10 STEPS TO SOIL-IMPROVING CROPPING SYSTEMS (SICS)

INTRODUCTION

This resource has been produced to provide farmers with an overview of how to adopt soil-improving cropping systems (SICS) in 10 steps. Firstly, we look at the range of soil threats relating to agriculture before introducing the concept of SICS. We then provide an overview for each of the 10 steps to achieving SICS, using real-life case studies throughout to illustrate how these can be carried out in practice. These SICS can help you to increase your overall soil quality in the long-term, thus increasing your resilience and profitability.

THE SOILCARE PROJECT

The aim of the EU-funded SoilCare project was to identify and evaluate promising SICS that can increase profitability and sustainability at various scales. A trans-disciplinary approach was used to evaluate the benefits and drawbacks of several SICS, incorporating all relevant bio-physical, socio-economic and political aspects.

In total, 28 experiments exploring the efficacy of various SICS were carried out in 16 countries. The findings of these experiments have given us the ability to identify the steps farmers need to take if they are to adopt SICS.

Read more about the SoilCare project here.

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SOIL THREATS

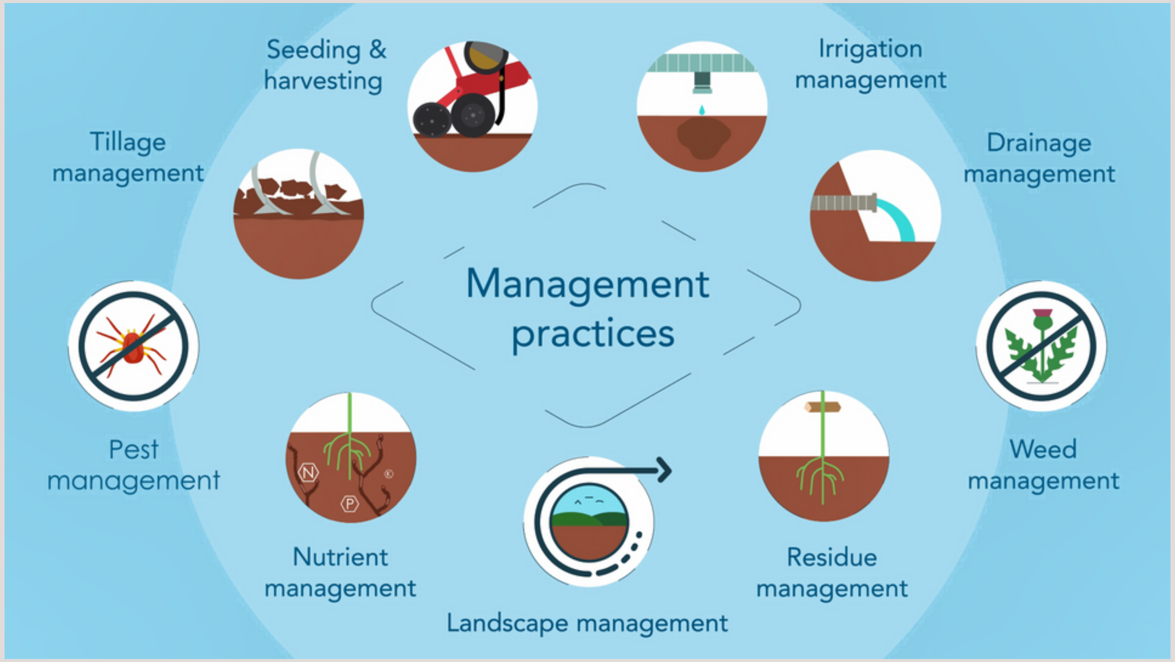
Soils are crucial for food production and for delivering several environmental services. However, soils across Europe and beyond are facing several soil threats (see below), all of which can be exacerbated by agriculture. These threats are of concern as the slow rate of soil creation makes it a finite resource. This booklet, based on the findings of the EU-funded SoilCare project, will explain how using soil-improving cropping systems (SICS) can help to improve soil quality and have positive impacts on your profitability and sustainability,

WHAT ARE SICS?

Soil-improving cropping systems (SICS) are specific combinations of crop types, crop rotations, and management practices. These systems aim to maintain or improve soil quality whilst increasing the profitability and sustainability of cropping systems by tackling the locally relevant soil threats introduced on the previous page.

The image below shows some of the crop husbandry and soil management practices which can be used as part of a SICS.

You can learn more about SICS by watching this 2-minute explainer video.



10 STEPS TO SICS

This booklet will introduce the following 10 steps to achieving SICS:

1. KNOW YOUR SOIL
2. CONSIDER YOUR CROP ROTATION
3. HAVE CONTINUOUS SOIL COVER
4. BUILD ORGANIC MATTER
5. MINIMISE SOIL DISTURBANCE
6. PREVENT SOIL COMPACTION
7. MANAGE WATER FOR SOIL
8. USE SOIL-FRIENDLY WEED/PEST CONTROL
9. LANDSCAPE-SCALE MANAGEMENT
10. PERSEVERE WITH YOUR SICS

1. KNOW YOUR SOIL

Soil testing is a crucial part of farming as it enables you to examine several soil properties including texture, density, organic matter, and nutrient levels. This is vital for ensuring that you're able to decide on what to grow, what tillage practices to use, and how much fertiliser (whether organic or conventional) to apply.

There are various types of soil testing - whilst visual evaluations of soil structure can be completed on-farm to provide a good overview of soil health, soil samples are often sent to laboratories for in-depth analysis.

HOW TO DO A 'VESS' TEST

Visual examination of soil structure (VESS) testing is a commonly used way of understanding soil health. Use this VESS analysis chart to understand your soil structure whilst undertaking this test.

1. Dig out an intact chunk of soil measuring around 30x30cm and place it on a plastic sheet or tray
2. Identify any horizontal layers and record each layer's thickness in centimetres.
3. Carefully break up each soil layer by hand to reveal the soil aggregates. How big are they? Are they rounded or sharp and pointed?
4. Break open the aggregates and assess the porosity (voids and spaces) within. Are cracks and pores visible or are aggregates solid dense blocks?
5. When breaking up the aggregates, note how easy it is to break them. Do aggregates crumble easily or does it require effort to break them?
6. Examine the roots, do they grow throughout the layer and within aggregates or are they distorted and restricted to cracks between aggregates?
7. Assess the soil colour, are orange blotches visible or are blue/grey zones present?
8. Apply the score that best describes the soil properties. Conduct the same assessment on any other layers found within the sample block. To get an overall score, simply multiply the score for each layer by the thickness of the layer. Add these layer scores up and divide the result by the total depth of the sample block.

A. A sample exhibiting good structural quality

B. A sample exhibiting poor structural quality

Photos from Teagasc (2021).

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2. CONSIDER YOUR CROP ROTATION

Using crop rotations, as opposed to monocropping, can have several benefits for soil quality including increased biodiversity, reduced erosion, improved water infiltration, and reduced soil compaction. For example, root crops can have an adverse effect on soil structure due to the high levels of disturbance used during harvest and because little residue remains in the soil afterwards. By introducing a subsequent cereal or oilseed crop, this can help the soil to recover.

In addition, using rotations can improve crop yields, reduce the need for chemical inputs, and diminishes production costs due to the increased workability of the soil.

Another key reason to use crop rotations is to minimise crop pests. Rotating crops can prevent crop-specific pests from accumulating and thus becoming harder to control. In addition, rotations minimise the risk of pests developing resistance to the active ingredients used to control them. Read some tips about how to plan your rotation here.

CASE STUDY: EARLY SOWN WHEAT IN FRANCE

Alongside having a crop rotation rather than monocropping, it is important to consider timings. For example, sowing wheat during mid-November, the rainy season in Brittany, France, was resulting in soil erosion and nitrogen loss. An experiment was, therefore, undertaken to explore whether sowing wheat in August would improve soil health. Whilst this resulted in increased soil organic matter, good sowing conditions and incorporating companion plants is likely the only way to make this approach economically viable. In cases such as these, it may be worth considering changing to a crop which results in less erosion if possible.

CASE STUDY: CHANGING CROP TYPE IN GREECE

An experiment was undertaken to explore whether growing avocados rather than oranges could result in soil health improvements and greater financial gain. Overall, it was found that growing avocados was significantly more profitable than oranges whilst maintaining good soil quality overall. Read more here. This indicates that where crops are causing soil damage and failing to maintain profitability (for various reasons), it may be worth experimenting with changing crop type.

3. HAVE CONTINOUS SOIL COVER

THE IMPORTANCE OF CONTINUOUS SOIL COVER

Cover crops are grown between main crops to prevent soils from being left bare over winter. They are, in some cases, then ploughed into the ground to add biomass and increase soil organic matter. In other cases, they are grazed by livestock who again, add organic matter to the soil.

There are several benefits to growing cover crops, including:

- Improved soil structure and quality
- Reduced soil erosion and runoff
- Increased soil organic matter
- Increased nutrient availability (e.g., nitrogen)
- More efficient weed and pest control (depending on the cover crop used and local context)
- Habitat creation

Many farmers experiment with several cover crop mixtures over a few years to explore which mixture works best on their farm. Examples of cover crop species include brassicas (mustards, radishes, turnips), legumes (vetch, clover), and grasses and cereals (oats, rye). Learn more about cover crops here.

Cover crops in France

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CASE STUDY: COVER CROPPING IN PORTUGAL

Under intensive cropping systems, the high levels of fertilisers used can result in a high risk of nutrient leaching during the winter. Cover crops were grown to produce green manure to determine whether this would mitigate nutrient leaching, improve nutrient recycling, help to control weeds, and increase soil organic matter. It was found that several different cover crops (pea, clover, lupins) adapted well and produced high quantities of biomass (8 tonnes per ha for some clovers). This resulted in a reduced need to apply mineral fertilisers and improved weed control (particularly by clover). Read more about this experiment here.

CASE STUDY: COVER CROPPING IN DENMARK

This experiment found that using cover crops, applying animal manures, and planting legume-based leys in combination led to huge soil quality improvements on an organic farm and reduced the yield gap between conventional and organic production. In addition, growing cover crops was found to reduce nitrogen leaching, thus resulting in economic savings.

4. BUILD ORGANIC MATTER

Organic matter consists of any material that originated from living organisms. These materials include plant residues, mulch, compost, and other materials. Soil organic matter is important to farmers because of its capacity to improve the soil's ability to supply essential nutrients (e.g., nitrogen, phosphorus, potassium, calcium and magnesium) to crops. High organic matter content also improves the structure of soil alongside its ability to store and buffer water and increase soil biodiversity. In addition, soil organic matter helps soil to cope with changes in soil acidity and helps soil minerals to decompose faster so that they become available to crops.

SoilCare has identified several practices which appear successful for building organic matter:

1. Applying amendments including woodchips, sewage sludge (where appropriate), manure, compost depending on availability and financial viability
2. Using crop residues - for example, chop and leave straw on the field
3. Adopting crop rotations rather than monocultures
4. Using organic farming practices
5. Minimising cultivation (see step 5 of this booklet)
6. Growing cover crops to feed the soil (leguminous where appropriate for the soil type) (see step 3 of this booklet)

Another way to build soil organic matter is to introduce grazing livestock to the rotation as their manure can contribute to building organic matter. Livestock must, however, be managed to avoid compaction and poaching.

CASE STUDY: AMENDMENTS IN BELGIUM

An experiment in Belgium found that applying woodchips to soil may result in long-term build-up of soil organic carbon without having negative effects on crop yields or quality. In addition, it was found that if woodchips were economically viable, stakeholders were receptive to using them as part of their farming system.

Read more about this experiment here.

CASE STUDY: MANURE IN POLAND

A SoilCare experiment in Poland explored the effects of applying manure and lime on soil organic matter and crop yields. It was found that manure applications and lime, and cover crops in conjunction led to the most significant increases in grain and straw yields. The additional production costs must, however, be considered to ensure that adopting these practices is financially viable. Making a long-term plan for increasing soil organic matter is more likely to be viable than attempting to adopt these practices for a short period of time. Read more here.

5. MINIMISE SOIL DISTURBANCE

TILLAGE PRACTICES

As shown by several SoilCare experiments, using appropriate cultivation practices can result in improved soil structure and overall soil quality.

Tillage (or ploughing) can disrupt soil structure and increase erosion and runoff, particularly where it is carried out under inappropriate weather conditions. In recent years, many farmers have, therefore, begun to adopt minimum or zero tillage to minimise soil disturbance. Where well planned and carried out effectively, these practices can result in significant soil quality improvements. It is, however, important that you seek advice before making significant changes to your cultivation technique.

PRECISION FARMING

Precision farming can minimise soil disturbance by only passing over the land as many times as is necessary. For example, Agrointelli has a navigation platform which defines working areas within a field. This means that robotic equipment follows a single route, only passing over each patch of soil once. In addition, AgroIntelli can programme robots to to perform mechanical weed control only in areas where it is required rather than across the entire field.

PERENNIAL CROPS

Growing perennial crops can avoid the need to reseed and plough as the plants return each year. In addition, perennial crops will develop strong root structures, thus leading to improved soil structure.

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CASE STUDY: MINIMUM TILLAGE IN THE CZECH REPUBLIC

Left - conventional tillage; centre - minimum tillage; right - zero tillage

A SoilCare experiment in the Czech Republic explored whether adopting different tillage practices would result in soil health improvements. It was found that adopting minimum or zero tillage both led to increases in soil organic carbon, reduced erosion, earlier emergence of plants with higher soil moisture and greater stability in crop yields when compared to conventional tillage.

CASE STUDY: STRIP TILLAGE IN BELGIUM

This SoilCare experiment found that strip-tillage prevents soil erosion, a threat that is costly to farmers and the environment. There are, however, practical considerations to be made before adopting strip-tillage due to the increased labour costs and risk of increased pest burdens.

6. PREVENT SOIL COMPACTION

PREVENT COMPACTION FROM HAPPENING IN THE FIRST PLACE

Once soils are compacted (particularly where compaction occurs in the subsoil), it is time-consuming and difficult to alleviate. It is, therefore, vital that compaction is prevented before it occurs. Several of the practices previously mentioned in this booklet (minimum/no-tillage, direct drilling, having continuous cover) can prevent compaction from happening. Farmers should do routine visual soil assessments (see stage 1) to check compaction levels and take remedial action as necessary, such as:

SUBSOIL LOOSENING

Subsoiling is used to break up compacted layers of soils without destroying surface vegetation or mixing layers. This should be carried out in dry conditions using winged tips to improve soil fracturing. Certain soil types (e.g., heavy clays) are, however, harder to break up. To test whether your subsoiling has been a success, you should find that pushing a tool into the ground is easier than before. In addition, soil bulk density should drop after subsoiling.

DEEP-ROOTING CROPS

Growing deep-rooting crops with large taproots can help to alleviate compaction by creating pore spaces. A SoilCare experiment in the UK, however, found that where fields are already heavily compacted, this may not offer a solution as this can inhibit root growth. Instead, these crops could be grown to prevent compaction from occurring in the first instance.

MANAGED TRAFFICKING

Using controlled trafficking can minimise soil compaction. One way of minimising soil damage is to use unmanned, lightweight machinery such as Robotti. In addition, trafficking should take place when soils are dry and thus less prone to compaction. Lastly, using tramlines, low-pressure tyres, and avoiding over-cultivation can also help with minimising soil disturbance.

CASE STUDY: COMPACTION ALLEVIATION IN THE UK

In this experiment, SoilCare explored whether direct drilling would alleviate compaction within a highly compacted field as this was inhibiting root growth. However, it was found that the compaction was too high to enable direct drilling to result in its usual benefits.

In this case, traditional ploughing appeared necessary to alleviate compaction and increase yield. However, subsoiling was found to alleviate compaction and was at least as profitable as traditional ploughing. In addition, subsoiling resulted in better soil structure results than traditional ploughing.

Once compaction has been alleviated in compacted subsoils through ploughing or subsoiling, then adopting practices such as direct drilling and zero-till are more likely to be a success.

7. MANAGE WATER FOR SOIL

Several of the practices already mentioned during this booklet can be beneficial for water infiltration and holding capacity, including cover crops (step 3), managing organic matter levels (step 4), and tillage practices (step 5).

SMART IRRIGATION

Using appropriate irrigation strategies to save water and protect soil health is important across all soil types. Extensive irrigation can increase the risk of soil contaminants being pushed deeper into the soil profile. In addition, some irrigation uses groundwater or recyled wastewater which may be contaminated with pollutants. Drip irrigation is one way to reduce the risk of soil damage by applying water precisely and directly on crop roots.

In arid regions, deficit irrigation, whereby water is saved without resulting in reductions in crop yields, is used to save water. Salinity of the soil must, however, be closely monitored when altering irrigation strategy as the resulting reduction in leaching, whilst positive for water quality, can lead to salinisation.

WELL MANAGED DRAINAGE

By managing on-farm drainage, this can reduce flood and waterlogging risk. Where soils are frequently waterlogged, this can result in soil compaction and loss of nutrients due to leaching. According to CAFRE (2021), well-managed drainage can also improve soil biology. This is because well-drained soils spend less time in an anaerobic state. As a result, these soils are more able to uptake nutrients, promote root growth, and withstand soil disturbance.

CASE STUDY: SPAIN

This SoilCare case study took place in Almeria (South-East Spain), where the soils suffer from desertification due to low rainfall in the region (<300mm per year). It was expected that using deficit irrigation may increase soil fertility, reduce erosion, and increase fruit yields and quality. The use of less water led to cost savings for the farmer. As a result, the farmer decided to continue using deficit irrigation after the end of the experiment, reducing water usage by 25%. This is encouraging, as long term adoption is key for addressing soil threats.

HEALTHY SOILS = HEALTHY WATER

Where soils are in good condition (i.e., uncompacted), they are more able to absorb and hold water. As a result, there is less water available to runoff into nearby watercourses. Where runoff occurs at a high rate, nutrients and sediment are carried to watercourses, causing water pollution. European-level and national-level legislation exists to reduce the contributions of agriculture to water quality problems, thus providing another reason to ensure that water is managed on-farm to protect both soil and water.

8. SOIL-FRIENDLY WEED/PEST MANAGEMENT

IMPACTS OF PESTICIDES ON SOIL HEALTH

Synthetic pesticides, where used excessively, can result in soil contamination and pollution. This can have adverse effects on crop yields and quality, storage capacity, soil biodiversity, and nutrient balances.

INTEGRATED PEST MANAGEMENT

Integrated pest management considers the lifecycles of pests to target pesticide applications. In many cases, biological and other non-chemical methods are preferable to chemical applications where they are effective. This results in a reduction in the amount of pesticide applied, thus minimising the risk of soil damage. Read more here.

BIOCONTROL OF PESTS

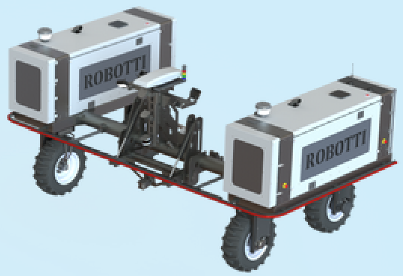
In recent years, several biological control agents have been developed as a safer alternative to synthetic pesticides. These approaches include semiochemicals such as pheromones, physical and mechanical techniques such as trapping and mulching, and the use of selective chemicals, for example. insect growth regulators. In some cases, natural predators can be introduced to control pest species - for example, ichneumonid wasps can be used to control certain weevils.

ORGANIC FARMING PRACTICES

Many organic farmers adopt ploughing to control pests as they are unable to use pesticides. This can have a detrimental effect on soil structure, so it is important to weigh up the potential benefits and disadvantages of using pesticides versus ploughing.

ROBOTICS FOR TARGETED WEEDING

Robots, such as Robotti by Agrointelli, are becoming increasingly able to target individual weeds, thus negating the need to disturb the soil across an entire field. In addition, this equipment is half the weight of the tractors traditionally used for these tasks, thus they can reduce the risk of soil compaction whilst controlling weeds.



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9. LANDSCAPE-SCALE MANAGEMENT

Landscape management provides a holistic view of SICS and includes several components such as trees, perennial strips, and alternative crops. The key to landscape management is to create continuity both on-farm and at a wider scale to mitigate soil erosion and runoff and reduce the likelihood of waterlogging. In addition, well managed landscapes can result in biodiversity gains and overall improvements in soil health.

REDUCED SOIL EROSION

- Tree planting
- Hedgerows
- Strip cropping
- Terracing
- Shelterbelts
- Grass strips

PREVENTION OF WATERLOGGING

- Creation of water holding areas
- Well-managed ditches
- Natural flood management approaches

INCREASING WIDER BIODIVERSITY

- Tree planting
- Hedgerows
- Buffer strips

REDUCED FLOOD RISK

- Tree planting
- Hedgerow planting and management
- Woody debris barriers
- Ponds/floodplains
- Buffer strips
- Flood resistant crops
- Other natural flood management approaches

10. PERSEVERE WITH YOUR SICS

THE IMPORTANCE OF TRIAL AND ERROR

Every farm is different - practices or specific measures which are successful on one farm may not be a success on another. This is due to different soil types, microclimates, topography, and pre-existing soil health. It is, therefore, important that you feel empowered to experiment on your farm.

Did your first attempt at cover cropping fail? Why not try a different mix next time? Once you identify the SICS which work for you, you will then start to reap the benefits of improved soil quality and in many cases, better yields.

SOIL HEALTH IMPROVEMENTS TAKE TIME

Several of the SoilCare experiments, which took place over 2-3 years, found that long term adoption of SICS is necessary if soil threats are to be addressed. When changing practices it is, therefore, important to have patience and give them a chance to improve soil quality.

For example, growing cover crops has, in some cases, been found to result in temporary crop yield declines for the first few years of establishment. However, once the right cover crop mix is used and the soils have adapted to their use, yields can recover and even increase whilst offering substantial benefits for soil health.

USE AVAILABLE SUPPORT AND GUIDANCE

There are several sources of information and advice out there to help you to adopt SICS. For example, all EU member countries have an advisory service where you can seek guidance. In addition, agronomists may be able to advise on how to improve your soil health without affecting yields. An equally important source of information comes from other farmers; peer-peer sharing may help you to decide which SICS to choose when attempting to address soil threats in your local context.

SUMMARY

- There are several SICS which can help you to address the soil threats on your farm and improve your profitability and sustainability, from tillage practices to pest management to landscape scale interventions
- Seek advice and guidance before making significant changes to your farming system
- Be prepared to experiment and try SICS out for several years to determine whether they are leading to soil health improvements
- Further resources and information are available on the SoilCare website.

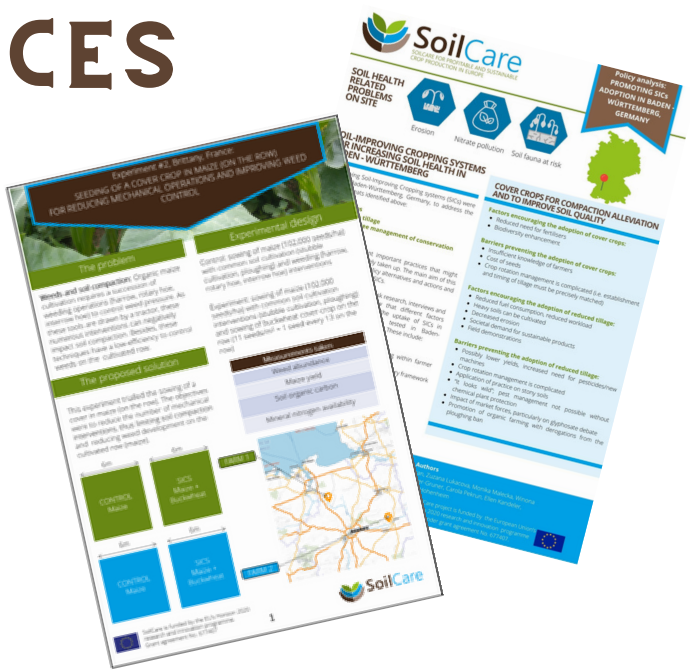
REFERENCES

Infographics courtesy of Pix Videos.

Teagasc (2021): Visual evaluation of soil structure - Teagasc.

CAFRE (2021): Managing drainage systems for soil health

FURTHER SOILCARE RESOURCES



All of the SoilCare resources are available in several European languages.

- Read our booklet on 10 common practices and their harmful impacts on soils here
- Read our soil-improving guides for each soil threat here.
- Learn more about the 28 SoilCare experiments here.
- Interested in our policy findings? Access our policy briefs and summaries here.
- Read our review on soil-improving cropping systems (SoilCare deliverable 2.1) here.

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Factsheet authors: Charlotte-Anne Chivers & Jane Mills, Countryside and Community Research Institute, UK