EIP-AGRI Focus Group

Moving from source to sink in arable farming

FINAL REPORT

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1. Executive summary

Agriculture can significantly contribute to climate change mitigation by storing carbon in plants and soils. Worldwide, soil contains about three times as much organic carbon as plants and twice as much as the atmosphere. However, arable soils, especially in the most intense cropping regions have lost much of their soil carbon. The knowledge on management practices to store carbon in soils is widespread among farmers. Still, more information is needed on the time and resources required to adopt these practices, and their impact on soil carbon storage. The main question addressed by the Focus Group on "Moving from source to sink in arable farming" was '*Which cost-effective farm management practices and tools could foster and ensure long-lasting carbon storage in arable farming, contributing to climate change mitigation?*'

The Focus Group identified the following management practices that capture carbon in agricultural soils in the long term while improving soil quality:

- Keeping the soil covered, including intercropping, cover crops
- Crop rotations (including perennials)
- Agroforestry
- Adding organic amendments from local sources
- Reduced tillage techniques and precision farming
- Regulating irrigation water use

The 20 Focus Group experts, including farmers, researchers and advisers, discussed success and fail factors for the adoption of these practices, and their transferability to different conditions. Finally, they identified knowledge gaps and research needs with practical impact on the topic of the Focus Group.
The experts furthermore noted that a combination of several of these practices is likely to be more effective, and that the local climate would also influence their effectivity, so local testing and adapting of different combinations of practices would be useful. The Focus Group also considered that it is essential to increase awareness among farmers and consumers on the importance of capturing carbon, not just to mitigate climate change but also to increase soil health and fertility. Increased soil carbon will also insure farmers for risks of crop failures because their soils will be better adapted to environmental and climate change.

Long-term experiments are very valuable to determine the impact of different management practices, on soil carbon. Unfortunately, they are rare and not present in all farming regions and for all management practices. Therefore, the Focus Group identified possible soil carbon indicators that can be used to assess the impact of agriculture practices also on a shorter time scale. Advances in remote sensing may open opportunities to develop smart farming technologies that offer possibilities to monitor soil conditions and further raise awareness on the impact of agriculture practices on soil carbon.

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2. Introduction

Agriculture can significantly contribute to climate change mitigation by reducing greenhouse gas emissions and by storing carbon in plants and soils. Globally, soil contains about three times as much organic carbon as plants and twice as much as the atmosphere. Thus there is a large potential for storing carbon in agricultural soils and mitigating climate change. However, arable soils, especially in the most intense cropping regions have lost much of their soil carbon. Monitoring activities by the European Commission have found that soil carbon has been depleted in many agricultural soils across Europe (1). Furthermore, 50% of EU arable soils are regarded as low in soil carbon and more than 10 million ha are subject to erosion (2).

The capacity of soils to store carbon depends on a wide range of soil factors that can be improved by appropriate management techniques. There is great scope for involving farmers when it is possible to show the positive co-benefits that management can have on several factors. Some examples are: promoting soil carbon sequestration in connection with higher yields, improved soil structure, less fertiliser use through retention of nutrients, reduced soil bulk density, improved water holding capacity and higher biological activity, and last but not least, the resulting long-term higher profits (3). Even though there is knowledge available on how to manage agricultural soils and promote soil carbon, there are still barriers to overcome when it comes to implementing good practices. The know-how among farmers is widespread and awareness on soil carbon in agriculture is growing, but the full values of soil carbon and the investment in time and resources are not yet fully understood and documented.

This report presents the results of the EIP-AGRI Focus Group on 'Moving from source to sink in arable farming'. It includes good practices to improve carbon storage in arable farming as well as barriers for implementation. It also highlights the values of soil carbon, and proposes ideas for innovative projects and further research.

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3. Brief description of the process

3.1 Aims of the Focus Group

The aim of the Focus Group was to determine how arable soils can be turned from source to sink. The main question for the group was "*Which cost-effective farm management practices and tools could foster and ensure long-lasting carbon storage in arable farming, contributing to climate change mitigation?"*

To answer the question, the following tasks were addressed by the Focus Group:
- **Take stock of the current practices and tools,** which could foster long-lasting carbon storage in soils and improve soil quality in the different geographical and climatic conditions of the EU. Identify challenges and opportunities for implementing these practices.
- **Collect good practices and success stories** from different European areas, especially focusing on farmers' and advisers' experiences.
- **Compare different management practices** while taking account to the feasibility and cost-effectiveness at farm level.
- **Identify success factors** (such as knowledge requirements, partnerships) **and technical/economic/social barriers, or fail factors**, concerning the adoption of practices fostering carbon storage in arable farming.
- **Discuss how these practices may be transferred to other conditions** (location, type of production).
- **Suggest innovative solutions and provide ideas** for EIP-AGRI Operational Groups and other innovative projects.
- **Take stock of the state of play of research. Identify needs from practice and possible gaps in knowledge** concerning carbon storage capacity in arable farming that may be solved by further research.

3.2 The process

Most of the work of the Focus Group was carried out during two meetings attended by the experts, which were held between Nov 2017 and June 2018. The first meeting was held in Alicante, Spain, on 29-30 November 2017 and the second in Tulln, Austria, on 13-14 June 2018. The experts also produced a series of mini-papers on different topics that help answer the Focus Group's main question (see list of mini-papers Annex Table b). A starting paper with an overview of current knowledge on soil carbon management and results of a survey among the Focus Group experts before the first meeting, provided a basis for the Focus Group's work.

At the first meeting, the Focus Group identified a number of management methods that are important for promoting soil carbon in crop production and listed possible agronomic advantages and disadvantages of these methods (see tables Annex Table d). Members of the Focus Group also presented examples of management that they have applied on their own farms or that they have seen as good practices on farms in their region. These examples included: the use of cover crops, reduced tillage in organic farming, new crops with deep root systems, novel amendments and machinery.

At the second meeting, the Focus Group experts presented the work that they had carried out on the mini-papers and discussed how to finalise these papers. They also focused on identifying success and fail factors, the needs for research and ideas for Operational Groups.

In Austria the Focus Group visited the farm of one of the Focus Group experts, Alfred Grand. He showed how he, as an organic farmer, uses cover crops in combination with no till methods. Representatives from two local Operational Groups met with the Focus Group and presented their projects testing different reduced tillage practices and cover crop rotations, as well as management practices to avoid losses of soil carbon and nitrogen, and to better manage weeds and pests.

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4. State of play

4.1 Framing key issues

The Focus Group identified a set of issues which need to be addressed to improve soil organic carbon in arable farming. First, two cross-cutting issues with the best practices were identified: (i) awareness on the importance of soil carbon in farm management and (ii) the availability of tools to assess organic carbon content in soils. Both are important to be able to change decisions on practices and to implement them in the future. Secondly, a set of good practices were selected and described below.

Awareness on soil carbon in farm management

The awareness on the value of carbon can contribute to adoption of practices that will increase soil carbon in agriculture (see table 1 for examples). The Focus Group considered that the most important stakeholders to target were farmers, landowners and their extension services, farmers' organisations and enterprises. As soil carbon is linked to climate change, there is an increasing interest in finding ways to ensure that agriculture can help to mitigate climate change, rather than contribute to it. A number of organisations have developed web-based information that can be used to raise awareness on the topic for a range of different people – from school children to farmers.

Table 1: Examples of open access resources to enhance awareness on soils and soil carbon

Initiative (Organisation)	Stakeholder and scale	Web link
4 per mille initiative (UNCCC)	Decision makers globally	https://www.4p1000.org
Global soil partnership (FAO)	Decision makers globally	http://www.fao.org/global-soil-partnership/en/
European Soil Partnership (FAO)	Decision makers - Europe	http://www.fao.org/global-soil-partnership/regional-partnerships/europe/en/
World soil day (UN)	Decision makers globally	http://www.un.org/en/events/soilday/
EU soil data centre (JRC.EU)	Decision makers and researchers in Europe	https://esdac.jrc.ec.europa.eu
Soils awareness examples (Links 4soils project)	Land use stakeholders globally	https://alpinesoils.eu/soil-awareness/
Learning and teaching resources (Virtual Soil Science Learning Resources)	Land use stakeholders globally	https://soilweb.ca/raising-awareness/

Training advisory services in the regions can help to raise awareness on soil carbon among advisers and farmers. The benefits of soil carbon on fertility and soil quality can also have financial advantages for farmers. Reductions in costs or financial incentives can help to promote implementation of management practices that increase soil carbon. Values of soil carbon sequestration in arable land are important for estimates of the cost efficiency of the practices that can determine the values of the soil fertility or the soil natural capital which can give future profits for the farmer (4). The soil carbon can also help to reduce yield variability caused by too little or too much water and will serve as an insurance for more stable yields (5).

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Carbon sequestration in soils can be valued as a common good contributing to climate change mitigation. Farmers could be paid for this through global carbon credits for example. Consumer awareness on the value of soil carbon and the impact of food production on soil carbon is still limited. It takes a long time to build up soil carbon, and therefore this may deter farmers from investing in this process. So there is a need for educational activities linked to local-level mitigation activities to sequester carbon.

Tools to assess soil C

The organic C content for a field is usually given as a stock in tonnes (Mg) of carbon per hectare or as a concentration of grams of carbon per kilogram of soil. Reliable estimates of changes in C storage are only possible by repeated measurements over long periods (> 10 years), as changes in C are small compared to the C storage and the variability of the parameters required to calculate the C storage is high (6). Long-term experiments are very valuable as they can provide evidence on the effect of management on soil carbon. Unfortunately, these experiments are rare and not carried out in all farming regions and for all management practices. Indicators for changes in soil C are useful to advise farmers on the effects of different management options, and they can encourage the acceptance of improved soil management practices by already showing trends in soil carbon in the short term.

The indicators can be **model-based**, **evidence-based** or **field-based**:

1) **Model-based indicators** reflect the changes in C storage under a given agricultural management practice over a long time period. Regional examples are:
   - Simeos-AMG (France): www.simeos-amg.org (7)
   - Demeter tool (Belgium): https://www.vlm.be/nl/projecten/Europeseprojecten/Demeter/Demetertool
   - SOM-calculator (Ohio, USA): https://southcenters.osu.edu/soil-water-bioenergy/extention/som-soil-organic-matter-calculator
   - Humusbilanz (Swizerland): https://www.humusbilanz.ch/
   - Humusbilanz VDLUFA (Germany): https://www.lfl.bayern.de/iab/boden/031164/index.php.
   - Cool Farm (global alliance): https://coolfarmtool.org/
   - C-bank (Scania, Sweden) http://c-bank.lu.se
   - UK farm tool (UK): http://www.farmcarbontoolkit.org.uk/

2) **Evidence-based indicators** are sensitive to soil carbon changes and reflect conditions for biological functioning of the soil. Examples are:
   - A soil fractionation scheme giving a ratio between coarse and fine fraction of soil which indicates soil carbon over time (8).
   - Measuring microbial biomass, analysing potential N and C mineralisation or enzymatic activities used as biological indicators.

3) **Field-based indicators** can integrate management and biological processes and be assessed and be used at field demonstrations.
   - Indirect methods for soil carbon storage assessment are visual soil examination and evaluation techniques including field-based estimations of soil structure: https://www.teagasc.ie/environment/soil/research/square/visual-soil-examination-and-evaluation/.
   - Monitoring soil carbon using agricultural machinery or remote sensing (i.e. from UAVs or satellites) (9).

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4.2 Good practices

Soil carbon levels are an outcome of the atmospheric carbon converted into **plant biomass** and **soil organisms** on the one hand and losses through decomposition processes on the other. This is controlled by the plant carbon and interactions between microorganisms (fungi and bacteria), ecosystem engineers (roots, earthworms, termites, ants) and the soil mineral matrix. Thus, it is a complex system of interactions among living soil organisms which is influenced by their diversity, abundance and abiotic factors.

There is scientific evidence on how to preserve soil carbon from long-term agricultural experiments conducted across the world, and in some cases these experiments have been running for over a 100 years (10). A number of management practices are particularly important for soil organic carbon: tillage, organic or crop residue amendments, fertiliser types and rates, and crop rotation schemes. At an EU level there is an EMAS (EU Eco-Management and Audit Scheme) outlining best practices across Europe (11). The EU also has regulating frameworks setting minimum standards of practices in the CAP (Common Agricultural Policy) such as the good agricultural and environmental conditions[1].

Good practices to preserve carbon in arable farming may be evaluated based on their impact on soil quality in terms of fertility and yield. However, when identifying the key management practices, the economic and environmental aspects are important and also need to be evaluated. The Focus Group summarised a number of aspects for the following good practices: keeping the soil covered, returning biomass to the soil, and reduced tillage.

Keeping the soil covered: cover crops, winter crops and intercropping

When the soil is constantly covered with **perennial crops** and **inter-crops** or **cover-crops**, soil carbon can increase more than under annual crops alone since they allocate a larger portion of C into roots and root exudates and thus provide more soil carbon through roots than from harvest residues (12). The above ground plant parts sequester carbon but **roots** are equally important in producing soil carbon (13). There is an increasing interest in cover crops among farmers and the trade-off with weed management is a common barrier to implementation in farming. Ongoing long-term experiments on crop rotations with perennial plants show evidence that a covered soil surface has great impact on soil carbon, and for shorter term predictions models of soil carbon can help to estimate impact of cover crops (14).

Agroforestry is a practice that can be considered as an intercropping system with perennial plants and can provide carbon to the sub soil layers. Maeght, Rewald and Pierret (15) demonstrated that root-derived C from trees can be considered as long-term carbon pools which provide several other ecosystem functions to the farming system.

[1] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Good_agricultural_and_environmental_conditions_%28GAEC%29

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In Europe there is still a high proportion of farms that have bare soil during the winter (Fig 1).

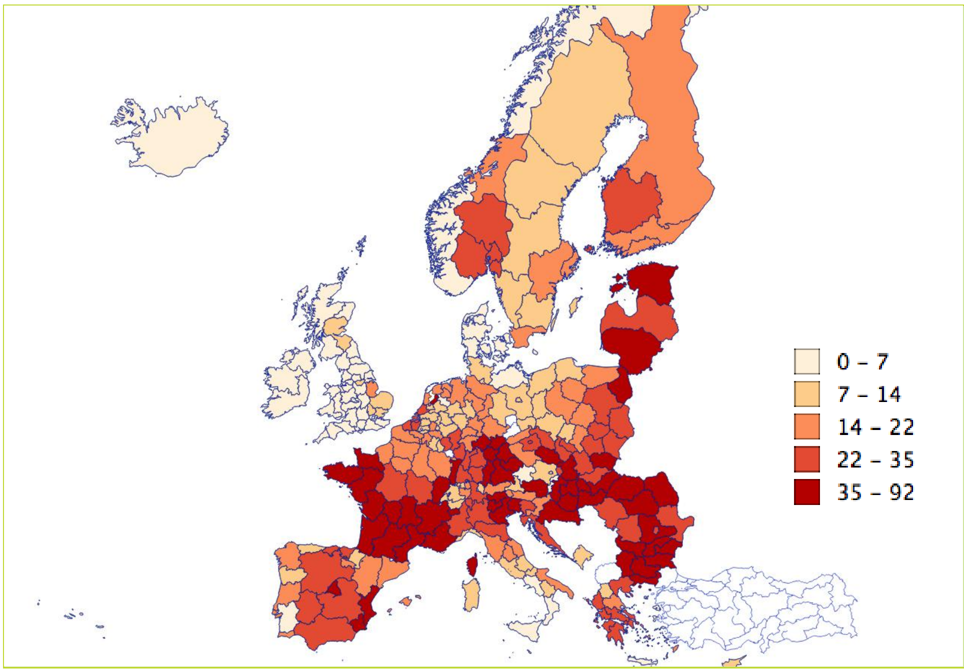

Figure 1 Proportion of bare soil on arable land (area %), 2010 (Eurostat, Nuts 2 level, ef_pmsoilaa)

Return of locally produced biomass: organic amendments

Practices based on amendments can be either to retain the **crop residues or cover crops** and to incorporate these into the soil, or to use organic material that is not produced on the field, such as manure (discussed below), recycled material from **household compost** or **sewage sludge**. Long-term effects on soil carbon from crop residues is highly variable and has often shown non-significant effects with the exception of severely eroded soils (16, 17). In a long-term experiment in Denmark, annual application of straw only showed a significant increase in soil carbon when 12 tons/ha of barley straw was added to the soils, which corresponded to twice the amount of what the field actually produced (18). However, if crop residues are not returned to the soil, this can induce a decrease in the soil carbon stock.

The effect of organic amendments which are not produced on the field, is dependent on the carbon content, stability of the amendment and the dose applied. Amendments of organic residues such as sewage sludge have doubled the soil carbon in 20 years in an experiment in Sweden (19). However, concerns about other environmental effects such as residues of pharmaceuticals and heavy metals have influenced the use and regulations of sewage in Europe.

Applications of **animal manure** are generally regarded as positive for soil carbon but when given in very high amounts, the leaching of nutrients may cause problems like eutrophication of ground and surface water. Pig slurry is a common form of manure but it contains less organic matter than cattle slurry. As many factors determine manure nutrient and organic matter content, a large variability also exists within one manure type (20). The effect on soil carbon sequestration of manure is higher when the dry-matter content is higher. Thus, solid manure is more effective than slurry, but to reduce the risk of N and P pollution, the nutrient content of the manure should be taken into account, balancing this with the crops' demand over time.

Biochar is a product of heating organic biomass in low oxygen conditions (21). It is a charcoal-like product with carbon contents ranging from 50-95% by weight. The long-term stability mainly depends on the feedstocks and process conditions, but biochar usually consists of large stable fractions of organic compounds (22). Biochar is a recent amendment to soil and has received large interest and will increase soil carbon, but the effects on soil quality are still being debated (23).

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Conservation agriculture: reduced tillage

Practices such as the ones mentioned above are rarely used one by one in a real farming situation but combined, such as in conservation agriculture. The concept of conservation agriculture was introduced by FAO and is based on three core principles: minimal soil disturbance, permanent soil cover by crops and crop residues and diversified crop rotations and species diversity. The practice has its origin in soil and water conservation, which was developed in the 1940s in response to drought and soil erosion in the USA and led to an increased demand and interest in conservation agriculture systems and the gradual replacement of ploughing by reduced tillage.

Tillage has been suggested as one of the major management practices that may influence carbon sequestration, for instance there is evidence of C-loss due to ploughing (24). A recent systematic review of 300 studies shows that reduced and no tillage practices can sequester more carbon (both as stocks and concentrations) than conventional tillage in the upper soil layer (25). No significant effects of reduced tillage on changes of the carbon stocks in the layers down to 60 cm were shown, similar to the effects measured in another study (26). To increase soil carbon stocks, reduced tillage generally needs to be combined with biomass restitution and the use of cover crops. An additional benefit of conservation agriculture is the reduced fuel costs by reducing tillage.

4.3 Success and fail factors

For each good practice discussed above, the Focus Group identified the following success and fail factors for applying the practices.

Keeping the soil covered: cover crops, winter crops and intercropping

Legumes are often used for **intercropping** with other crops and they can be harvested as a single crop or in association with cereals (e.g. pea/wheat, lupine/triticale, pea/oat, lentils/wheat). Legumes are efficient in releasing carbon compounds from their roots which then triggers intense biological activity, creates biomass and will fix nitrogen from the air (27). When not harvested, legumes can be used as associated cover crops or nitrogen-fixing intermediate crops. The main challenge for intercropped legume cover plants concerns the destruction of the plants before mulching, and competition for nutrients and water. The use of oilseed rape with Faba beans or a mixture of frost-sensitive cover plants is a practice in France and in the UK, which may prevent difficulties in mechanical termination of the companion crops (28) .

It is important to understand the effects of plant diversity and root exudates in order to identify best practices of cropping systems for long term carbon storage in plant biomass and soils. **Plant breeding** programmes of new varieties promoting more living biomass, and especially roots, should be encouraged. **Agroforestry**, where roots of trees are present deeper down in the soil will provide additional soil carbon as determined in several long-term trials (29).

Factors limiting the use of cover crops include costs for handling crops which are not harvested and the complex management that may be needed. There are, however, environmental incentives to use catch crops in order to reduce losses of nitrogen and prevent erosion. In fact it may be possible to combine the functions of covering the soil and catching nutrients while promoting soil carbon in this way (30).

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Success stories
Local farmers in dry climates with a wide knowledge of their soils and climate conditions have developed an innovative win-win strategy to ensure continuous soil cover and optimise the storage of soil C under rainfed conditions. Farmers in Italy and Spain have developed reduced tillage systems, maximising soil cover and reducing the bare soil period as much as possible, while maintaining farm profits. Cover crop mixtures are inter-sown in double cropping systems or after the harvest of the main crop and terminated mechanically or chemically immediately before the following crop ensuring a continuous soil cover all year round and diversifying the quality of the residues returned to the soil.

In **Piedmont**, NW of Italy, a farmer applying continuous no-till on 80 ha is under-sowing a mix of winter cover crops (legumes, grasses, Cruciferae) within a summer crop of soybean or buckwheat. The cover crops are terminated chemically before the following spring crop. The continuous soil cover and diversification of crop residues led to higher soil carbon stock and higher soil biological and chemical fertility compared to soils in the surroundings, which were tilled with annual crops only.

In **Tuscany**, Central Italy, a farmer in Cenaia (close to Pisa) has been experimenting since 2008 with direct seeding of spring crops (i.e. sunflower and sorghum wheat or maize) on the mulch provided by a winter vetch cover crop, established by minimum tillage and terminated by roller crimper or by herbicide applications. Other crops in the 6-yr sequence are durum wheat and oilseed rape, depending on soil type. Compared to the standard system (i.e. same crop rotation, annual ploughing and no cover crops), the farmer reported an increase of 13% in soil carbon in the first 30 cm of depth in only five years[2]. There could be an environmental trade-off here if herbicides are used to promote soil carbon in case the roller crimper is not sufficient to terminate the cover crop.

In two different regions of Spain (i.e. **Garinoain-Navarra** and **Perdiguera-Aragona**), farmers have used no-till for the past 15-20 years. They have combined this practice with mixtures of legumes and non-legume crops or summer cover plants (i.e. sorghum or spontaneous weeds as *Salsola kali* or *Kochia scoparia*) that are chemically killed just before seeding the main crops. The farmers reported the same cash crop productivity as the standard average of their respective areas but with an evident increase in soil carbon content (+0.2% in topsoil after only 6 months for a farm in Navarra, and values between 0.9 and 1.75%, substantially higher than the average of the Aragon region).

Return of locally produced biomass: organic amendments

The **barriers** for the use of organic soil amendments and local biomass depend on the type of amendment/biomass and the region. Frequently mentioned factors are potential pollution with heavy metals, weed seeds and antibiotics, non-continuous supply, competition of biomass with other uses (such as bio-energy production encouraged by subsidies), acceptability by citizens (smell, extra traffic for transport) and regional separation of cattle breeding and crop production and the associated costs for processing and transport of animal manure. The use of (processed) organic materials/residues as soil amendment is subject to a range of European and national **legislation**, such as the Water Framework and Nitrates Directives, the Fertiliser regulation, the Waste Framework Directive and Industrial Emissions Directive. This legislation prevents misuse and contamination of the environment (e.g., eutrophication of surface waters and contamination of soils by heavy metals), but it may also hamper local recycling of organic materials due to the heavy and costly administrative burden. The use of sewage sludge is regulated under European legislation in order to avoid negative environmental effects such as the accumulation of toxic elements such as heavy metals and pharmaceuticals.

2 https://www.youtube.com/watch?time_continue=6&v=qPDyK48CZkI

Farm surveys in arable (cereal) regions in the Centre and South of Italy and two regions (arable and mixed vegetables/pig farms) in Belgium revealed that farmers are well aware of the advantages of farm yard manure for soil quality and fertility, including increasing soil carbon (31). Major barriers are: the availability of farm yard manure in the neighbourhood, costs for transport and spreading, the availability of slurry – resulting in farmers using this rather than better products such as farmyard manure- , the strict manure legislation and less predictable availability of mineral N for the crop compared to mineral fertilisers. A survey in Belgium (Flanders) showed that farmers recognise that compost applications have beneficial effects on soils, such as improved soil quality, higher soil biodiversity, lower erosion risk, better water infiltration and drainage, increased humus content, improved soil structure and increased nitrogen mineralisation potential (32). However, the adoption rates were very low, i.e., no mixed farmers and only 7% of arable farmers, due to barriers such as shortage of compost material, animal slurry surplus, complex regulations and lack of experience.

Success stories

The **Biogasdoneright™ system** recently proposed in Italy is an example of multifunctional and sustainable agriculture based on year-round cultivated soil, efficient recycling of organic matter and nutrients and conservation tillage practices (33). Farmers grow feedstocks for biogas via on-farm anaerobic digestion and part of that carbon is recycled (by digestate) and accumulates in the soil in stable forms. The system is being applied in a dairy farm in the Po valley (Palazzetto farm, Cremona, Italy), transitioning from a conventional agricultural system, mainly based on maize monocropping (soil covered 6 months per year, above ground biomass of 20 t dry matter ha^{-1} yr^{-1}), to a sequential cropping system (two crops per year, up to 30 t dry matter ha^{-1} yr^{-1}). Digestate recycling to the farmland results in an increased rate of organic matter input when compared to the conventional system (34). The soil organic carbon increased with 0.5 to 1.0 t C ha^{-1} in the first years of Biogasdoneright application.

Local biomass hubs examples exist in Europe. For example, in France, since the year 2000, a collective composting of green waste on the farm is organised in a Mediterranean area (Sommières, Gard area).

Conservation agriculture: reduced tillage

Tillage practices are commonly used to improve seeding conditions and decrease the impact of weeds. Although tillage loosens the soil, it also causes soil compaction below the plough depth ((34). Reduced tillage generally needs to be combined with other practices, such as keeping the soil covered by plants or the use of organic amendments, in order to have a positive impact on farm productivity (35). Reduced tillage can help control erosion and improve the efficiency of the use of water and fertilisers.

Reduced-tillage has not been widely established in organic cereal cropping systems as mechanical weed control is the main method to reduce weeds. The Rodale Institute in Pennsylvania (USA) developed the Roller-Crimper method, which makes it possible to practice no-till cropping in organic farming. This method is currently being tested under different climate conditions and crop rotations (36).

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Success stories

Austria: Alfred Grand has an organic arable farm in Austria near Vienna where he stopped ploughing 25 years ago. In 2006 he converted the farm to organic cultivation. Since 2016, trials have been carried out on his farm to adapt the Rodale Institute's Roller Crimper method to no-till in organic farming (see this video[3]). An overwintering rye cover crop is rolled and crimped in spring and at the same time the cash crop seed is placed below the resulting mulch into the soil. The method has shown significant and promising results with maize and soybean. If successful, no mechanical weed management is needed and it will significantly contribute to storing carbon in the soil.

Italy: The LIFE HelpSoil project developed and promoted conservation agriculture in Italy through a network of 20 demonstration farms that were monitored from 2014 to 2017 (www.lifehelpsoil.eu). Among these, for example, Ruozzi farm in the Emilia-Romagna region, which started its first experience of conservation tillage with LIFE HelpSoil, decided to convert almost all of its land (25 hectares) to no till at the end of the project. This farm now implements a typical rotation of the Parmigiano-Reggiano cheese agricultural system, with alfalfa for 4 years followed by wheat-maize-barley and again alfalfa, only with sod seeding and a few herbicide treatments, with good results. Fertilisation is based on cattle slurry distributed with innovative equipment to reduce both soil disturbance and ammonia emissions in air (shallow injection with trailing shoe).

Poland: Grzegorz Ożga from Tarnawa (gmina Żarów, dolnośląskie voivodship, Poland) is one of the pioneers in no-till cultivation in Poland. Since 1999, he has been using no-till cultivation techniques, and this has enhanced soil life in his fields considerably, and improved the farm's economic efficiency. According to the farmer, the key to a successful introduction of the no-till technique is a good rotation system, appropriate catch-crops and the incorporation of straw and other crop residues. Results were a soil carbon increase of 1,5% to 3,5%.

3 https://www.facebook.com/rodaleinstitute/videos/10154149211192233/

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5. What can we do? Recommendations

5.1 Raising awareness on benefits of soil carbon in agriculture

The Focus Group experts pointed out that raising awareness on the benefits of soil carbon is very important, and that this could also help to inform on its economic value and even to translate this into business models. They also considered that it may also be useful to develop more incentives and schemes for promoting soil organic carbon in agriculture. Increased soil carbon will not only mitigate climate change but also insure farmers for risks of crop failures because their soils will be better adapted to environmental and climate change.

The following activities, involving farmers, advisers, agricultural education and communication professionals, may help to raise awareness:

- Create material for farmers on benefits of increasing C in the soil.
- Create web portals with information on open-access material
- Include awareness and knowledge of soil carbon in advisory businesses.
- Show case pioneer farmers as inspiration and learning for other farmers
- Initiate local networks for knowledge sharing and learning.

5.2 Management suggestions

Conservation agriculture

It is widely understood that soil carbon is better preserved when the soil is disturbed as little as possible and covered as much as possible. In conservation agriculture with reduced tillage and diverse crop rotations, soil organic carbon is enhanced. This can have a positive impact on soil organisms that further promote soil fertility and multiple benefits such as water retention, infiltration and nutrient retention (37). For farmers, diversifying crop rotations is an important tool to both reduce diseases and weeds but also to promote soil carbon. Perennial grass leys can provide soil carbon through the grass roots and through the promotion of the soil organisms that are boosted by this.

Reduced tillage can allow farmers to manage their land with reduced energy inputs and at the same time it is an effective erosion control measure. The effect of reduced tillage on yields depends on many other circumstances and in some cases where the yields are lower, this may be compensated by the reduction in fuel and labour costs. A sustainable and well performing conservation agriculture system may be implemented through a peer-to-peer knowledge transfer, led by pioneer farmers. For conservation agriculture, reduced tillage and other farm management practices to increase soil carbon, a long-term time frame is required to achieve an improved soil structure and soil carbon stocks.

Organic amendments

Applying organic amendments is another tool farmers can use to increase soil organic carbon in arable soils. However, not all organic amendments are equally stable and, as a consequence, do not contribute as much to longer term carbon sequestration as others. Moreover, the emission of other greenhouse gases such as N_2O and CH_4 during storage, processing and after soil application should also be taken into account. Sludge can be treated in different ways to address food safety factors, and there are different processes to convert it into biosolids, such as by anaerobic digestion, dewatering and composting. Sewage sludge composted with wheat straw resulted in higher soil organic carbon content at equal carbon input than dewatered or liquid sludge in an Italian long-term field experiment (38).

How much carbon can be sequestered per ton of amendment added to the soil? Results from long-term field experiments show that plant-based compost on average retains 0.26 ton C per ton amendment applied, cattle manure 0.20 ton C per ton manure (39, 40), while composted sludge provide 0.20 ton C per ton C added (38).

Intercropping

Among the diversity of agricultural systems, intercropping, the simultaneous cultivation of multiple crop species and intermediate crops may:

- **Increase the capture and storage of organic C in the soil** by increasing crop biomass per unit area and soil carbon supply through root exudates. In addition, the C captured in the plants above the ground may also partly turn into soil carbon if the crop residues are returned to the soil in the same field or other parts of the farm.
- **Reduce the impact of water run-off on the soil surface by improving the structural stability of the soil** –which reduces the loss of soil organic carbon and soil erosion.

Long-term organic matter stabilisation is controlled by interactions between soil organisms and the soil mineral matrix. Thus, to enhance the effects of intercropping and mixed cropping on soil carbon, it is of paramount importance to sustain the activity and long-lasting presence of microbial communities in the rhizosphere. This can be achieved by including legume crops and perennial species in crop rotations, presence of tree rows in field margins or even within fields (i.e. in agroforestry systems). The legumes can specifically improve soil structure with their roots, which limits soil compaction and run-off leading to soil erosion. They can also grow with less or no nitrogen fertiliser and provide nutrients to the crops in the rotation. In many intercropping systems, there may be competition for nutrients among the different crops, especially in the early stages. Generally, this competition favours the growth of cereal crops to that of legumes. The spatial design of the crops, crop variety and seeding rates of intercrops is essential to maximise the biomass production of the intercrops, reduce competition from weeds and reduce pests and pathogens.

Local adaptation strategies to increase or maintain the content of C in soils under arable farming

Local climatic and soil factors of arable land in Europe can sometimes limit the adoption of certain strategies to increase soil carbon. Climatic factors, such as variable precipitation during the growth season, may require tailoring of irrigation or drainage strategies. Soil texture in combination with the climate can give high risks of wind or water soil erosion, exporting soil carbon from the surface soil layers. In soils that are saline or alkaline, soil carbon will be more difficult to sequester. In addition to the need for increased awareness, local adaptations need to be considered in detailed assessments of the different strategies for soil carbon storage in arable land.

Some case-studies illustrate possible ways to successfully adapt local measures to improve carbon storage in arable lands. They include:

- Adoption of soil management strategies to improve soil carbon storage in irrigated systems.
- Precision farming and other high-tech solutions able to generate local diagnosis and adaptive strategies for increasing soil carbon and reducing GHG emissions.
- Innovative strategies for extending soil cover and introducing cover crops in rotations in areas with limited water availability or prone to harsh weather conditions.
- Adaptation of soil management to cope with water bombs and hail risk
- Management of rainfed and low input crops to maintain and increase soil carbon in dry climates and soils prone to erosion.

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5.3 Ideas for Operational Groups

Title	**Description**	**Stakeholders to involve**
Tools to asses soil carbon sequestration and its benefits	Develop decision support tools. Test available tools and adapt them to local conditions. Develop guides for different stakeholders on what to use for purposes such as: ▶ Fertility/soil quality ▶ Economic impact/cost benefit analysis ▶ Multi-functional benefits, such as improved soil structure, weed control and soil water storage capacity	Farmers, advisers, research laboratories, NGOs
Best practices and advisory service on irrigation with C sequestration	Test, adapt locally and showcase good practices of water management strategies which can also help increase soil carbon content, especially in dry climatic conditions. The use of novel irrigation techniques can be shown and tested together with best practices for soil carbon	Farmers, agricultural techniques companies., local administration bodies
Climate-change adaptation of crops.	With a changing climate crops need to be adapted to a warmer climate at a specific latitude. An OG can test different varieties together with crop breeding companies in rain-fed conditions and low-input practices. Special attention should be paid to crops such as cereals and cover and catch crops that will provide more soil carbon in mixed cropping systems.	Farmers, local organisations, farmers' organisations, NGOs, certification organisations, demonstration farms, breeding companies.
Local implementation of precision and conservation agriculture	Find and test ways to integrate conservation agriculture with precision farming techniques. This would target advisory activities for farmers on smart/digital agriculture, so as to fine-tune agricultural practices to better capture C in soils, such as for example developing precision farming with sensors for soil carbon when allocating fertilisers or organic amendments.	Farmers, advisers, industry for new technology application, researchers
Soil cover plant mixtures in crop rotation for different farming regions and different farming systems	Experiments at farms to show the benefits in soil carbon of using crop cover plant mixtures that are tailor-made for regional climate and production systems. Also showcase how soil cover plant mixtures can benefit biodiversity in the agricultural landscape (test, demo).	Farmers, seed companies, research

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Agroforestry – multiple benefits to carbon and water retention in dry climates	Agroforestry benefits include carbon storage, wind breaks, double cropping, temperature reduction. Test soil carbon storage capacity and other agronomic benefits of agroforestry systems and showcase those which produce more benefits. Synthesise data and experiences from existing agroforestry management practices to explore which ones produce more benefits.	Farmers, researchers, advisory services
Local use of biomass/crop residues/excess manure	Facilitate interactions for local biomass use and reallocation to increase soil carbon. Develop quality control mechanisms, so farmers can trust the quality of the compost or other biomass that they may bring to their farm to improve the quality of their soil.. This can also showcase business opportunities to the actions of relocation and storage, composting of plant biomass. Here the use of locally produced digestates from gas production is one example.	Farmers, stakeholders with biomass (e.g. nature conservation companies), municipalities, policy, composting experts, facilitators.

5.4 Research needs from practice

Title	Description of knowledge gaps
Organic amendments and retention of nutrients in the soil	▶ There is a tradeoff between soil nutrients and carbon and nitrogen content in soil amendments: If C content in the amendments is too high, soil microorganisms may require a lot of N to degrade it, reducing soil N content. On the other hand, If N content is too high, there is a risk of nutrient leaching and water pollution. C and N levels in amendments should be balanced in order to avoid problems of nutrient availability in the plant-soil interface. Therefore, the following knowledge gaps should be addressed: ▶ How can nutrients be regulated and made available to plants at higher carbon amendments? ▶ How can different types of amendments shift the trade-offs between carbon and nitrogen, and how to optimise the retention of both in the soil. ▶ Are there priming effects so that soil microorganisms will degrade carbon at low nutrient levels?
Estimating soil carbon levels under different farming/agricultural practices	Modelling of soil carbon in agriculture is a topic where knowledge gaps are still present. The following gaps were identified: ▶ Role of root exudates in soil carbon modelling ▶ Role of arbuscular mycorrhizas in carbon sequestration ▶ Carbon saturation – Can we detect optimal carbon levels for different cropping systems and pedoclimatic conditions? ▶ Multiple management, i.e. use of multiple farming practices to increase soil carbon content, are their effects on soil carbon cumulative or not? Most long-term experiments on soil carbon involve a single treatment and variable fertiliser rates, but there is a lack of knowledge on whether practices are cumulative, synergistic or even neutral in combinations.
Local biomass use for increasing soil carbon content	There are research gaps when considering a systems approach on the carbon that is produced locally. When the demand for local biomass increases, as is expected in the future, will this mean a loss of biomass in other parts of the region or even other parts of the world? The allocation of carbon for different purposes needs to be treated in a systems approach where the soil carbon and the above ground carbon are regarded in one system. ▶ Need for life cycle assessment of C in cropping systems ▶ Local availability of biomass, find best biomass management practices to both increase soil carbon content and provide sufficient biomass for other purposes ▶ Indicators in quality of the amendment (not only nutrients but microbiology, pollutants, C quality) ▶ Food safety aspects ▶ Cost-benefit analyses of keeping crop residues on the field, or using it for other purposes
Value of soil carbon to society and farmers	Increasing soil carbon content helps to mitigate climate change and it also increases soil water retention and soil fertility, and improves soil structure. The value of soil carbon can be brought into decision and business models in order to enhance the adoption of practices that can increase soil carbon, or to create incentives to mitigate climate change and increase food

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	production with soil carbon. Tools and models need to be developed to estimate more clearly: ▶ Values of soil carbon to farmers: methods to increase benefits of the association (yield, gross profit, C storage, ecosystem services, insurance against extreme weather) ▶ Values to society: can be done with cost-benefit analyses, testing different types of incentives (economic, legislative)
Agroforestry	Associations of trees and crop species that benefit each-other, can be used also in European agriculture, but research is needed on how this can be managed for optimising production and storing more carbon. Combinations of agroforestry and for e.g. conservation agriculture, organic farming or eco-intensive farming are areas that lack knowledge on how they can provide benefits to the environment and to climate change.
Cover crops, intercropping	In a changing climate there will be more opportunities for farmers to produce more than one crop per year, and also for intercropping and using cover crops. Knowledge on and technical solutions for benefits and tradeoffs at cropping systems level in different agronomic aspects (fertility, weed management, C storage, diseases management) in the short and long term are currently lacking. Here synthesis of knowledge from other climatic regions and research from experimental farms implementing new cropping systems are needed.
Soil biodiversity involved in plant health and food safety	The impact of soil biology and soil carbon in plant health. There is a lack of knowledge on how the biodiversity of soil organisms interacts with plants and their growth, while promoting plant health, and on how to enhance the diversity of the soil microbiome through different agricultural practices. Knowledge gaps here include: ▶ How to use the diversity of soil organisms as an indicator of soil health? ▶ Management of soil organism communities through agricultural practices

5.5 Other recommendations, including improving take up

The Focus Group found that **awareness** on the value of soil organic carbon is essential to promote management that will improve soil carbon. In addition, incentives such as certification schemes or subsidies to local farmers cooperatives that could start new markets with certified products may also support the uptake of such farm management measures. Communication on benefits of soil carbon and agriculture both to farmers and society[4]. Farmer organisations such as UK LEAF[5], NGO's FAO, global soil assessment framework IPCC, promote the values of soil carbon to a wider audience. However, this happens either bottom-up locally or very high up in global policy. There is more to be done to include activities of awareness in, for example, rural development programmes, national environmental objectives, etc. There are also a number of initiatives starting to calculate the **economic values** of soil carbon for farmers and society (4).

Bridging research knowledge to farmers and policy is an area that is expanding every year; here are a number of tools have been developed:

- UK farm tool: http://www.farmcarbontoolkit.org.uk/
- C-tool (41)
- Smartsoil: https://web04.agro.au.dk/projectnet/smartsoilDST/
- C-bank: http://c-bank.lu.se/
- Oscar Living mulch and cover crop Toolbox: https://web5.wzw.tum.de/oscar/toolbox/database/
- KnowSoil: http://www.catch-c.eu/KnowSoil/

Enabling research by providing **open access data** from scientific knowledge is a field where long-term agricultural experiments are very valuable. There is a need for resources to digitise current data in local languages in accessible formats. It is also important that data-holders with intellectual property rights receive benefits from providing their data. There are ways of assigning DOI (Digital Object Identifier) numbers and publishing datasets to promote open access while acknowledging the original data-holders and data collectors.

Mapping and monitoring soil carbon levels in soils is a work that has started in the EU through the soil carbon monitoring and the LUCAS database (1). National monitoring schemes will also greatly help to find and identify front runners that are using best practices and regional factors influencing soil carbon sequestration. With data from mapping and monitoring, it will be possible to summarise knowledge on soil carbon and soil carbon management on a global level, as well as to predict future scenarios of farming and soil carbon sequestration

Technological innovations: soil carbon monitoring (manual or spectral analyses) can be found across all member states such as the LUCAS soil database. Sentinel 2 satellite imagery has shown a potential to produce high resolution soil carbon maps for croplands when they have just been seeded, i.e. bare soil (42). This information can then further be used to develop precision farming tools for integrating soil carbon in decisions when allocating fertilisers or organic amendments at field scale.

Conclusions

The Focus Group experts identified a set of management practices that can increase soil carbon in agriculture. They stated that it is not enough to use single practices, in order to make a significant change it is necessary to combine different practices, such as keeping the soil covered with plants or plant residues, diverse crop rotations, agroforestry, reduced tillage and water management. This will be the basis for building and sustaining the soil organic carbon and for attaining overall soil quality.

Raising awareness on the values of soil carbon may be an additional tool to show its economic value and this could even be translated into business models. It may also be useful to develop more incentives and schemes for promoting soil organic carbon in agriculture.

Increased soil carbon will not only mitigate climate change but also insure farmers for risks of crop failures because their soils will be better adapted to environmental and climate change.

[4] https://www.nature.com/news/agriculture-engage-farmers-in-research-1.15108
[5] https://leafuk.org

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Annex A: Members of the EIP-AGRI Focus Group

Name of the expert	Profession	Country
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Perrin Anne-Sophie	Researcher	France
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Facilitation team		
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You can contact Focus Group members through the online EIP-AGRI Network.
Only registered users can access this area. If you already have an account, you can log in here
If you want to become part of the EIP-AGRI Network, please register to the website through this link

Annex B: List of minipapers

Mini-paper title	Contributors
Transforming arable land into a sink for C based on Conservation Agriculture	Gottlieb Basch Alina Syp Alfred Grand Benoît Lavier Paolo Mantovi Paul van Dijk Rok Mihelič Giampaolo Sarno Daniele Antichi
Tools to judge cropping systems performance on C storage in the soil.	Bas van Wesemael María Almagro Edoardo Costantini Alfred Grand Anne-Sophie Perrin Paul van Dijk Íñigo Virto Annelies Balkema Nicole Bartelds Benoît Lavier Greet Ruysschaert Mateusz Sekowski
Local and regional adaptation strategies to increase or maintain the content of C in soils under arable farming	Edoardo Costantini Íñigo Virto Giampaolo Sarno María Almagro Daniele Antichi Katarina Hedlund.
Implementation/incentives/business/capital: What incentives can scale up successful cases with respect to C capture in soils?	Greet Ruysschaert BenoÎt Lavier Mateusz Sekowski Alfred Grand Oriol Comellas Paolo Mantovi Nicole Bartelds
How can we promote biomass return in soils?	Edith Le Cadre Daniele Antichi Oriol Comellas Ann-Sophie Perrin María Almagro.
Potential of organic amendments for C storage potential on arable soils.	Greet Ruysschaert Rok Mihelic Alfred Grand Bas van Wesemael Alina Syp María Almagro Paolo Mantovi.

Annex C: Relevant research projects

Research projects	Relevance for Soil carbon research	Links
SOILSERVICE: EU-FP7	Biodiversity ecosystem services and management	https://www.biology.lu.se/research/research-groups/soil-ecology/research-projects/soilservice
LIBERATION: EU-FP7	Eco-intensification of agriculture	http://www.fp7liberation.eu
Biodiversa: SoilClim	Soil carbon and drought effects on agriculture	https://www.biology.lu.se/research/research-groups/soil-ecology/research-projects/soilclim
Biodiversa: Ecoserve	Agricultural systems and agro-ecological conditions	http://ecoserve-project.eu
Agroforest: national (Fed. Ministry of Education and Research Germany)	Emergence of soil organisms from different habitats including arable fields and flower strips.	
Earth microbiome project	The EMP analyses microbial communities across the globe	http://www.earthmicrobiome.org
OSCAR (Switzerland)	Subsidiary crops (e.g. cover crops)	https://www.wur.nl/en/show/oscar.htm
NFP68 – Soil as a Resource	Impact of management practices on mycorrhizal fungi	http://www.nfp68.ch/en

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Digging-Deeper (Biodiversa) Europe	Agro-ecosystem diversification soil biodiversity and ecosystem services	https://diggingdeeper2017.wordpress.com
LUCAS soil expandable dataset JRC EU	JRC initiative to estimate soil biodiversity	https://esdac.jrc.ec.europa.eu/projects/lucas
Rotation 4pour1000 (France)	Soil conservation project at farms scale – soil carbon changes through crop diversification cover crops and organic amendments	https://ec.europa.eu/eip/agriculture/en/find-connect/projects/rotation-4-pour-1000
ABC'Terre-2a (France)	Mitigation of greenhouse gas budgets of cropping systems at the territorial scale by accounting for soil carbon storage	http://www.agro-transfert-rt.org/projets/abcterre-2a/
OSCAR (EU-FP7)	Subsidiary crops (e.g. cover crops)	https://web5.wzw.tum.de/oscar/index.php?id=2
RESOLVE	soil carbon management in eroded soils under organic viticulture	http://www.resolve-organic.eu/
LegValue (EU-H2020)	To boost inclusion of legumes in crop rotations and add value to legume value chains	http://www.legvalue.eu/
SMOCA (Italy)	Smart Management of Organic Conservation Agriculture	http://smoca.agr.unipi.it/?page_id=382&lang=en
IC-FAR (Italy)	LInking Long Term Observatories with Crop Systems Modeling For a better understanding of Climate Change Impact and Adaptation StRategies for Italian Cropping Systems	http://www.icfar.it/
Catch-C (EU FP7)	Analysis of European field experiments: effect of best management practices on e.g. soil carbon and GHG emissions	www.catch-c.eu
CANTOGETHER - Crops and animals together (EU-FP7)	Mixed crop-livestock farming systems to improve nutrients and carbon cycles	https://cordis.europa.eu/project/rcn/101746/factsheet/en
Circular Agronomics (H2020)	Improved management of carbon and nutrients in agriculture	www.circularagronomics.eu
REcare (FP7)	Empowering soil managers: For the past five years the RECARE project has been working with stakeholders across Europe from Iceland to Cyprus and from The Netherlands to Romania to develop a new way of saving the soil.	https://www.recare-project.eu
Landmark (H2020)	LANDMARK is a European Research Project on the sustainable management of land and soil in Europe.	http://landmark2020.eu
SoilCare (H2020)	The overall aim of the SoilCare project is to identify evaluate and promote promising soil-improving cropping systems and agronomic techniques that increase both the profitability and sustainability of agriculture in Europe.	https://www.soilcare-project.eu
Circasa (H2020)	CIRCASA project aims to strengthen the coordination and synergies in European and global research on soil carbon sequestration in agricultural soils leading to an improved understanding and scientific basis to target ambitious practices required to preserve and enhance soil carbon.	https://www.circasa-project.eu

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Research synthesis- policy input		
EVIEM: Mistra Council (SE) Global scale	Evidence and data on soil carbon and agricultural management on a global scale	http://eviem.se/en/projects/soil-organic-carbon-stocks/
Global Soil Biodiversity Assessment	Soil biodiversity and agriculture on global scale 2	https://www.globalsoilbiodiversity.org

Annex D: Management methods to promote soil carbon

Tillage practices		
Practices	**Agronomic advantages**	**Agronomic disadvantages**
No tillage or zero tillage	Increased fertility Less annual weeds Better soil structure and water infiltration.	More perennial weeds In acid soils - reduce the efficiency of liming Manure applications
Reduced tillage	Less compaction More predators More resilient system to extreme weather	Weed competition Nutrient stratification Snails/slugs/mice
Reduced frequency of tillage	Applied to more crops Improved weed & pest control	Not the benefit of no till Not efficient control of weeds
Strip tillage	Improved fertilizer application	Weeds snails compaction difficult after grass.
Contour tillage	Prevent erosion and therefor carbon loss	More logistic needed Risk on steep slopes

Crop rotation strategies		
Practices	**Agronomic advantages**	**Agronomic disadvantages**
Diverse crop rotations in space and time	Increase OM input root and soil structure. Higher soil biodiversity	More technical
Agroforestry	Improved biomass production x area. Nutrient efficiency diversify production	Competition between tree and herbaceous crops Need to adapt farm machinery
Plants with high C/N ratio	Lower mineralisation rate of residues (more C storage)	Less N available for next crop Higher N demand
Legumes	N input deep roots	Low C input compared to cereals
Grass in rotations	Higher total biomass production	Herbicide applications
Cover crops	N retention Improved soil structure	More management
Intercropping	Multiple root functions	Plant competition Weed control
Roller crimper/Intercropping	Better soil structure direct drilling weed control higher decomposition of the mulch	Only applicable for some crops and has timing restrictions. Lower soil temperature

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Amendment strategies		
Practices	**Agronomic advantages**	**Agronomic disadvantages**
Compost	Low/High CP/CN ratio Increases water retention	Variable composition of nutrients
Digestate	Increasing microbial activity	Harmful microorganisms
Sewage sludge	Increases water retention Fertiliser effects	Contamination soil crusts
Water sediments	Organic matter adding of mineral particles (region- specific)	Weeds case-by-case (variability)
Terricciato (Italian) / terre végétale (France)	Organic matter & mineral soil	-
Biochar	Easy application	Limited effect on soil fertility Bulky so transport could be problematic Light so easily carried away by the wind
Wood chips	Water retention fertility (long term) soil biota enhancing	Nitrogen limitation
Crop residues	Organic carbon input Weed control Increase infiltration Soil structure improvement in case of minimum soil disturbance Erosion control Water balance improved Increase soil fertility Decrease soil erosion Increase soil and above ground biodiversity	Competition for nitrogen Crop establishment requires specific equipment

Fertiliser strategies		
Practices	**Agronomic advantages**	**Agronomic disadvantages**
Manure - farm yard	Improved soil structure and biology Higher fertility	Risk of compaction while applying Difficult to apply correct dose Fresh manure may contain weed seeds
Manure - slurry	Better soil structure and biology Fresh manure applied on surface inoculates microorganisms. Higher fertility	Transportation may influence soil compaction
Sewage sludge	Better soil structure and biology Fresh manure applied on surface inoculates micro organism. Higher fertility	Increase of heavy metals and organic pollutants
Digestate	Efficient in N and P	Increase of heavy metals and organic pollutants
Green manure - legumes	Reduce nutrient leaching less erosion better infiltration competition with weeds	Difficult to synchronise release of N with next crop needs
Mineral fertilizers	Easy to apply High efficiency	Should be linked to crop rotation

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eip-agri

AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as through the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

An EIP AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- ✓ to take stock of the state of play of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on:
http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf

funded by European Commission

Join the EIP-AGRI network & register via www.eip-agri.eu

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