this discussion also inform the MACC which uses gross margin in the calculations of cost effectiveness. The participants were asked to rank the importance of the following drivers:

- Gross margin/profit: Farmers make a balanced assessment of both income (yield x price) and costs when making decisions
- Maximising yield: Given uncertainties (prices, weather, disease etc.) farmers seek to maximise yield as one element within their control. This will maximise income but puts lesser weight on costs
- Reducing uncertainty (yield variation): refers more to optimising yield in the presence of constraints, e.g. avoiding practices that might increase risks to crops yield such as those resulting in soil erosion, compaction. Essentially given environmental conditions there may be a risk involved in seeking the highest possible yield
- Resilience (soil moisture etc): Farmers are concerned with reducing uncertainty by adopting measures that reduce the impact of extreme events (drought, flood) ( e.g. maintaining soil moisture against water stress or irrigation requirements)
- Minimising costs: Farmers place less weight on income and seek to control costs. This might reflect cash flow issues, or degree of certainty/uncertainty over yield and income (e.g. fertiliser, plant protection)

The outcomes of these sessions for each case study workshop are considered in turn below with a summary for each which tries to identify any practices which are both cost-effective (according to the assessment), and have limited barriers to implementation.

Although the context of the discussion was the case study region, highlighting region specific barriers and opportunities, the workshops also discussed these in the national context since many of them are relevant to farmers throughout the country. The partners approached the reports slightly differently, some (Italy for example) referred to practices beyond the five core soil carbon management practices (Section 3), while for Poland, farmer interview data is used to support the findings.

## 10.2. Zealand, Denmark

### 10.2.1. Barriers to implementation of soil carbon management practices

Below are details of the barriers to implementation of different soil carbon management practices identified during the Danish workshop. These barriers are also summarised in Table 10.1.

**Zero and minimum tillage** - In this workshop it emerged that zero- or reduced tillage is regarded as being technically difficult and therefore only attractive for the very skilled or dedicated farmers. Farmers generally felt they had a lack of practical skills to implement this measure, with the difficulties exacerbated by the cold climate. Specific problems identified related to germination/crop growth; perennial weed problems; and a lack of appropriate existing technology to control weeds on organic farms. The main social barrier related to the aesthetic value of fields with zero or minimum tillage regarded as looking 'messy'. The economic barriers related to an increased risk of crop failure and the need to change crop types in order to maintain yields. The two main barriers of these practices were identified as a risk of crop failure and perennial weed failures.

**Catch crops** are mandatory in Denmark and are unpopular. The participants reported that the benefits of catch crops to farmers are unclear and that there is a lack of scientific knowledge and communication to farmers. A number of technical difficulties with cover crops were reported, including a lack of time after harvest to accommodate catch crops and difficulties in successful establishment due to germination problems. Also catch crops were considered to prevent efficient mechanical weed control and to allow less flexibility in choosing winter crops vs. spring-sown crops. Economic barriers reported for catch crops related to potentially high crop replacement costs (winter wheat replaced with spring barley); time consuming (involving extra field operations); and costly to establish. The two main barriers to uptake identified were uncertainty about the benefits of catch crops and less flexibility in the choice of crops.

**Residue management** – No technical or social barriers were identified as preventing the uptake of residue management and in fact it was suggested that regulations have helped to encourage the implementation of this practice. The only barrier identified was an economic one related to loss of income from straw.

**Adding legumes** – Growing catch crops in Denmark is mandatory, but legumes are not accepted as one of the mandatory catch crops. As a result it is considered costly to grow legumes as a catch crop in addition to those required by legislation. Also concerns were expressed about the potential risk of crop failure when using catch crops.

**Long/short grass rotation** – No barriers to implementation of long/short grass rotation were identified on dairy farms, however, on non-dairy farms there was concern about the availability of livestock to graze on the grass/sward and also the lack of biogas plants for using grass as an input. Consequently, on non-dairy farms grass rotations were not considered an-effective option.

Table 10.1 Barriers to implementation of soil carbon management practices in Zealand/Denmark

<b>Practice</b>	<b>Technical</b>	<b>Social</b>	<b>Economic</b>	<b>Identify the top 2 barriers</b>
<b>Zero tillage</b>	Lack of practical skills in practicing measure; cold climate problematic for germination/crop growth; perennial weed problems; lack of appropriate existing technology to control weeds in organic farms	Aesthetic value is lost (fields look 'messy')	Potential risk of crop failure; need for change of crop types to maintain high yields	Risk of crop failure; Perennial weed problems
<b>Minimum/non-inversion tillage</b>	As above but less difficult	Same as above		Same as above
<b>Catch/cover crops (CC)</b>	Little time after crop harvest to accommodate catch crops; difficult to establish successfully (germination problems); CC prevent efficient mechanical weed control; less flexibility in choosing winter crops vs. spring-sown crops	CC are mandatory and unpopular (please see Session 1); CC benefits are unclear; lack of scientific knowledge and communication to farmers	Crop replacement cost can be high (winter wheat replaced with spring barley); time consuming (involving extra field operations); costly to establish catch crops	CC benefits are unclear; less flexibility in choice of crops
<b>Residue management</b>	No problem	None; regulations have helped to implement residue management	Loss of income from straw	Loss of income from straw
<b>Adding legumes</b>	Potential risk of crop failure	Legumes not accepted as mandatory CCs	Costly to have legumes as CC ,they need to be grown in addition to mandatory CCs	Risk of crop failure; costly
<b>Long/short grass rotation</b>	Dairy farms: No problem. Non-dairy farms: Lack of animals to graze on the grass/sward, biogas plants for using grass		Non-dairy farms: Not cost-effective due to lack of demand	Lack of cost-effectiveness

### 10.2.2. Opportunities for implementation of soil carbon management practices

The workshop participants suggested that farmers are particularly interested in implementing residue management. An early (1990) ban against burning straw in the fields led farmers to incorporate straw which was found to be beneficial to soil structure/soil aeration. In relation to adding legumes, a change in the national regulations so that legumes are acceptable as a catch crop would result in a wider uptake of legumes.

The cost-effectiveness of undertaking new practices is important to farmers so the provision of more information on the short and long term benefits of individual measures could encourage wider implementation. Currently, it was felt that hard evidence of the economic benefits of these measures for individual farmers is missing.

### 10.2.3. Motivations of farmer decisions in Zealand

Table 10.2 Motivations of farmer decision in Zealand/Denmark

Motivation	All crops
Profit/gross margin	Profit and time. If pig or dairy farmer, there is not much time for field operations and crop management
Maximizing yield	Yes
Reducing uncertainty (variation in yield)	Yes
Resilience ( e.g. maintaining soil moisture against water stress or irrigation requirements)	Not often a prominent driver
Minimizing costs (e.g. fertilizer, plant protection, seeds and machinery use etc.)	Yes
Minimizing costs (land preparation, weeding, harvest etc.)	Yes
Cross-compliance/ local agri-environment regulations	Regulations (what is mandatory, what is forbidden) are main drivers for farmers decision
Farming systems (arable/mixed production systems)	In case of mixed farming, grass/sward is preferred for fodder

The workshop participants were asked to identify the motivations for farmer decisions in the region and whether these varied across crop types. Profit /gross margins were identified as a main driver for farmer decision making. In addition, time requirements were also considered important for pig and dairy farmers who have limited time available for field operation and crop management. Mandatory

regulation was also considered another important driver of farmers' decisions, whereas a less prominent driver was the need to ensure resilience.

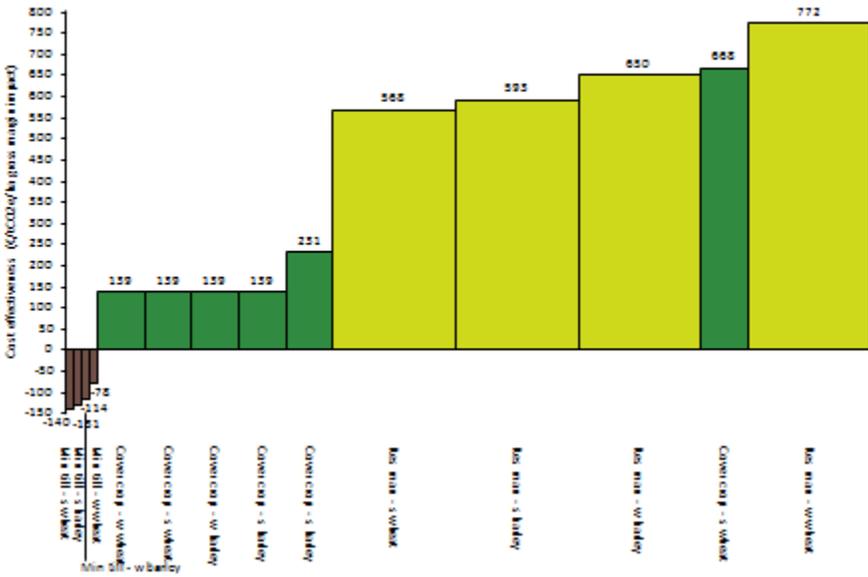
#### **10.2.4. Summary of findings for Zealand, Denmark**

Generally, soil in the region and in Denmark is considered an important resource and farmers are aware of soil carbon benefits and its effects on soil 'stability' (stability of soil aggregates; resistance to soil compaction) and on crop productivity. It was suggested that farmers are particularly interested in implementing residue management as a soil carbon management practice, whereas currently, zero- or reduced tillage is regarded as being difficult to implement and only attractive for the very skilled or dedicated farmers.

Whilst there is an awareness of SOC effects, the practices adopted by farmers will depend on the regulations in place. For example, the uptake of legumes is limited as they are not considered one of the mandatory catch crops required by legislation.

The MAAC figures for Zealand (Figure 10.1) suggest that minimum tillage would be the most cost-effective practice (according to MACC) for farmers, however, as identified above, farmers have a number of concerns about taking up this practice, particularly in terms of the risks of crop failure and perennial weed problems. The provision of more technical advice and information may help to overcome some of these concerns. However, it was also suggested that the proposed soil carbon management options (for cost effectiveness calculations) cannot be evaluated independently from each other and per crop. Changing management requires a holistic approach to the whole farm/arable area. Management and choice of crop rotations need to be decided together. For example, minimum tillage and incorporation of straw cannot be considered as two separate management options. In Zealand and Denmark as a whole minimum tillage will require straw incorporation in order to work properly.

SOC MACC for Denmark – mean yield impact (per ha all measures and crops)



SOC MACC for Denmark – mean yield impact (best measure for each crop)

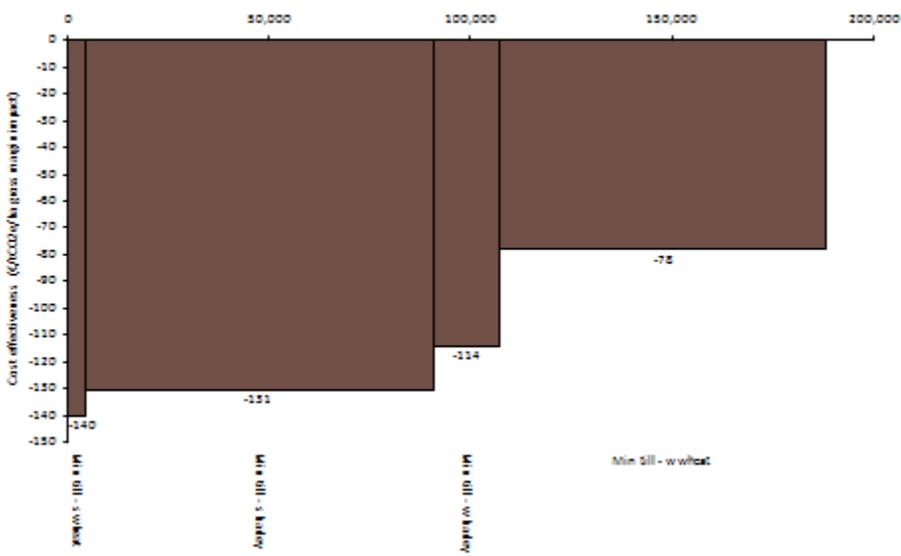


Figure 10.1 SOC MACC for Denmark

## 10.3. Central Region, Hungary

### 10.3.1. Barriers to implementation of soil carbon management practices

Below are details of the barriers to implementation of different soil carbon management practices identified during the Hungarian case study workshop. These barriers are also summarised in Table 10.3.

**Zero and reduced tillage.** The practice of zero or reduced tillage is limited in the region due to a lack of necessary equipment, particularly for the small farms that, due to a lack of financial resources, are not in a position to acquire the machinery required for more advanced soil carbon management. Also a more widespread uptake of conservation and zero-tillage practices is limited due to knowledge barriers. Amongst the less educated farmers there is both a lack of appropriate knowledge about soils in general and at the same time a strong attachment to “traditional” methods, with a limited openness towards new approaches.

**Catch/cover crops.** There is a limited use of green manure crops due to time constraints; harvesting is considered more important than establishing green manure crops. Furthermore, catch crops and cover crops are rarely used, as they are not considered a traditional practice, although in some agri-environment measures, the crop rotation requirement includes legumes.

**Residue management.** One reason for limited uptake of residue management practices is that the straw can have a high economic value. For example, local mushroom producers will often pay a very high price for straw and even undertake the baling themselves. Also a misinterpretation of the bioenergy/bioeconomy concept has led to an overutilization of soil organic carbon sources available on the field (e.g. straw and crop residues). One agronomic barrier identified is the difficulty of utilizing crop residues under certain/extreme weather conditions.

**Adding legumes.** For the sandy soils grown in the region, the type of crops that can be grown are limited and are often not suitable for legumes. Furthermore, legumes are often not profitable in the region and grown only on an occasional basis.

**Nutrient management.** Some of the advisory services on nutrient management are out of date and there are often contradictions between specialists interested in nutrient management and those with an interest in soil protection. Furthermore manure application is considered administratively burdensome due to (over) regulation.

Table 10.3 Barriers to implementation of soil carbon management practices in Central Region, Hungary

Practice	Technical (agronomic, technical, env)	Social (cultural, skills, lack of advice)	Economic policy legislative	Other	Identify the top 2 barriers
<b>Zero tillage</b>	Limited provision of necessary equipment	Lack of knowledge; Controversial technical advice; Insistence to traditional methods; Limited learning capacity	Investment requirements Lack of subsidy	farm size	“economics”; lack of knowledge
<b>Reduced tillage</b>	Limited provision of necessary equipment	Lack of up-to-date knowledge; Controversial technical advise	Investment requirements;		
<b>Catch/cover crops</b>	Time conflict of harvesting vs. seeding.		Lack of subsidy		Not typical practice Economics!
<b>Residue management</b>		Lack of up-to-date knowledge	“Economics”; Market issues		Profitability motivation
<b>Adding legumes</b>	Soil suitability barriers		Lack of market (limited marketability)		Ecologic capacity
<b>Nutrient management</b>	Partly out of date advisory services		administrative/legal (over)regulation	admin& policy burden	

### 10.3.2. Opportunities for implementation of soil carbon management practices

A number of opportunities for encouraging the adoption of soil carbon management practices in Hungary were identified during the workshop and are summarised in Table 10.4. It was suggested that the efficiency of some practices, such as zero tillage could be increased through better preparation, such as mechanical cutting of residues and better management of available organic sources. Also developing the livestock sector could increase availability of manure. An important opportunity identified related to improved knowledge transfer through a better resourced advisory service. Uptake could be increased through the provision of good practical examples through an “open farm” network. It was felt that there was currently a large number of data collection activities with significant overlap and underutilization of this information. Also emphasis should be placed on the mutual benefits or synergies from soil carbon management practices, especially as 50% of the soils in the region are climate sensitive.

Finally, either introducing or increasing economic incentives was considered important to encourage the uptake of soil carbon management practices. Specific machinery subsidies could be provided or soil carbon measures could be incorporated into AEM or some sort of economic incentive related to GHG quota could be introduced. Furthermore, the introduction of specific marketing labelling or “branding” would add value to the product.

Table 10.4 Opportunities for implementation of soil carbon management practices

<b>Technical (agronomic, technical, env)</b>	<b>Social (cultural, skills, lack of advice)</b>	<b>Economic , policy &amp; legislative</b>	<b>Other</b>	<b>Identify the top 2 opportunities</b>
Sustain the optimal soil structure/condition	More “practice” oriented advisory services	Introduction/inc rease of subsidy; decrease of administrative burden; specific machinery subsidy	Best practice through “open farm” network Alternative economic incentives (GHG quota) Marketing/”labeling/branding” Questionable data sources: Put more effort on the use/analysis of existing data/inform.	Subsidy; knowledge transfer; best practice

Workshop participants were asked to rank the most promising soil carbon management practices for the region (see Table 10.5). The three practices identified as the most promising were: non-inversion tillage, green manure/nitrogen catch crop and crop rotation with perennials.

Table 10.5 Ranking of the most promising soil carbon management practices

<b>1.</b>	<b>Non inversion tillage</b>
<b>2.</b>	<b>Green manure / nitrogen catch crop</b>
<b>3.</b>	<b>Crop rotation with perennials</b>
4.	Avoid summer fallow
5.	No tillage
6.	Crop rotation with annual crops
7.	Avoid winter fallow
8.	Optimize irrigation
9.	Placement of hedges
10.	Switch to woody crops
11.	Improved grass mixtures

### **10.3.3. Motivations of farmer decisions in the Central Region, Hungary**

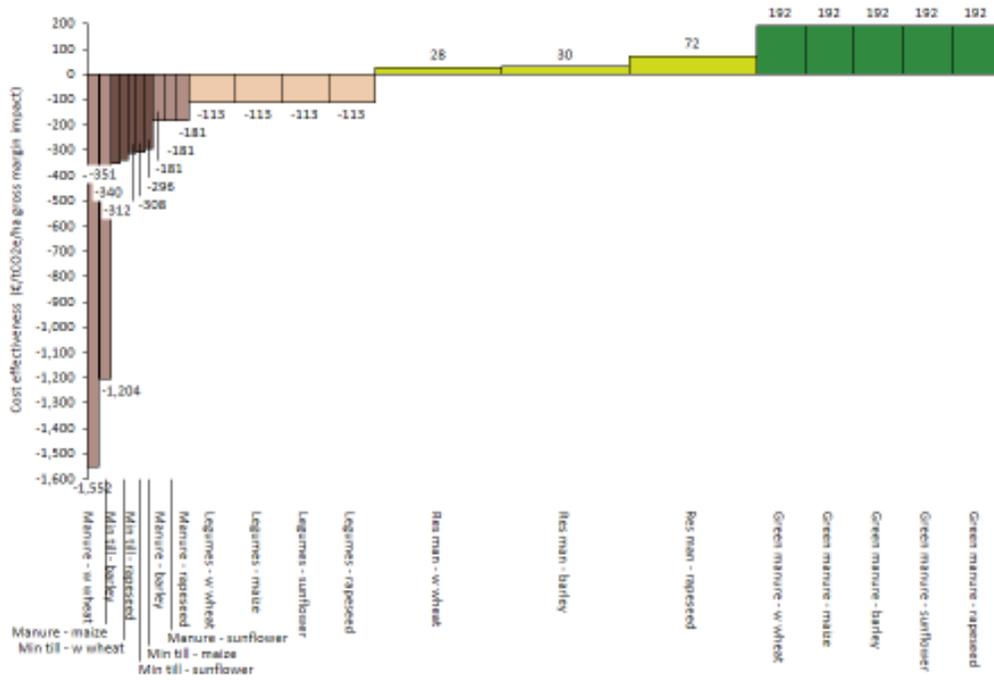
Motivational differences are related to tenure, management and income arrangements. There are the “land speculators” who aim to minimize investments/costs and are often satisfied with lower than technically and economically available short-term profits. These “farmers” generally have little interest in resilience and sustainability issues. In contrast, there are the professional market oriented farms, who view their production as a long-term primary source of income. These farms are very much concerned about long term issues including sustainability and soil carbon management. A third distinguishable group of land users are the ones, who farm as an additional source of income, often producing fruits and/or vegetables on a small nearby parcel or even kitchen garden, where these issues are less relevant.

### **10.3.4. Summary of findings for Central Region, Hungary**

A number of barriers were identified as currently preventing the implementation of soil carbon management practices in Hungary. In particular, the lack of appropriate advisory services to promote the practices and a cultural reluctance amongst many farmers to take up new practices were highlighted. Also there is currently a lack of economic incentives to encourage the uptake of these practices. Opportunities to encourage uptake that were identified related to improving the knowledge and advisory services available, particularly by providing demonstrations of good practices, and finding appropriate economic incentives.

The results of the SOC MACC identified the most promising cost-effective measures as being manure application, min tillage, application of legumes in the crop rotation and residue management (Figure 10.2). However, as Table 10.3 shows all of these practices were identified as having some barriers associated with them that affected implementation.

### SOC MACC for Hungary – mean yield impact (per ha all measures and crops)



### SOC MACC for Hungary – mean yield impact (best measure for each crop)

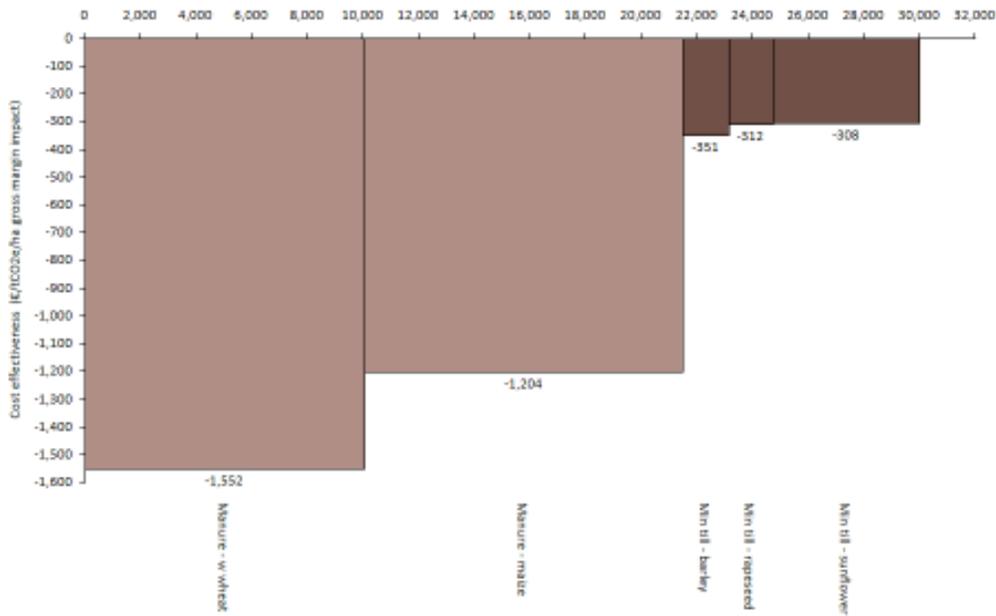


Figure 10.2 SOC MACC for Hungary

## 10.4. Tuscany, Italy

### 10.4.1. Barriers to implementation of soil carbon management practices

Below are details of the barriers to implementation of different soil carbon management practices identified during the Italian workshop for the Tuscany region. These barriers are also summarised in Table 10.6.

**Minimum/zero tillage.** In the Italian case study workshop minimum/zero tillage practices generated the most comments in relation to barriers to implementation. A reported technical barrier affecting implementation of this practice related to increased uncertainties in both the quality and quantity of crop yields. It was suggested that water and nutrient competition as the result of increased weed population would affect yields. Also, with regards zero tillage there were additional concerns about meeting market standards for product health and quality. It was also suggested that farmers may lack the required machinery to undertake this practice and therefore would be deterred by the need for new investments. Furthermore, these measures would increase organizational /logistical complexity and would require changes in the management system. As with any new practice farmers are concerned that it will take time to integrate the practice into the existing farm management system, which initially could result in a loss of both yields and income.

Farmers in the region can have difficulty in accepting any practice that is “outside” their knowledge and experience and this is a particular barrier for the older farmers. Currently, there appears to be a lack of farmer awareness about minimum tillage practices due to insufficient dissemination and communication about these practices and their benefits. In particular there is a lack of practical real-life examples and inadequate specific regional agricultural services to provide this information and train farmers. The main economic barriers reported relate to increased income uncertainties and a concern that the practice may result in higher costs for weeding and for new machinery investment.

**Crop rotation.** Concerns were expressed about the difficulties of identifying a cost-effective crop rotation to improve soil organic carbon. It was suggested that farmers’ choice of crops to grow in the rotation is hampered by market uncertainty (what to sell and when). Sometimes such a crop rotation is perceived as a limitation because the farmer is tied into a particular cropping pattern (sometimes over a long period). Economic barriers related to concerns about higher management costs due to the different operations that have to be applied to a wider variety of crops. Also concerns were expressed about the potential for a reduced income due to difficulties of selling the final product on the market.

**Residue management.** The only potential barrier to adopting residue management related to the need to sometimes add mineral fertiliser before incorporation of the residues. In such situations, this practice would result in higher costs.

**Hydraulic soil protection infrastructure.** The main technical barrier to the uptake of this practice relates to the difficulty of applying it across hilly land, such as that found in Tuscany. Also it was suggested that there was inadequate technical assistance available to help apply this practice. It was also suggested that the practice would incur higher costs.

**Green manure.** The main barrier to applying green manure is economic. The practice would result in higher costs from the management of a crop that does not provide any economic profit. Any technical-agronomic advantage is only realised in the long-term.

**Organic manure.** A number of technical barriers to using organic manure were identified. These included the perceived difficulties in managing the purchasing, transportation, handling and spreading of the manure. Also concerns were expressed about the increased logistical complexity of handling organic manure, including the requirement for appropriate machinery. The odour from the organic manures was considered a social constraint and would present difficulties for farmers that also provide tourism services. It was also felt that a barrier to manure application is the existing restrictive legislative rules for manure spreading and transportation and the need to comply with the EU Nitrates Directive. Also it was suggested that higher costs would be incurred due to the requirements for more staff to handle and apply the manure.

**Exogenous biomass** A number of technical barriers to the uptake of exogenous biomass application were identified. These related to constraints due to health and certification requirements and the strict rules on spreading, logistical and organisational constraints and the high variability in the quality of the biomass, which might, for example include plastic, glass, seeds. Culturally, this is not a traditional practice in Tuscany and therefore there is no expertise amongst the farmers in applying the biomass.

**Catch crops.** This measure is considered to increase operational complexity and result in more agronomic difficulties for managing crop rotations and higher costs. It is not a traditional practice in the region and there is currently a lack of farmer awareness about the practice and insufficient dissemination/communication of its benefits.

**Sowing into mulch** was considered a promising soil carbon management practice, but one that required further testing.

**Ecological focus areas,** included practices such as set aside, environmental corridors and buffer zones. The main barrier with these practices related to the need to use productive land resulting in a reduced income and issues with weed control and increased fire risk.

Table 10.6 Barriers to implementation of soil carbon management practices in Tuscany, Italy

Practice	Technical	Social/Cultural	Economic/political
Minimum tillage	<ul style="list-style-type: none"> <li>• Crop yield uncertainties in terms of quality and quantity</li> <li>• Practice cannot be applied on all soils in the region. Due to the high variability in soils, it can only be applied in certain areas.</li> <li>• Lack of adequate technical skills and information about the new practices and their benefits.</li> <li>• Current machinery inadequacy: specific machines are required (new investments).</li> <li>• Water and nutrients competition with the increased weed population.</li> <li>• Higher organizational /logistic complexity: sometimes the acquisition of new practices requires changes in the management system.</li> <li>• Waste of time: a new practice requires time to be integrated into the farm management. This could also imply loss of both yields and income.</li> </ul>	<ul style="list-style-type: none"> <li>• Not traditional practice: farmers have difficulty accepting a practice that is “outside” of their knowledge and experience</li> <li>• Lack of farmer awareness due to insufficient dissemination /communication of the practice’s benefits.</li> <li>• Lack of a practical proof (real example) of the practice itself and its potential benefits.</li> <li>• Mental rigidity of older farmers to innovation and to switch to new practices.</li> </ul>	<ul style="list-style-type: none"> <li>• Income uncertainties</li> <li>• This practice may imply higher costs for weeding and for new investments</li> <li>• Lack of specific regional agriculture services which “properly” inform and train farmers</li> </ul>
No tillage	<ul style="list-style-type: none"> <li>• Same as above. In addition:</li> <li>• Decline in quality and health of the final product. The final product might not meet required standards for market. For instance, the likely increase of pests and crop diseases related to this practice could result in an increment of phytosanitary treatments. These, in turn, would lead to products with quality unacceptable by the market because of the health restrictions imposed by the food legislation (EU and National).</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above</li> </ul>	<ul style="list-style-type: none"> <li>• Same as above</li> <li>In addition:</li> <li>• Quality and health issues as mentioned in “technical issues”</li> </ul>
Crop rotation	<ul style="list-style-type: none"> <li>• Difficulties in defining a cost-effective crop rotation: farmers’ choice is hampered by the</li> </ul>		<ul style="list-style-type: none"> <li>• Higher management costs due to different crop operations to</li> </ul>

	market uncertainty (what to sell and when). Sometimes this practice is perceived as a limitation because tied to its life span (sometimes very long) and to the type of crop to be included in the rotation.		be applied <ul style="list-style-type: none"> <li>• Potentially reduced income due to the difficulties of selling the final product onto the market</li> </ul>
Residue management	<ul style="list-style-type: none"> <li>• Sometimes need for external inputs of mineral fertilization before incorporation of residues</li> </ul>		<ul style="list-style-type: none"> <li>• Higher costs due to external mineral inputs</li> </ul>
Hydraulic soil protection infrastructure	<ul style="list-style-type: none"> <li>• Difficult to apply across hilly territories, thus in Tuscany</li> <li>• Inadequate technical assistance</li> </ul>		<ul style="list-style-type: none"> <li>• Higher costs</li> </ul>
Green manure			<ul style="list-style-type: none"> <li>• Higher costs: the practice requires the management of a crop that does not provide any economic profit; technical- agronomic advantage is deferred over time.</li> </ul>
Organic manure	<ul style="list-style-type: none"> <li>• Difficult management in retrieving, purchasing, transporting, managing, spreading manure</li> <li>• Higher organizational /logistical complexity (necessity of adequate machinery)</li> <li>• Environmental impacts (i.e. Nitrate EU directive)</li> </ul>	<ul style="list-style-type: none"> <li>• Social constraints: the odour of manure, thus difficult to apply on farms which provide tourism services (e.g. agriturismo)</li> </ul>	<ul style="list-style-type: none"> <li>• Restrictive rules for manure spreading and transportation</li> <li>• Higher costs due to higher number of personnel</li> <li>• Compliance to Nitrate EU directive</li> </ul>
Exogenous biomass	<ul style="list-style-type: none"> <li>• Constraints in exogenous biomass health and certification</li> <li>• Logistical and organizational constraints</li> <li>• High variability of biomass components (i.e. presence of plastic, glass, seeds, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>• Not traditional practice, no expertise in Tuscan farmers</li> </ul>	<ul style="list-style-type: none"> <li>• Strict rules in its spreading</li> </ul>
Cover crops	<ul style="list-style-type: none"> <li>• More agronomic difficulties (i.e. operation plans) to manage crops rotation</li> </ul>	<ul style="list-style-type: none"> <li>• Not traditional practice</li> <li>• Lack of farmer awareness and insufficient dissemination /communication of its benefits</li> </ul>	<ul style="list-style-type: none"> <li>• Higher costs</li> </ul>
Sowing into mulch	<ul style="list-style-type: none"> <li>• Promising practice, but it still needs to be tested</li> </ul>		
Ecological focus areas(set aside, env. corridors, buffer zones)	<ul style="list-style-type: none"> <li>• Use of productive parts of field</li> <li>• Weed control</li> <li>• Fire risk</li> </ul>		<ul style="list-style-type: none"> <li>• Lower income</li> <li>• Legislative constraints</li> </ul>

#### **10.4.2. Opportunities for implementation of soil carbon management practices**

A number of opportunities for encouraging the implementation of soil carbon management practices in Tuscany, Italy were identified during the workshop and are summarised in Table 10.7. Across all the soil carbon management practices it was suggested that economic incentives would encourage uptake. Also for a number of practices there is currently a lack of appropriate advice or training and an improvement in these services could lead to a greater uptake. More specifically, minimum and non-tillage were considered to offer the greatest opportunities for uptake as these practices required less manpower and would therefore reduce labour costs. Also, if appropriate machinery was available, such as a shredder or plough, then there may be opportunities to introduce residue management. A number of opportunities were suggested for the uptake of hydraulic soil protection infrastructure, in that it can be shown to produce other benefits, such as reducing soil erosion, producing better soils in water recovery areas and facilitating climate adaptation and is a traditional practice in some areas of the region and is used for landscape maintenance. Organic manure application was considered another opportunity for those farms with existing livestock and further uptake would be encouraged if there were less restrictive rules for spreading and transportation of manure. The use of exogenous biomass was considered to have potential due to a plentiful supply, but the regulations needed to be simpler. Finally, another practice that was considered to have potential was sowing into mulch, although further experimentation was required.

Table 10.7 Opportunities for implementation of soil carbon management practices in Tuscany, Italy

Practice	Technical	Social/Cultural	Economic
Minimum tillage	<ul style="list-style-type: none"> <li>• Reduced need of manpower (lower labour costs)</li> <li>• Increase of technical skills (Farm Advisory Service)</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriate advisory/training agricultural services</li> <li>• Successful experiences nearby</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> <li>• Lower costs mainly due to reduced manpower</li> </ul>
No tillage	<ul style="list-style-type: none"> <li>• Reduced need of manpower (lower labour costs)</li> <li>• Increase of technical skills (Farm Advisory Service)</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriate advisory/training agricultural services</li> <li>• Emulation: successful experiences of “neighbour” farmers</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> <li>• Lower costs mainly due to reduced manpower</li> </ul>
Crop rotation	<ul style="list-style-type: none"> <li>• Increase of technical skills (Farm Advisory Service)</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriate advisory/training agricultural services</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> </ul>
Residue management	<ul style="list-style-type: none"> <li>• Availability of specific agronomic machinery (i.e. shredder, plough)</li> <li>• Increase of technical skills (Farm Advisory Service)</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriate advisory/training agricultural services (Farm Advisory Service)</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> </ul>
Hydraulic soil protection infrastructure	<ul style="list-style-type: none"> <li>• Lower soil erosion</li> <li>• Indirect benefits in SOC</li> <li>• Better soils in water recovery areas</li> <li>• Climate adaptation</li> </ul>	<ul style="list-style-type: none"> <li>• Traditional practice (in some areas of the region)</li> <li>• Landscape maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> </ul>
Green manure	<ul style="list-style-type: none"> <li>• Easier to apply than manure</li> </ul>		<ul style="list-style-type: none"> <li>• Economic incentives</li> </ul>
Organic manure	<ul style="list-style-type: none"> <li>• Presence of livestock within the farm</li> </ul>		<ul style="list-style-type: none"> <li>• Less restrictive rules for its spreading and transportation</li> <li>• Lower costs</li> </ul>
Exogenous biomass	<ul style="list-style-type: none"> <li>• Easy biomass supply</li> </ul>	<ul style="list-style-type: none"> <li>• Appropriate advisory/training agricultural services*</li> </ul>	<ul style="list-style-type: none"> <li>• Economic incentives</li> <li>• Simpler regulations</li> <li>• Lower costs</li> </ul>
Cover crops			<ul style="list-style-type: none"> <li>• Economic incentives</li> </ul>
Sowing into mulch	<ul style="list-style-type: none"> <li>• Promising practice, but it still need to be tested</li> </ul>	<ul style="list-style-type: none"> <li>• Promising practice, but it still need to be tested</li> </ul>	<ul style="list-style-type: none"> <li>• Promising practice, but it still need to be tested</li> </ul>
Ecological focus areas (set aside, environmental corridors, buffer zones)	<ul style="list-style-type: none"> <li>• Higher level of organic matter/ biodiversity /ecosystems services</li> <li>• Availability of smaller agronomic machinery</li> </ul>		<ul style="list-style-type: none"> <li>• Economic incentives focused on ecological focus areas</li> </ul>

### 10.4.3. Motivations of farmer decisions in the Tuscany region, Italy

Table 10.8 provides details of the main motivations for farmers' decision-making in the Tuscany region of Italy. The ranking shows that the main driver of decision-making is a consideration of the impact on profit and gross margins with the lowest ranked driver related to the idea of increasing resilience.

Table 10.8 – Main drivers of farmer decisions in Tuscany, Italy

MOTIVATION	Overall ranking from 1 (highest) to 5 (lowest)
profit/gross margin	1
maximising yield	2
minimising costs (e.g. fertiliser, plant protection)	3
reducing uncertainty (variation in yield)	4
resilience ( e.g. maintaining soil moisture against water stress or irrigation requirements)	5

It was suggested that Tuscan farmers have some difficulties linking crop production to soil quality. Although both soil and machinery are factors of economic production, farmers tend to place greater importance on using high-technology machinery. Moreover, farmers are often unaware of the environmental impacts of specific agronomic choices, although this perception is slowly changing.

### 10.4.4. Summary of findings for Tuscany, Italy

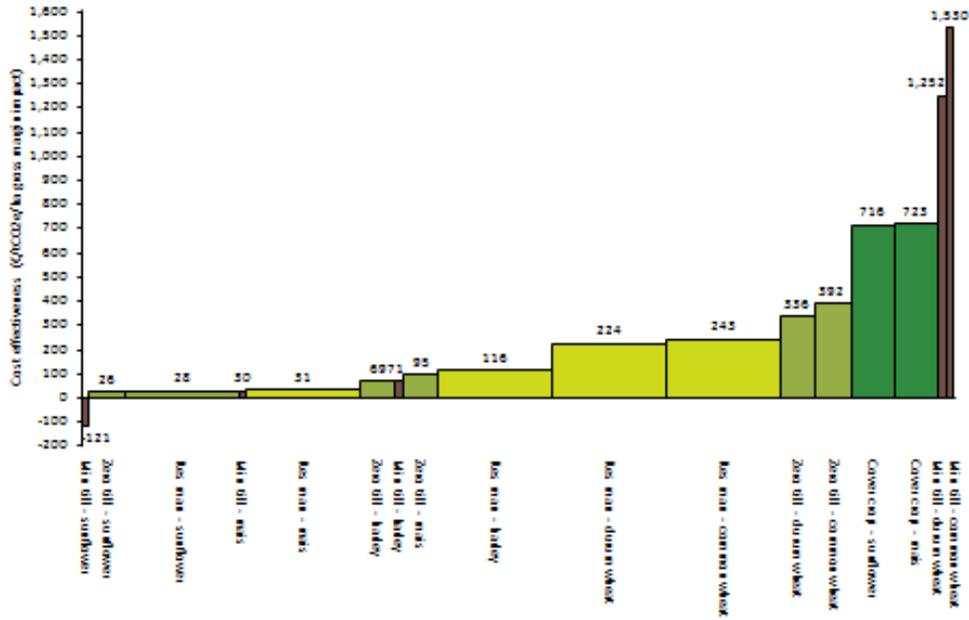
In terms of technical barriers, the lack of technical skills was one of the main barriers identified by stakeholders across all the soil carbon practices. Similarly, apart from unfamiliarity with some practices (e.g. minimum tillage, no tillage, cover crops, exogenous biomass), one of the main social/cultural barriers was the lack of farmers' awareness of the practices' benefits mainly due to the current unsatisfactory regional advisory/knowledge transfer system. Higher costs, as well as a lack of specific regional agricultural services devoted to farmer training/education, are the main economic/political barriers identified by stakeholders.

Two main opportunities identified for increasing soil carbon management practices are economic incentives and improvements in appropriate advisory/training agricultural services to improve farmers' technical skills.

All stakeholders agreed that the trade-off between income and costs (profit/gross margin) is the main driver of farmer decision-making processes. Currently, creating/maintaining "good soils" is not the primary aim of Tuscan farmers. However, this perception is slowly changing as the new generation of farmers tends to give more attention to environmental issues, and thus to good soil quality. The results of the SOC MACC (see Figure 10.3) identified minimum tillage as the most promising cost-effective measure for maize and sunflower, no-tillage for barley, and residue management for durum and common wheat, the most cultivated crops in Tuscany. Residue management has the greatest opportunity for uptake, as currently it is widely adopted by farmers with evident soil organic matter/carbon enhancement in the region. However, as evidenced by stakeholders, this practice often

requires addition of mineral fertilizers. Consequently, the adoption of this practice may imply higher costs. On the contrary, minimum tillage or no-tillage, even if showing the best cost-effectiveness for barley, sunflower and maize crops, has a number of barriers which negatively affect implementation (see Table 10.6).

SOC MACC for Tuscany – mean yield impact (per ha all measures and crops)



SOC MACC for Tuscany – mean yield impact (best measure for each crop)

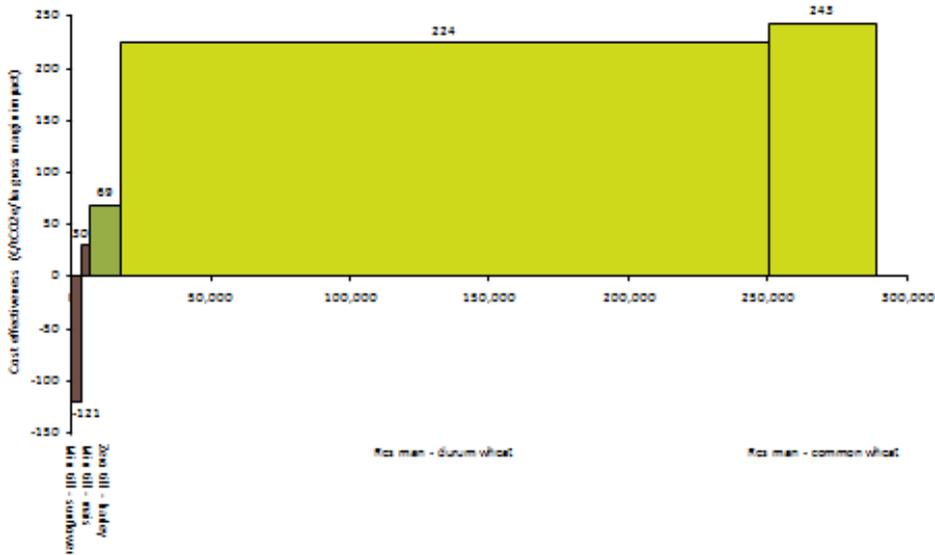


Figure 10.3 SOC MAC for Tuscany, Italy

## 10.5. Mazovia, Poland

Below are details of the barriers to implementation of different soil carbon management practices identified during interviews and the workshop held in the Mazovian region of Poland. The most important barriers identified for specific practices are presented in Table 10.9.

### 10.5.1. Barriers to implementation of soil carbon management practices

Both farmers and consultants claimed that the main obstacle hampering the introduction of adequate soil carbon management practices is the absence of a clear, long-term vision for agricultural development. Consequently, farmers do not plan their activities in long-term cycles, but instead only react to market developments; adjusting their production systems to what is profitable in a given year<sup>4</sup>. However, this limitation seems to apply mainly to small and medium-size farms. As the owner of a large farm (interviewed previously) said that his priority was production planning, not following the short-term market conditions:

*"...I think my neighbours do not take rational decisions. I must care for my soil, because it determines the success of my production. Thus, I apply a crop rotation and stick to adopted plans. But it's easier for me. As a large farm owner, I am able to negotiate better prices not only for my crops, but also for seeds, fertilizers and chemical agents. That's why I can afford to proceed rationally"<sup>5</sup>.*

Yet even that farmer admitted that agricultural policies were unpredictable.

*"Neither I nor my advisers can rest assured that no fresh requirements are introduced, forcing me to alter my plans. New regulations are imposed without consulting farmers, who often don't have a sufficient transition period to adapt".*

Among other barriers hampering the introduction of technologies to increase organic carbon content in soil, economic constraints are considered the most important. This is because many of the measures require investments that the farmers are unwilling to bear. This is the case with cover crops that farmers refuse to grow, because the costs of the seeds and fuel render the practice unprofitable. Also, trying to sell the produced crop is a problem that aggravates the situation, as a farmer previously interviewed commented:

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<sup>4</sup> More accurately, what farmers think will be profitable. That's because they base their decisions on the profitability of the previous season, dropping those enterprises that brought little or no profit; therefore, they focus production on those enterprises that were highly profitable in the previous year (information obtained during a meeting with consultants. Bielice 21.03.2014).

<sup>5</sup> Interview with farmer. District Ostrów Mazowiecka. 3.03.2014.

*“...Time ago, when I used to keep animals at the farm, I grew cover crops or legumes for feed. Now, with specialisation, there is nowhere that I can sell this crop, so I stopped producing it”<sup>6</sup>.*

Economic barriers also affect the uptake of non-tillage farming practices. According to agricultural consultants, most Mazovian farms cannot afford to buy the new machines necessary for such practices. Also, as farming co-operatives were abolished, producers have no options to lease equipment and must rely on their own machinery<sup>7</sup>.

Agronomic barriers are important with regard to cover crops. In recent years, deficient precipitation has been an increasingly serious problem; soils are dry in the autumn, complicating cultivation. Farmers are also ceasing from growing cover crops, fearing that they will deplete soil moisture, thereby reducing next year's spring harvests.

Social barriers are also important. Mazovia's rural areas are rapidly ageing. Older farmers, especially those owning small farms, are reluctant to change their traditional practices, and choose to continue with the old farming practices. They make little use of agricultural consultancies or Internet portals; their main sources of knowledge are their neighbours and their own conviction (often wrong), that farming should be done their own way. As a result, increasing numbers of small farms produce only for their own needs. Furthermore, as the land trading market is virtually non-existent<sup>8</sup>, the introduction of new agricultural practices is highly unlikely<sup>9</sup>.

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<sup>6</sup> Interview with farmer. Sanniki, 28.02.2014

<sup>7</sup> Agricultural advisers' opinion. Meeting in Bielice 21.03.2014.

<sup>8</sup> The reason is the existence of a special social insurance system exclusively for farmers (the Agricultural Social Insurance Fund, KRUS); pension and healthcare contributions to KRUS are much lower than under the general system. If the farmer sells his land, he will not be entitled to KRUS benefits anymore.

<sup>9</sup> Some consultants disagree. In their opinion, a huge (but unknown) area of arable land in Mazovia is leased. During the meeting in Bielice (21.03.2014), the example of one of the region's communes was addressed, where only 2,500 farms out of the total 11,000 take agricultural subsidies. The consultant says that it means that all owners of remaining 8,500 farms have leased their land to other producers.

Table 10.9 The primary barriers for implementation of selected agricultural practices in Poland<sup>10</sup>.

	Main barriers		
	Technical	Social	Economic
<b>Zero tillage</b>	Lack of equipment, small farms for which purchasing equipment is uneconomical	Lack of tillage demonstrations. Equipment leasing unavailable	Excessive costs of new machinery
<b>Reduced tillage</b>		Lack of knowledge about tillage practices and farmers accustomed to current production methods	
<b>Cover crop<sup>a</sup></b>	Autumnal droughts that complicate sowing	Fear of reducing moisture for spring crops by introducing cover crop	Expensive fuels, seeds. No demand for cover crop products
<b>Residues management</b>	No barriers		
<b>Legumes</b>	Specialisation and decreased livestock production has reduced interest in growing legumes		High cost of implementing tillage, lack of market for produced crop
<b>Manure and organic fertilizers</b>	Specialised production (resignation from animal production), switching from barn to slatted floor rearing		High cost of acquiring organic fertilizers from outside the farm

<sup>a</sup> – in consultants' opinion, cover crops are applied almost solely on farms with mixed production (plant/animal), where it is used as feed. The crop that is universally followed by applied cover crop, is maize grown for silage.

### 10.5.2. Opportunities for implementation of soil carbon management practices

Two basic conditions that should be met in order to disseminate more sustainable production methods in agriculture are: to ensure a more stable policy for this sector and increase the economic power of farms. As a farmer (previously interviewed) said:

<sup>10</sup> Barriers identified by agricultural consultants. Bielice 21.03.2014.

*“If I knew the prospects of agricultural produce sales over the next several years, then I would be able to plan production not only to make it profitable, but also to adjust to the requirements of soil protection”<sup>11</sup>.*

If the economic power of farms does not increase, the short-term profit maximising perspective will continue to prevail. Also, because most owners of small farms consider their agricultural activity an additional source of income (as their basic income is achieved outside agriculture), they do not plan production, instead react only to current market trends, an approach possibly entailing the use of methods that reduce organic carbon content in soil<sup>12</sup>.

Other factors that would boost the use of soil organic carbon-protecting tillage methods, are presented in Table 10.10.

Table 10.10 Factors favouring the selected agricultural practices in Poland<sup>13</sup>.

	Basic factors		
	Technical	Social	Economic
<b>Zero tillage</b>	Increasing the size of farms	Educating farmers. Availability of machinery leasing	
<b>Reduced tillage</b>		Educating farmers, supporting agricultural consultancies	
<b>Cover crop</b>	Increased animal production and consequent higher demand for plants grown as cover crops		Subsidising cover crops, to ensure their profitability
<b>Residue management</b>	As it is universally applied, no additional action is necessary		
<b>Legumes</b>	Higher animal production and consequently rising demand for crop		Higher subsidising of legumes production. Developing markets for product
<b>Manure and organic fertilizers</b>	Return to mixed plant/animal production. Return to barn rearing	Educating farmers in the need of organic fertilizing of region's sandy/light soils.	Legal requirement of organic fertilizing, or subsidising its application.

<sup>11</sup> Interview with farmer. Sanniki, 28.02.2014.

<sup>12</sup> Agricultural advisers' opinion. Meeting in Bielice 21.03.2014.

<sup>13</sup> Barriers identified by agricultural consultants. Bielice 21.03.2014.

### 10.5.3. Motivations of farmer decisions in the Mazovian region, Poland

The above table shows that economic factors may be the most important drivers influencing farmers' choice of production systems. Although the main factor involved in selecting cereals for cultivation are their low soil requirements, all interviewed respondents claimed that economic motives were crucial. Producers' main objective is to maintain financial liquidity; which is why they intentionally cease from investing in potentially profitable production, if they deem it as cost excessive within their short-term business perspective. Therefore, cost minimisation may be considered the decisive factor in selecting the production systems and methods. Another driver is the desire to maximise profit. In this case, action is undertaken if the farmer is certain it will bring a healthy profit in the short-term (meaning, within one growing season as maximum).

The role of other factors in farmer decision-making is secondary. Farmers are not striving to maximise crop yields, as they are fearful of possible problems with selling it; moreover, it would require additional expenditure on fertilizers and plant protection agents. If they do attempt to increase production, then social reasons are often the cause.

*“Many farmers like to boast how well they manage their businesses. Frequently the main motivation of such actions is to demonstrate to one’s neighbours an excellent productivity”<sup>14</sup>.*

Due to ever more evidently negative effects of climate change (early start to the growing season and consequently rising sensitivity of crops to frost, frequent droughts interrupted by torrential rainfalls), the increasingly decisive factor in selecting a crop is the resistance of chosen plants to unfavourable conditions.

### 10.5.4. Summary of findings for Mazovia, Poland

The difficult economic situation of agriculture and the lack of appropriate policies are the main reasons for insufficient uptake of soil carbon management practices in the Mazovian region. Also, the market-forced specialised production systems, as well as changes in animal rearing (move away from indoor rearing in order to observe compulsory health standards), has resulted in deficient organic matter in most Mazovian soils. Ploughing of crop residues is the only way to boost carbon content that is currently applied; although the increasing promotion of biodigesters is likely to convince more farmers to sell their straw, instead of incorporating it into the soil.

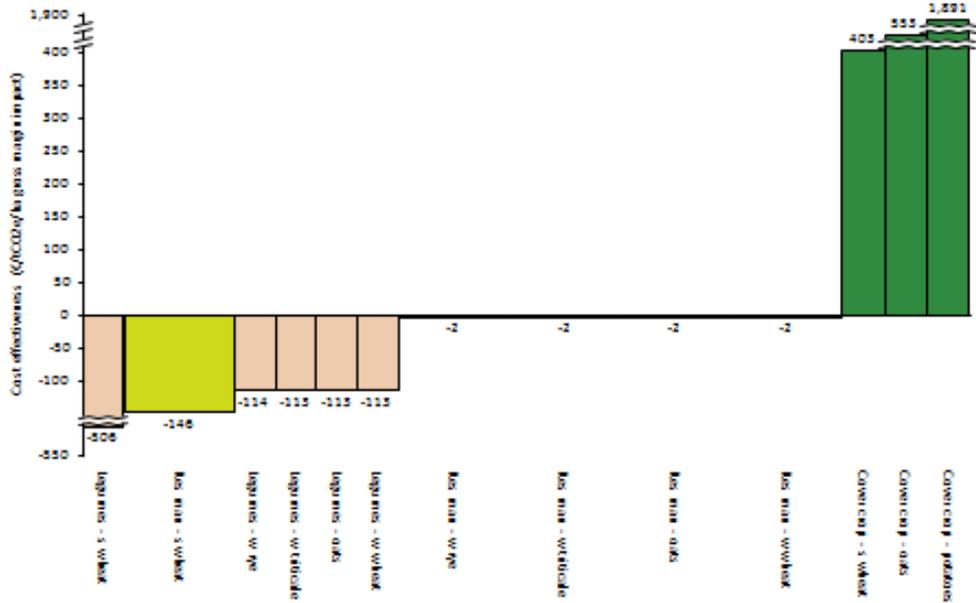
The results of the SOC MACC (see Figure 10.4) identified the growing of legumes and residue management as the most promising cost-effective measures. Residue management is already quite universally adopted across the region, although its practice might diminish if there is increased demand

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<sup>14</sup> Agricultural consultants' opinion. Bielice 3.03.2014.

for straw for biodigesters. However, as Table 10.9 shows legumes were identified as having some barriers that affected implementation and specifically concerns about a lack of market for the product.

### SOC MACC for Poland – mean yield impact (per ha all measures and crops)



### SOC MACC for Poland – mean yield impact (best measure for each crop)

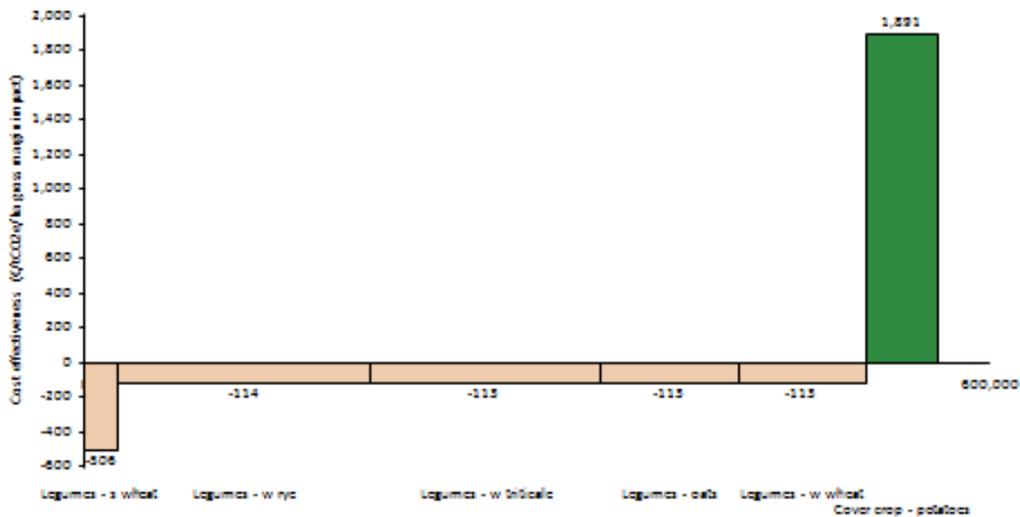


Figure 10.4 SOC MACC for Poland

## 10.6. Scotland

The workshop in Scotland was a pilot workshop and did not follow the same format and content as the other later workshops, hence discussion followed slightly different themes, as the analysis shows. It was also directed more generally at the country level rather than at the Eastern Scotland regional (case study) level.

### 10.6.1. Barriers to implementation of soil carbon management practices in Scotland

The session in the workshop discussed the barriers to the uptake of soil carbon management practices collectively, and then focussed on specific examples. In discussing the barriers, the participants further distinguished between the different levels in the advisory process, specifically suggesting some barriers were more important at an advisory or policy level rather than at the farmer level. For example, the role of scientific uncertainty as a barrier is more central to advisory services or to policy.

This division of barriers between different levels in the advice and support process was also picked up in the terminology used throughout the workshop discussion. Participants felt that to a certain extent soil carbon issues are not a primary interest for farmers, rather this level of interest and discussion of soil carbon is more specific to the advisory level. These comments were picked up later in the discussions around specific barriers including lack of knowledge and low importance of soil carbon.

**Economic barriers.** Participants all agreed that the lack of financial incentives or subsidies ranked highly as a barrier to the uptake of soil carbon management practices. There was some tentative feeling that this could link to perceptions of the practices being uneconomic, however, participants felt that the concern for soil carbon management practices as being uneconomic, impractical or needing investment was an advisory-level concern. However, the discussion heavily focussed on the need for economic incentives. As illustrated by one advisor's comment:

*"... You have to put it into the terms they find attractive e.g. economic. In general most farmers think they can improve the structure of their soils because they know they'll make money if the soil is well structured."*

One participant felt that the lack of incentives was an important concern for agri-businesses, particularly because banks' lending is based on profit and not the asset value of the land:

*"If there's a need to increase carbon in the soil, it's got to be something that's tangible to growers. It has to be that they make more money... It's all to do with profit. Farmers can't exist without profit."*

It was felt that there is a need to put a financial figure on organic matter as well as the products used in managing soil organic matter locally (e.g. straw incorporation in Scotland) to understand the total value.

The difficulty of demonstrating any economic benefits of soil carbon management practices over a long time scale was recognised. It was suggested that conflicts exist between the short term need for businesses to survive and raising the levels of organic carbon. Many farms are being let on contract farming agreements and this exacerbates short term perspectives: *“The guy who is doing the contract farming is definitely on a year to year basis, and he couldn’t care about organic matter levels.”* There is a need to change policy so that it is not a good financial incentive for landowners to work with contract farming agreements. Also there is a need to demonstrate resilience and the downstream impacts with a recognition that causalities happen up to a year and a half after the bad year.

**Social/cultural barriers.** Participants suggested that there are social/cultural barriers to using the term soil carbon which is considered of low importance to farmers. Participants suggested that it would be useful to discuss barriers in terms of soil health more generally, rather than soil carbon as they felt this was more appropriate to improving farm level engagement. As one advisor suggested *“I think you’re right to talk about soil carbon, in the sense that when farmers hear it they switch off... We should look at how we sell it to them without them actually realising.”* Generally, it was felt a need to get back to the basics of soil management rather than having a specific carbon element. To encourage involvement and engagement the advice should focus on principles such as biological nutrient management, organic or soil structure as these are terms they are more familiar with, or characteristics of what improved carbon management could do.

There was a suggestion that some commercial advisors can contradict good soil management advice. It was suggested that growing to sell onto commercial buyers challenges sustainable soil management. The commercial buyers demand perfection in the product, as they will not buy a product they do not like. An example was given of the practices involved in potato growing, including stone separation, which can damage soil structure. One participant discussed how in a review of advice sources trade advice counted for slightly more than independent advice and this is likely to increase into the future. They further stated that *“The problem is that they have a very narrow view on what agronomy is about and they don’t give a jock about what happens to the soil.”*

Participants agreed that there was some scientific uncertainty about the benefit of soil carbon management practices which limits the credibility of some advice. Participants were active in keeping up to date with research, but had found contradicting papers on the benefit to the climate from injecting slurry, for example. There was agreement that many of the scientific uncertainties may not filter down to the farmer level. This may be because that there is a barrier to what research reaches that level, however, it may also connect to the low importance to farmers. The comment from one advisor illustrates this point:

*“I believe there is scientific uncertainty, however, I’m unsure as to how high a barrier it is at the farm level, but it could be more at an advisory level or policy level, but not for the standard farmer.”*

Participants felt that there was a slight lack of knowledge to make satisfactory recommendations to farmers. Knowledge transfer is a key area, but difficult without scientific certainty and conflicting advice from commercial agents. It was considered essential to convince advisors about new practices, as they are part of the farming team and support system ensuring business viability.

The participants mentioned a new monitor farm in Fife, Scotland which appears to be helping with knowledge exchange as they have several meetings per year with farmers in attendance. It is seen as a good opportunity to talk about the practices and get people interested. Generally, there was agreement that there are a lack of best practice examples to demonstrate the benefits of the practices and that there is a lack of knowledge exchange from those that are there:

*“There are probably people doing these but the message isn’t coming across, but then it comes back to the fact that it’s not applicable for every farm anyway. I think it’s a lack of knowledge exchange.”*

Generally, it was suggested that there is a need to raise awareness of soils, for example through equivalent measures for soils of nutrient budgets, greenhouse gas emissions. It could also be tackled through encouraging routine soil sample testing.

**Technical/agronomic barriers** relate to the difficulties of integrating soil carbon management practices into existing farm management systems. It was suggested that constraints on time in the farm management system are encouraging people to take up minimum tillage. However, constraints on time in mixed systems can result in practices being dropped once focus needs to be on the animals. For example, the cyclical management demands of poultry.

It was mentioned that regional soil context has a heavy influence on which practices can be taken up. For example, in Scotland minimum tillage is not working well. This is the same for cover crops in Scotland due to the late harvest and weather related limitations. Some soils have a certain level of organic matter which is difficult to raise, meaning that a lack of change can discourage longer term farm management system implementation. Also the price of straw is increasing whilst wheat and potash is dropping, so the relative price is not favourable to growing or implementing cover crops.

### **10.6.2. Opportunities for implementation of soil carbon management practices in Scotland**

The initial discussion in the workshop centred on the terminology and the use of soil health as a more accessible and familiar concept rather than soil carbon. With this, the messages should be integrated into other programmes to increase awareness of soils whilst relating it to other fundamental elements and practices of the farm. For example, comparing soil management to the way farmers look after and provide for their livestock.

Individuals also felt that a central theme would be to alter financial incentives, which in part are encouraging contract farming. Change needs to be at the policy level to ensure that there is a conducive environment encouraging the implementation of long term perspectives, rather than the government

threat of right to buy for example. In part, participants felt that this could be related to improving resilience, so farmers feel secure to look to the longer term and absorb any shocks more efficiently. Demonstrating resilience with soil carbon management practices remains a challenge, however, participants were hopeful that projects such as the new monitor farm in Fife, Scotland may support this.

### **10.6.3. Motivations of farmer decisions in Scotland**

The main discussion points of the session explored if farmers would be interested in the selected soil carbon measures and what drove their decisions as to whether to adopt the measures or not. Participants felt the primary reason farmers would be interested in these measures, and the main factors driving the decision, is the desire to maximise their yield and be profitable. As participants stated: *“It’s about maximising profit, isn’t it?”* And: *“They want to maximise yield, year in and year out.”* Individuals suggested that farmers were willing to take risk, of disease for example, if it is proven the yield will be higher. *When you say to farmers, if you grow this variety there is less risk involved, you are asked, “what’s the yield?” If you say 15% below the higher yielding ones, they will say give me the higher yielding one.”* It was maintained that the main driver is economic. This was linked to input costs, where participants discussed that farmers may be willing to take a slight reduction in yield, if they are saving on fuel and labour costs as is the case with minimum tillage.

Participants mentioned that improving soil structure may also drive farmers’ decisions to implement soil carbon management practices. In particular from a Scottish perspective, showing farmers that soils with higher organic matter are easier to work and with improved drainage is a message farmers are more likely to listen to rather than to talk about minimum tillage. Communicating the benefits of practices in terms of soil structure and soil resilience, is advantageous, but it is critical to understand the local context.

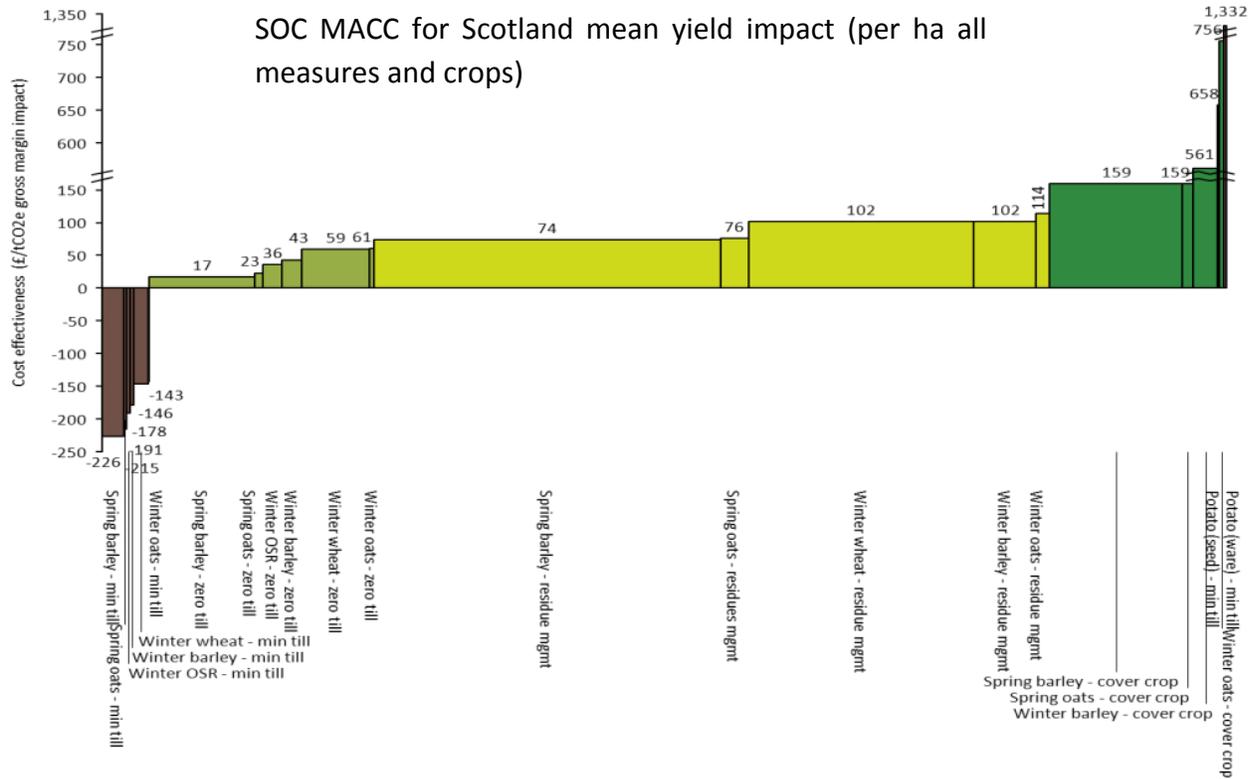
One of the recurrent issues discussed in the session was of regional variation and the context specificity of studies. The main concern of some individuals was that it is difficult to communicate the cost-effectiveness of the selected measures as knowledge and data is missing, and there is a high degree of regional variation in conditions and farm management practices. For example, conserving moisture in Scotland is not a large concern, whilst the incorporation of straw is an important management practice. In Scotland and Denmark the reason for minimum tillage is to allow good drainage. Whereas in Hungary or Poland minimum tillage is a popular practice in order to conserve soil moisture. It is important to understand that different practices will work for different soil types and conditions. For example, rotation is already popular in Scotland, but less so in East Anglia, which is linked to soil type.

Another central theme of the discussion was around the lack of data to prove and thus communicate cost-effectiveness. This is related to the complexity of carbon storage in crops, concern over accuracy of figures for different contexts and concern that if figures are produced they will be incorrectly interpreted in legislation. There is a requirement for an overall synthesis of research, to support cost-effective recommendations and the specific processes of carbon sequestration within the soil and crop. In this advisors, and the participants, can then support modifications for more sustainable practices.

#### **10.6.4. Summary of findings for Scotland**

Participants highlighted the main barrier at the farmer level as economic. Much of the discussion centred on the importance of profit to the farm business, with shorter term business perspectives negatively impacting sustainable soil management. Within this, individuals highlighted the need to alter these perspectives to enhance resilience of the business. However, demonstrating economic benefits over the longer term and integrating practices remain barriers, especially due to the rise in tenant farming and differences in regional soil context.

The results of the SOC MACC for Scotland (see Figure 10.5) identified the most promising cost-effective measures as being minimum tillage. However, as identified above this practice has some barriers associated with them that affect implementation.



SOC MACC for Scotland mean yield impact (best measure for each crop)

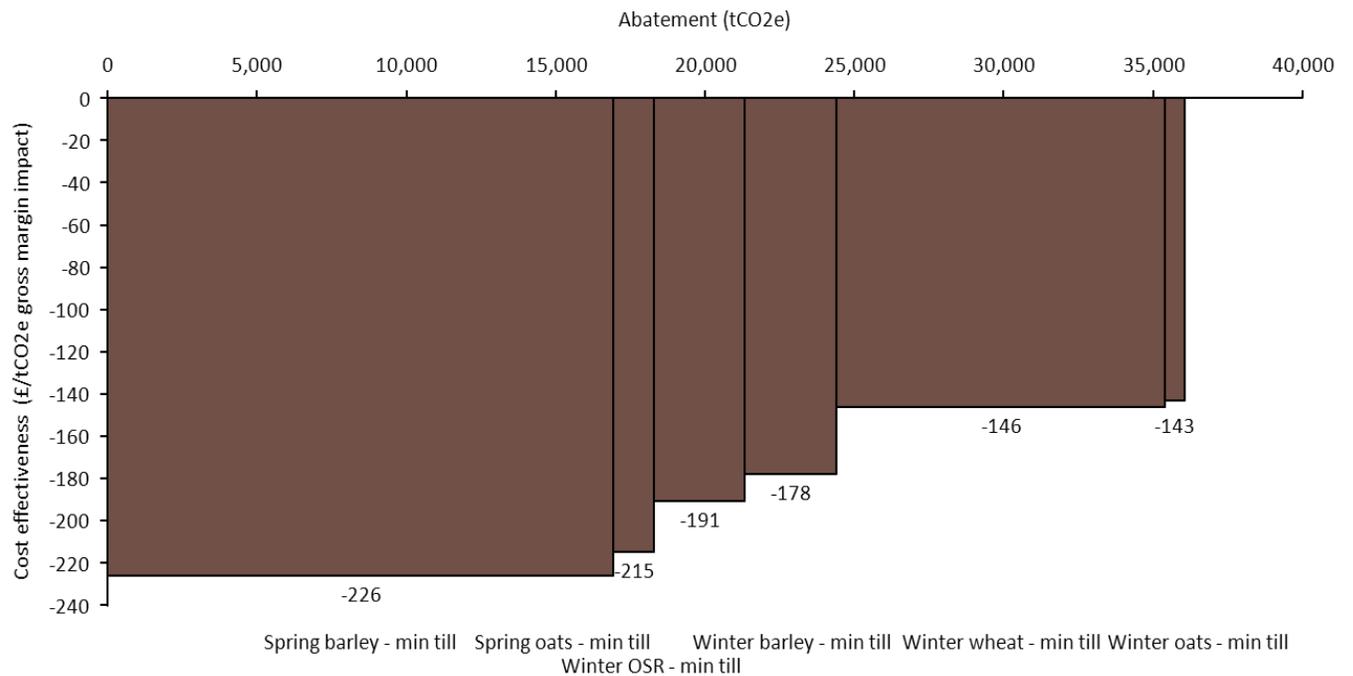


Figure 10.5 SOC MAC for South East Scotland

## 10.7. Andalusia, Spain

### 10.7.1. Barriers to implementation of soil carbon management practices

The main barriers to adopting the proposed soil carbon management practices in the case study and in Spain in general were identified by participants. The barriers are summarised for each practice in Table 10.11.

**Cover crops.** A potential barrier to the uptake of cover crops in rainfed systems in Spain is a concern about decreases in soil moisture and water and nutrient competition between the crops. Also this practice might increase costs due to the requirements for maintenance and management of the cover crop. As a social barrier, it was suggested that this practice currently has a low acceptance amongst farmers who would need to see it adopted more extensively in the surrounding areas before considering uptake. This reluctance highlights the need for farmer training adapted to regional conditions.

**Zero/minimum tillage.** Barriers to implementation suggested by participants related to concerns about additional costs for purchasing new machinery and the costs from additional weed control. It is particularly difficult for the small sized farms to absorb such costs and there are many smallholders in the region with less than 5 ha of olive groves. Also, as there is a strong tradition of conventional tillage practices in the region and an elderly farming population, there is low acceptance of these new practices, particularly as there is little evidence of other farmers in the surrounding farms adopting these practices.

**Residue management.** Potential barriers to adopting residue management related to concerns about additional costs for new equipment and increased labour costs as result of additional operations, such as removing and grinding crop residues. Currently, farmers practice stubble burning and therefore do not recognise the need for adopting such a practice. Also the demand for straw for animal feed means that residue management practices could result in income losses.

**Manure fertilisation.** Barriers identified in relation to this practice relate to the restrictive legislative requirements for manure management treatment and transportation. Also the amount of manure available is limited and sometimes transportation distances are long. Furthermore, there are concerns about increased costs from the operations required to apply and manage the manure. There is a low acceptance of this practice by farmers due to potential impacts on neighbouring farmers and issues with odour for farmers located near to urban or populated areas.

**Optimized fertilisation.** Barriers to uptake relate to the costs involved in introducing the practices. For example costs involved in new infrastructure, such as fertigation and monitoring systems, in addition to the costs of soil analysis. In general, farmers in the area are risk adverse in relation to fertiliser issues and therefore there is a need for training and capacity building.

**Crop rotation (with legumes)** This was not considered an appropriate practice in arid areas with precipitation of less than 400 mm/year. Economic barriers identified as potentially hampering uptake were concerns about increased costs due to more management and input requirements and the difficulties in selling legumes due to the lack of an existing market and competition with soybean imports. Cultural barriers also exist as the practice has been discredited in the past. Furthermore, there is uncertainty and a lack of experimental evidence on the N<sub>2</sub>O net emissions from growing legumes.

Table 10.11 Implementation barriers for the selected soil carbon management practices

<b>Practice</b>	<b>Technical, agronomic and environmental</b>	<b>Social</b>	<b>Economic, policy and legislative</b>	<b>The top 2 barriers</b>
Cover crop	In rainfed systems there is a risk of decrease in the soil moisture. Water and nutrients competition between crops. The required maintenance due to the practice implementation.	The low acceptance by the farmers. Farmers need to see the practice more extensively implemented in surrounding farms. Need for training adapted to regional conditions.	Increased costs due to requirements for the maintenance and the management.	Technical and social.
Zero tillage	Need of new machinery. Weed appearance and higher need for weed control. Small holding size.	The low acceptance by the farmers. Farmers need to see the practice more extensively implemented in surrounding farms. Conventional system is a strong tradition for farmers.	Increased direct costs by new machinery and additional spraying. In wet areas can be more expensive	Economic and social.
Minimum/conservation tillage	Need of new machinery. Weed appearance and higher need for weed control. Small holding size.	The low acceptance by the farmers. Farmers need to see the practice more extensively implemented in surrounding farms. Conventional system is a strong tradition for farmers.	Increased direct costs by new machinery and additional spraying. In wet areas can be more expensive	Economic and social.
Residue	Need of new	Farmers do not	Increased costs by	Technical

management	equipment and higher need for labour. The straw is extensively needed for animal feed.	recognize the utility and economic efficiency of the practice. The stubble burning seems to be an effortless practice for farmers.	additional farm operations (e.g. grinding crop, removing the residue). Income losses by not selling the straw for animal feed.	and economic.
Fertilization with animal manures	Requirements from manure management, treatment and transport. Low amount of manure available. Distance to farms with livestock.	The low acceptance by the farmers due to problems or impacts in neighbouring farms. Odours' problem in farms located near of urban or populated areas.	Increased direct costs by manure management. Lower yields in high productivity areas. Need to standardize the product.	Economic and technical.
Optimized fertilization	Infrastructure needs (e.g. fertigation systems, monitoring systems).	Need for training and capacity building for the farmers. The farmer is risk averse at fertilizer issues.	Soil analysis costs.	Technical and economic.
Crop rotations (with legumes)	In arid areas with precipitation less than 400mm/year is not recommended. Higher requirements in management and inputs application. Need of new varieties.	Need for training and capacity building for the farmers. Social discredit to the practice in the past. Lack of experimental evidence on the N <sub>2</sub> O net emissions from the legumes application.	Increased direct costs by more inputs application. Competition with soybean imports. Lack of market for some legume species.	Economic and technical.

### 10.7.2. Opportunities for implementation of soil carbon management practices

The opportunities to adopt the proposed soil carbon management practices in Spain were identified by participants and are summarised in Table 10.12.

Technical and agronomic opportunities relate to improved soil quality and soil water content, increased resilience through the use of cover crops, and zero and minimum tillage practices and increased system efficiency through the application of the other practices. One of the social and cultural opportunities reported was an increase in farm employment due to an increase in labour requirement for some practices (cover crops, residue management and organic manures), whilst an economic opportunity for zero and minimum tillage identified was cost reductions from reduced employment requirements. Other cost reductions due to lower fertiliser requirements were identified for residue management practices, organic manure application, optimized fertilization and crop rotation with legumes

Table 10.12 Implementation opportunities for the selected soil carbon management practices in Spain

Practice	Technical, agronomic and environmental	Social	Economic, policy and legislative	The top 2 opportunities
Cover crop	Erosion protection, leaching reduction and soil quality improvement. Soil water content increases under controlled management of the cultivation times. Improved vine vigour. Increased resilience.	Farm employment increase.	Rural development by farm employment increase. Avoiding costs by recovering degraded and highly eroded soils.	Technical and economic.
Zero tillage	Soil water content increases and soil quality improvement. Increases in the transfer of knowledge and new technology. Increased resilience.	GHG emissions reduction. Adoption gradually increasing.	Cost reductions from reduced labour requirements. Reduced uncertainty in yield variation.	Economic and technical.
Minimum/conservation tillage	Soil water content increases and soil quality improvement. Increases in the transfer of knowledge and technology. Increased resilience.	GHG emissions reduction. Significant evolution over conventional systems.	Cost reductions by labour needs decreases.	Economic and technical.
Residue	Increased system	Farm	Rural	Technical and

management	efficiency. Technology innovation promotion.	employment increase.	development by farm employment increase. Cost reductions by lower need of fertilizers.	economic.
Fertilization with animal manures	Increase the system efficiency. Inputs reductions (e.g. mineral fertilizers). Associated problems with mineral fertilization can be avoided (e.g. NH <sub>3</sub> volatilization, nitrate leaching). Increased manure monitoring and quantification.	Farm employment increase. A win-win solution to manage and use the livestock residue.	Cost reductions by lower need of mineral fertilizers.	Economic and social.
Optimized fertilization	Increase the system efficiency. Inputs reductions (e.g. nitrogen). Associated problems with mineral fertilization can be avoided (e.g. NH <sub>3</sub> volatilization, nitrate leaching).	Reductions in GHG emissions and health issues associated with reactive nitrogen. Increases on farmers' knowledge.	Cost reductions by lower need of mineral fertilizers.	Economic and technical.
Crop rotations (with legumes)	Increase use efficiency of nitrogen and water in the system.		Cost reductions by lower need of N fertilization.	Economic and technical.

### 10.7.3. Motivations for farmer decisions in the Andalusia region, Spain

Table 10.13 shows the ranking of farmers' motivations for decision making at the farm scale. The implementation of practices is mainly associated with economic determinants with the farmer adapting to market trends. Whilst farmers are motivated to save money by minimizing costs, their main concern is with maximising profits and yields.

Table 10.13 Ranking of motivations for farmers’ decisions to adopt practices at farm scale in Spain. (Ranking ranges from 1 to 5, whereby 1 indicates the highest motivation and 5 indicates the lowest).

Motivations	Cereals	Permanent crops
Profit/gross margin	1	1
Maximising yield	2	2
Reducing uncertainty (variation in yield)	3	4
Minimising costs (e.g. fertiliser, plant protection)	4	3
Resilience	5	5

There was a consensus amongst participants that although farmers are aware of the importance of maintaining soil quality, any positive actions are suppressed by annual strategies based on optimizing yields, higher prices and subsidy concerns. One advisor said *“So far the soil quality is not a farmer priority when making decisions, but it should be since the crop productivity and resilience lie in the quality of their soils”*.

#### 10.7.4. Summary of findings for Spain

The possible risk of water and nutrient competition was identified as an important agronomic barrier to implementing the practices of cover crops and crop rotations with legumes, especially in rain-fed systems and arid areas. However, under favourable conditions these practices may improve the system efficiency and the soil quality.

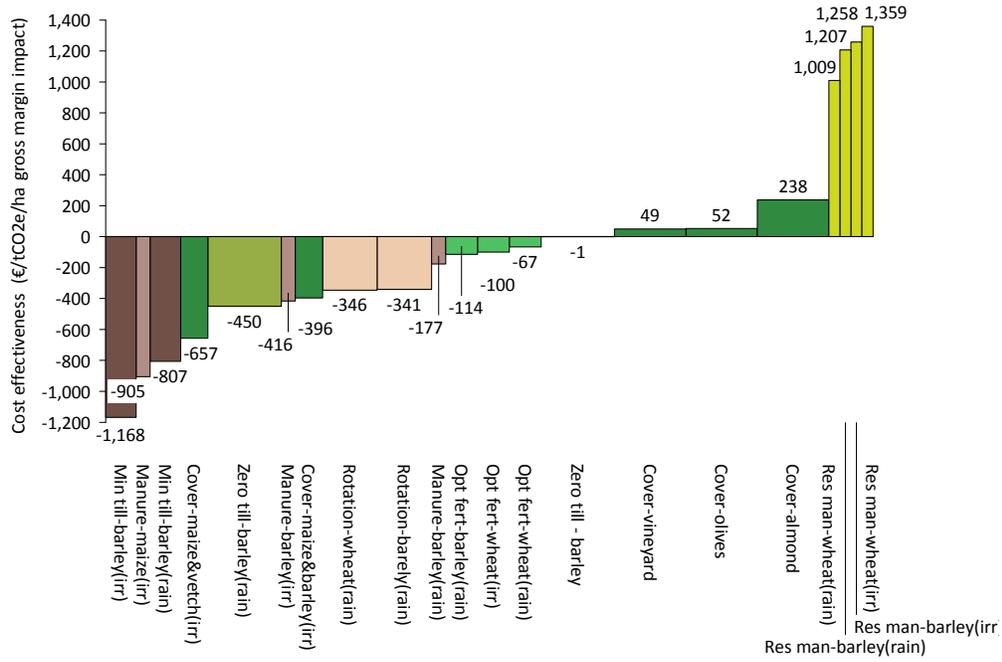
The common technical barrier for many of the soil carbon practices is the requirements for new machinery and infrastructure associated with implementing the new practice. Similarly, cost increases due to requirements for the maintenance and management of these new practices were considered common economic barriers to implementation. Improvements in the soil quality, the technology and farmer training in implementing these practices were identified as opportunities to increase productivity and to reduce costs through lower input requirements.

The main social barrier identified was the difficulty in changing farmers’ behaviour to a more holistic view about the soil carbon management and agricultural practices to mitigate GHG. The strong traditions of Spanish farmers make it difficult to change mind-sets, but farmer-farmer learning through practical demonstration may provide an opportunity to stimulate interest.

In summary, the barriers and opportunities most relevant to implementing these soil carbon management practices are social and economic. The most important motivation for the Spanish farmers to make a decision in their farm seems to be the profit or the gross margin achieved by the new activity more than the maintenance of soil quality.

None of the practices considered particularly stood out as providing a win-win opportunity in terms of delivering cost-effectiveness (according to the MACC) and being barrier free. The results of the SOC MACC (see Figure 10.6) identified the most promising cost-effective measures as being minimum tillage on barley (irrigated and rain fed), manure application on irrigated maize, cover crops with irrigated maize. However, as identified above all of these practices have some barriers associated with them that affect implementation.

### SOC MACC for Spain– mean yield impact (per ha all measures and crops)



### SOC MACC for Spain – mean yield impact (best measure for each crop)

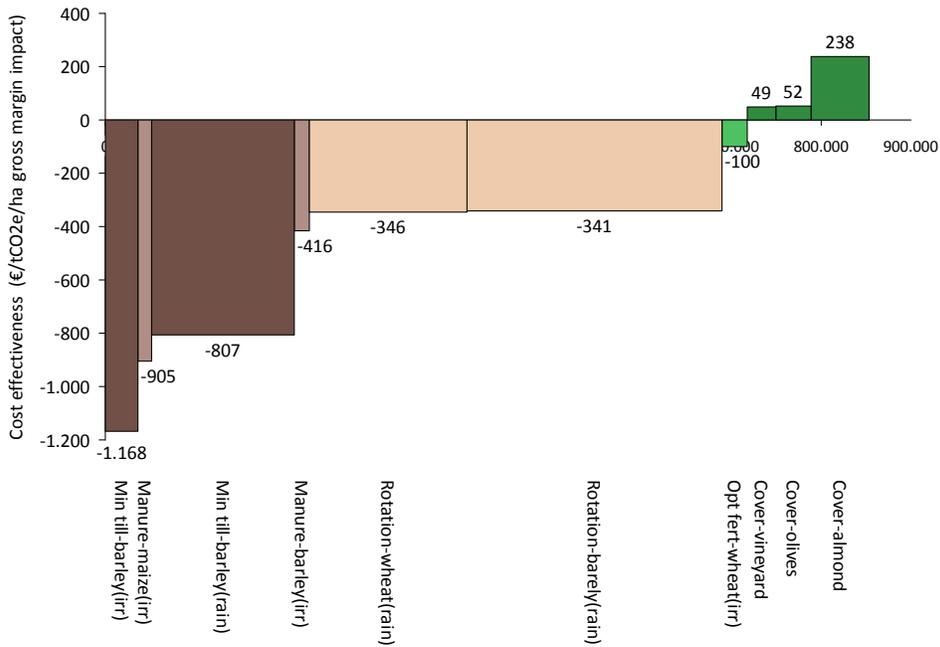


Figure 10.6 SOC MACCs for Spain

## **10.8. Summary - barriers and opportunities to implementation of cost effective soil carbon management practices**

It is acknowledged that due to limitations in case study data, some of the cost effectiveness assessments are quite rudimentary. Workshop discussion also highlighted the sensitivity of cost effectiveness, for example, to market prices. However, they do provide some indication of potential win-win practices - measures that offer soil carbon enhancement most cost effectively. It is apparent that practices assessed as cost effective (according to the MACC assessment) are subject to a number of technical/agronomic, economic/policy and social/cultural barriers and that different economic motivations drive economic decisions, suggesting that the MACC assessment needs to be refined.

The responses from this session of the workshops have highlighted the regional variations in the barriers and opportunities for the uptake of soil carbon management practices and the importance of understanding the context into which these practices are introduced. An example of such diversity is illustrated by responses to the uptake of residue management. In the Denmark and Poland case study regions residue management is common practice and considered a cost effective and barrier free practice. However, in Andalusia and Spain in general the burning of crop residues has preference over incorporating the residues into the soil and in some countries straw has a high economic value, for example local mushroom growers in Central Region, Hungary will pay well for straw and even bale it. Also the extent to which the costs and prices associated with a practice will fluctuate, changing with market demands, so for example, whilst crop residues may currently have little economic value in some countries, the increasing use of biodigesters means straw may start to have a value threatening its contribution to soil organic matter. The workshops have highlighted that the drivers of implementation are country and context specific and therefore it is important to approach any recommendations in this way.

Minimum tillage was another potential cost effective (win-win) practice identified in some regions, but again its application is context specific. In Zealand, Denmark it was considered an acceptable practice and uptake was increasing because it reduces labour costs. However, the costs of uptake were considered prohibitive in some countries with small sized farms, if new specialist machinery was required to implement the practice.

### **Barriers**

#### **Technical/agronomic barriers**

Regional climatic and environmental conditions can have an impact on the uptake of soil carbon management practices. For example, the cold climatic conditions in Denmark in general can make catch crop establishment difficult, similarly cover crops are difficult to establish in Scotland due to the late harvest and weather related limitations, whilst in Mazovia, Poland autumnal drought can impact on the sowing of catch crops. Whereas in arid conditions in Andalusia, Spain legumes, in crop rotations, do not grow well. The soil context can also influence which practices can be taken up. For example, in Scotland

minimum tillage is not working well due to the soil conditions and the sandy soils of Central Region, Hungary are not suitable for growing legumes.

Another common technical barrier mentioned was the requirement for investment in new machinery for some practices, which farmers are either unwilling or unable to bear. They are often unwilling to invest in new practices where they are uncertain about the results. Also smallholdings, in particular, which are predominate in the Italian, Polish and Spanish case study regions, may not be in a financial position to invest in new machinery.

### **Economic/policy barriers**

Concerns about income uncertainties from introducing the new soil carbon management practices were identified as a barrier to uptake by some regions. Farmers, particularly those who are risk adverse, are looking for more assurances about the income potential of these practices. Another barrier mentioned was the additional costs of operation and inputs for some practices, particularly for catch crops (Denmark, Italy, Poland, Spain case studies), but also in relation to minimum tillage (Hungary, Spain case studies), although in Zealand, Denmark and in Tuscany, Italy it was suggested that minimum tillage can reduce costs through lower labour requirements. Other barriers included: a lack of a market to sell products, this was particularly the case for legumes in the Hungary, Poland and Spain case studies; and restrictive legislation for manure application in the case studies in Hungary, Italy and Spain. Participants from most case study regions also ranked the lack of financial incentives or subsidies highly as a barrier to the uptake of soil carbon management practices. The subtleties of economic motivations for management decisions were also revealed. Profit/gross margin was ranked higher than maximising yield while resilience was ranked low in all workshops.

### **Social/cultural barrier**

A clear barrier mentioned in most regions was a lack of appropriate knowledge exchange and information available to farmers to explain the benefits of soil carbon management practices and to demonstrate these benefits through real-life examples. Also participants in some regions (in particular Hungary, Poland, Spain and Italy) felt hampered by a lack of a regional advisory services to deliver these messages. A further cultural barrier for some regions and particularly those dominated by an older farmer population was a reluctance to change and move away from their more traditional management practices to alternatives. Practice-specific social barriers identified were the aesthetic value of zero and minimum tillage with fields regarded as looking “messy” (Zealand, Denmark) and odour issues with manure application, affecting farm tourism activities and local populations (case studies in Italy and Spain).

### **Opportunities**

A number of opportunities to encourage the implementation of soil carbon management practices were identified. Dominant amongst these was the need to provide incentives to encourage uptake. These could take different forms, for example, subsidies to purchase necessary machinery or inclusion of these practices as part of AEM, or some sort of economic incentive related to GHG quota.

Opportunities should be taken to improve existing advisory provision and to establish real-life demonstrations of the practices in operation to demonstrate the economic benefits over the longer term and how these practices can be integrated into existing management systems. In particular it was suggested that advice needs to focus on identifying how practices can maximise profits and gross margins as this was identified in all countries as the main driver of farmer decision-making. Maximising profit did not always equate with increasing yield. In Mazovia, Poland, for example, farmers are not striving to maximise yields for fear of experiencing difficulties in selling the product.

Some of the workshops discussed the importance of profit to the farm business, with shorter term business perspectives negatively impacting sustainable soil management. Examples include: “land speculators” in Central Region, Hungary who aim to minimize investments/costs; farms in Scotland being let on contract farming agreements which exacerbates short term perspectives; small farmers in the case studies in Poland, Hungary and Spain (who are struggling to remain profitable or for whom the farm is not the main source income) who tend to react only to current market trends, rather than undertake long-term production planning. It was suggested that two of the main conditions that need to be met to ensure a long-term perspective to soil management is improving the economic prospects of farms and ensuring the presence of a stable agricultural policy.

With an increase in extreme weather as a result of climate change there might be an opportunity to promote the resilience benefits of soil carbon management practices, such as improving soil water capacity, to encourage long-term planning. However, the rankings produced for all regions suggested that resilience is not currently a driver of farmer decision-making.

## 11. Conclusions and next steps

A range of cropping systems and rotations were described both within and across the case study regions, attributed to diversity in biophysical conditions, farming system and to farm structural conditions. With respect to socio-economic drivers of farmers' cropping and rotation decisions, economic motivations are particularly strong. Macro drivers such as joining the CAP and urbanization also affect cropping and land use decisions. Olive production with intensive tillage in Spain was highlighted as being of particular risk to soil carbon, as was the cultivation of sandy low-humus soils in Mazovia, Poland. An oversimplified crop rotation (due to profit seeking behaviour of farmers) was identified as being a risk in Hungary. Some participants in Tuscany, Italy pointed out the difficulty in disassociating the risks to soil carbon from risks to soil as a whole, for example in dry, hilly landscapes soils are prone to erosion and water shortages.

Implementation of soil carbon management practices in the case study regions is strongly influenced by socio-economic factors. Some practices are considered uneconomic in some regions, for example, cover crops and legumes in Poland are unprofitable; crop residues are removed and sold off-farm to derive an income in some regions; a reduction in livestock numbers has led to reduced availability (and increased cost) of animal manure in Hungary. Farm tenure also plays an important role in management decisions. In regions where contractors and /or cooperatives manage the land this is thought to reduce the stewardship ethos. Also some tenure arrangements restrict long term cropping/practices planning. Farm size also drives management decisions, small scale farmers are thought to be less likely to implement soil carbon management practices than their larger counterparts because of their stronger motivation (and compulsion) to make a profit (livelihood). Cultural and traditional aspects, often associated with older and/or small scale farmers, also influence management decisions. Some policy measures have driven practice change, for example, catch crops are mandatory in Denmark, and nutrient management is a requirement within AEM in Hungary. However these measures come with restrictions, specifications and an administration burden that means they are unattractive to, or not followed by, some farmers, or in the case of Denmark, constrain the use of legumes (which are not accepted as catch crops).

Barriers to, and opportunities for, implementation of soil carbon management practices assessed as cost effective (according to the MACC assessment) are subject to a range of of technical/agronomic; economic/policy and social/cultural barriers. The regional variations in the barriers to, and opportunities for, the uptake of soil carbon management practices is illustrated by the range of approaches to (and economic value assigned to) residue management.

With respect to technical and agronomic barriers, regional climatic and environmental conditions such as droughty sandy soils or wet and cold conditions can have an impact on the uptake of soil carbon management practices –affecting specific crops (eg legumes) or systems (eg minimum tillage). Economic barriers such as the additional costs of operations and inputs for some practices (catch crops, minimum tillage) are apparent and limit adoption by small scale farmers. The subtleties of economic motivations for management decisions were also revealed. Profit/gross margin was ranked higher than maximising yield while resilience was ranked low in all workshops. Social and cultural barriers restrict the use of

some practices as well, there is a reluctance to move away from more traditional management practices to alternatives in regions dominated by an older farmer population. Also the lack of appropriate information or regional advisory services available to farmers to explain the benefits of soil carbon management practices was highlighted as a barrier.

A number of opportunities to encourage the implementation of soil carbon management practices were identified. Dominant amongst these was the need to provide incentives to encourage uptake. These could take different forms, for example, subsidies to purchase necessary machinery or inclusion of these practices as part of AEM, or some sort of economic incentive related to GHG quota, were suggested. An improved advisory service to support these was also proposed. In particular it was suggested that advice needs to focus on identifying how practices can maximise profits and gross margins as this was identified in all regions as the main driver of farmer decision-making. Maximising profit did not always equate with increasing yield.

The next steps in this consultation will be to feedback experiences with the MACC assessment to WP3 partners in the project so that the analysis can be refined. Further workshops will take place in 2015 to consult stakeholders about the SmartSOIL DST and toolbox, and to present refined cost effectiveness assessments.