Introduction

Linking soil degradation processes, soil-friendly farming practices and soil-relevant policy measures

Agriculture occupies a substantial proportion of Europe’s land area. It therefore plays an important role in maintaining natural resources and cultural landscapes and is a precondition for other human activities in rural areas. Farming has contributed over the centuries to creating and maintaining a rich variety of landscapes and habitats. However, agricultural practices can also have adverse environmental effects. Degradation of soil, pollution of soil, water and air, the fragmentation of habitats and loss of wildlife can be the result of inappropriate agricultural practices.

Recognising the environmental challenges of agricultural land use, the European Parliament has requested the European Commission to carry out a pilot project on ‘Sustainable agriculture and soil conservation through simplified cultivation techniques’ (SoCo). The project is a joint collaboration between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC).

This is the first of a series of ten fact sheets that summarise the core findings of the SoCo project. Three fact sheets will focus on soil degradation processes, three more on soil-friendly farming practices and a further three on soil-relevant policy measures. This fact sheet connects the topics presented in the individual fact sheets (fact sheet no. 1).

Soil is composed of mineral particles, water, air and organic matter, including living organisms. It is a complex, dynamic, living resource, which

(Source: Geertrui Louwagie)

(Source: Geertrui Louwagie)
perform many vital functions: food and other biomass production, storage, filtration and transformation of substances including water, carbon and nitrogen. Soil also serves as a habitat and a gene pool, and provides a foundation for human activities, landscape and heritage, and the supply of raw materials.

Soil is subject to a series of degradation processes. Some of these processes are closely linked to agriculture: erosion due to water, wind and tillage; compaction; declining soil organic carbon and soil biodiversity; salinisation and sodification; and soil contamination (by heavy metals and pesticides, or excess nitrates and phosphates). In the accompanying fact sheets, we pay closer attention to water erosion and compaction (fact sheet no. 2), soil organic matter decline (fact sheet no. 3), and salinisation and sodification (fact sheet no. 4). Links with related degradation processes and environmental issues (such as water quality, biodiversity or landscape) are also presented.

Soil degradation processes imply a need for protection, maintenance and improvement of soil quality. Soil properties as well as soil-forming factors such as climate, land use or soil management determine the extent of the soil degradation. Certain farming systems and practices address one or more soil degradation processes and can help to achieve better

### Effects (positive/negative) of farming practices on soil degradation processes, related environmental issues and economics and their encouragement through the GAEC requirement and agri-environment payments or both

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<th>Conservation agriculture</th>
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<td>No- or reduced tillage*</td>
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(Source: Stephan Hubertus Gay)

Legend: *: conservation agriculture encompasses this set of complementary agricultural practices; +: positive observed effect; -: negative observed effect; [x]: expected effect; (x): limited (e.g. short-term) or indirect effect; empty field: no particulars known; : encouraged through the GAEC requirement; : encouraged through agri-environment payments; : encouraged through the GAEC requirement and agri-environment payments.
Sustainable agriculture and soil conservation

Introduction

protection and maintenance of soil resources. The fact sheets on conservation agriculture (fact sheet no. 5), soil-friendly tillage practices (fact sheet no. 6) and farm infrastructure elements (fact sheet no. 7) describe such relevant practices.

Policy makers may decide to support particular farming practices (or systems) through relevant policies, or may even make them mandatory. The Common Agricultural Policy (CAP) plays an important role in preventing and mitigating soil degradation processes. The fact sheets on the requirement to keep agricultural land in good agricultural and environmental condition (GAEC) (fact sheet no. 8), agri-environment measures (fact sheet no. 9) and advisory services (fact sheet no. 10) elaborate on this topic.

Soil degradation processes, soil-friendly farming practices (or systems) and soil-relevant policies are interrelated. The table below gives an overview of the links that are presented in the accompanying fact sheets. Environmental as well as economic effects of soil-friendly farming practices are highlighted. Further details can be found in fact sheets nos. 2-9.

Further reading
http://soco.jrc.ec.europa.eu

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<tr>
<th>Soil degradation processes</th>
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Fact sheet no. 1: Linking soil degradation processes, soil-friendly farming practices and soil-relevant policy measures

This fact sheet is based on the findings of the ‘Sustainable agriculture and soil conservation’ (SoCo) project. It is part of a package of ten sheets organised around the three main topics of the project. The sheets cover the following topics:

- Introduction:
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  - Fact sheet no. 3: Organic matter decline;
  - Fact sheet no. 4: Salinisation and sodification;

- Soil-friendly farming systems and practices:
  - Fact sheet no. 5: Conservation agriculture;
  - Fact sheet no. 6: Soil-friendly tillage practices;
  - Fact sheet no. 7: Soil-friendly farm infrastructure elements;

- Soil-relevant policies:
  - Fact sheet no. 8: Requirement to keep land in good agricultural and environmental condition (GAEC);
  - Fact sheet no. 9: Agri-environment measures;
  - Fact sheet no. 10: Advisory services.

All SoCo fact sheets and project reports can be downloaded at: http://soco.jrc.ec.europa.eu.
Water erosion and compaction

What is erosion?
Erosion is the loss of soil. When raindrops reach the soil, they detach soil particles. The degree to which this happens depends on the size and speed of the falling raindrops. The detached soil particles are subsequently transported by overland water flow. Some particles fill up soil voids, sealing the soil surface. Erosion occurs when the precipitation rate exceeds the infiltration rate of the soil.

What is compaction?
When pressure is applied to the soil surface, compaction takes place. This alters soil properties such as porosity and permeability. Pores become disconnected and gas and water movement through soil is impeded, leading to reduced availability of water and oxygen. Root growth becomes restricted.

Why is it important to fight against erosion and compaction?
Soil is removed by erosion much more rapidly than soil-forming processes can replace it. The loss of topsoil leads to reduced fertility, resulting in lower yields. The transported soil also contributes to the contamination and silting up of waterways.

Soil compaction reduces the soil’s capacity to retain water and to supply oxygen to plant roots. When a soil is less capable of holding water yields decrease, water run-off increases and soils will be more vulnerable to soil erosion.

What causes erosion or compaction?
Water erosion is a natural process; the major drivers are intense rainfall, topography, low soil organic matter content, percentage and type of vegetation cover. It is however intensified and accelerated by human activities, such as inappropriate cultivation techniques and cropping practices, changes in hydrological conditions, deforestation and land marginalisation or abandonment.

Inappropriate land management is the main cause of soil compaction. Too many livestock for a certain field size, the inappropriate use of heavy machinery in agriculture and tillage of a field when it is too wet are examples of this. Wet soils are not strong enough to offer resistance to the weight and this leads to compaction.
What damage does erosion cause?

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<tr>
<th>On-site damage due to water erosion</th>
<th>Off-site damage due to water erosion</th>
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<tr>
<td>• Loss of organic matter</td>
<td>• Water pollution</td>
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<td>• Soil structure degradation</td>
<td>• Water eutrophication</td>
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<td>• Soil surface compaction</td>
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<td>• Reduced water infiltration</td>
<td>• Burial of infrastructure</td>
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<td>• Reduced supply of water to the water table</td>
<td>• Obstruction of drainage networks</td>
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<td>• Soil loss at the surface</td>
<td>• Changes in shape of watercourses</td>
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<td>• Nutrient removal</td>
<td>• Silting up of waterways and ports</td>
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<td>• Increase of the coarse fraction of soils</td>
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<td>• Rill and gully generation</td>
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<td>• Plant uprooting</td>
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<td>• Reduction of soil productivity</td>
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Location and magnitude

An estimated 115 million hectares – one eighth of Europe’s total land area – are subject to water erosion, and 42 million hectares are affected by wind erosion. The Mediterranean is particularly prone to erosion when heavy rain occurs after long dry periods.

It is estimated that a third of European subsoils are very vulnerable to compaction and a fifth moderately so. Susceptibility to compaction depends on soil texture; it ranges from sand (least susceptible) – loamy sand – sandy loam – loam – clayey loam – loamy clay – to clay soils (most susceptible to natural compaction).
The soil’s ability to resist erosive meteorological conditions (e.g. wind, rain, running water) depends mainly on soil texture and organic matter content, which influence the water-holding capacity and the ability of the soil to produce aggregates or crusts. When erosion occurs, the loss of topsoil causes a reduction in the soil’s fertility and contaminates the aquatic ecosystem. Loss of soil fertility and the breakdown of structure ultimately lead to desertification.

Soil compaction can induce or accelerate other soil degradation processes, such as erosion or landslides. Compaction reduces the infiltration rate, which increases run-off in sloping areas. Also, the presence of a layer with low permeability makes the upper part of the soil more prone to saturation with water and thus heavier. This upper part is at risk of sliding and causing landslides. On plains, compaction can cause waterlogging, resulting in the destruction of aggregates, and causing crust formation. Soil structure is improved by soil organic matter, reducing the soil’s susceptibility to compaction, erosion and landslides.

Further reading

http://soco.jrc.ec.europa.eu
Fact sheet no. 2: Water erosion and compaction

This fact sheet is based on the findings of the ‘Sustainable agriculture and soil conservation’ (SoCo) project. It is part of a package of ten sheets organised around the three main topics of the project. The sheets cover the following topics:

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Organic matter decline

What is organic matter decline?

Soil organic matter includes all living soil organisms together with the remains of dead organisms in their various degrees of decomposition. The organic carbon content of a soil is made up of heterogeneous mixtures of both simple and complex substances containing carbon. The sources for organic matter are crop residues, animal and green manures, compost and other organic materials. A decline in organic matter is caused by the reduced presence of decaying organisms, or an increased rate of decay as a result of changes in natural or anthropogenic factors. Organic matter is regarded as a vital component of a healthy soil; its decline results in a soil that is degraded.

Why is soil organic matter/carbon important?

Soil organic matter is a source of food for soil fauna, and contributes to soil biodiversity by acting as a reservoir of soil nutrients such as nitrogen, phosphorus and sulphur; it is the main contributor to soil fertility. Soil organic carbon supports the soil’s structure, improving the physical environment for roots to penetrate through the soil.

Organic matter absorbs water – it is able to hold about six times its weight in water – making it a lifeline for vegetation in naturally dry and sandy soils. Soils containing organic matter have a better structure that improves water infiltration, and reduces the soil’s susceptibility to compaction, erosion, desertification and landslides.

On a global scale, soils contain around twice the amount of carbon held in the atmosphere and three times the amount found in vegetation. Europe’s soils are an enormous carbon reservoir, containing around 75 billion tonnes of organic carbon. When soil organic matter decays, it releases carbon dioxide (CO\textsubscript{2}) into the atmosphere; on the other hand, when it is formed, CO\textsubscript{2} is removed from the atmosphere.
What causes organic matter decline?

Soil organic carbon content is affected mostly by climate, texture, hydrology, land use and vegetation.

**Climate**

Organic matter decays more rapidly at higher temperatures, so soils in warmer climates tend to contain less organic matter than those in cooler climates.

**Soil texture**

Fine-textured soils tend to have more organic matter than coarse soils; they hold nutrients and water better, thus providing good conditions for plant growth. Coarse soils are better aerated, and the presence of oxygen results in a more rapid decay of organic matter.

**Soil hydrology (drainage)**

The wetter a soil is, the less oxygen is available for organic matter to decay, so that it accumulates.

**Land use (tillage)**

Tillage mixes oxygen into the soil and raises its average temperature, thereby contributing to an increased rate of organic matter decay. Loss of organic matter also occurs because erosion washes away topsoil and humus. Overall, cropping returns less organic matter to the soil than does native vegetation.

**Vegetation**

Roots are a great contributor to soil organic matter. Grassland produces deep roots that decay deep in the soil. Forest soils in contrast rely primarily on the decay of surface litter for organic matter input. Crops produce more above-ground biomass than roots. The organic matter input on cropland depends on the land management practices, including whether crop residues are removed or left behind.

**Location and magnitude**

Recent trends in land use and climate change have resulted in soil organic carbon loss at a rate equivalent to 10 % of the total fossil fuel emissions for Europe as a whole. In general, soils with low organic carbon content can be found in warm, dry climates and soils with a higher organic carbon content can be found in colder, wetter climates. Almost half of European soils have low organic matter content, principally in southern Europe but also in areas of France, the United Kingdom and Germany.
Links with other soil degradation processes and environmental issues

Loss of soil organic carbon content can limit the soil’s ability to provide nutrients for sustainable plant production. This may lead to lower yields and affect food security. Less organic carbon also means less food for the living organisms present in the soil, thus reducing soil biodiversity.

Loss of soil organic matter reduces the water infiltration capacity of a soil, leading to increased run-off and erosion. Erosion in turn reduces the organic matter content by washing away fertile topsoil. Under semi-arid circumstances this may even lead to desertification.

Global warming is predicted to speed up the decay of organic matter, releasing more CO₂ and increasing climate change. Desertification might move north as a consequence. Carbon reservoirs, which are maintained by cold and wet climatic conditions, will release substantial amounts of CO₂ and methane (CH₄) into the atmosphere under warmer conditions. This also happens when wetlands are drained or peat harvested. Continued drainage of Europe’s remaining peat bogs, for example, would release 30 million tonnes of carbon annually, the same amount as from an additional 40 million cars on Europe’s roads.

Further reading
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Salinisation and sodification

What are salinisation and sodification?

Salinisation is the accumulation of water-soluble salts in the soil. These salts include potassium (K\(^+\)), magnesium (Mg\(^{2+}\)), calcium (Ca\(^{2+}\)), chloride (Cl\(^-\)), sulphate (SO\(_4\)^{2-}\), carbonate (CO\(_3\)^{2-}\), bicarbonate (HCO\(_3\)^-) and sodium (Na\(^+\)). The accumulation of sodium is also called sodification. Salts dissolve and move around with water. When the water evaporates, the salts are left behind.

Primary salinisation involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater. Secondary salinisation is caused by human interventions such as inappropriate irrigation practices, for example with salt-rich irrigation water and/or insufficient drainage.

Why is it important to fight salinisation and sodification?

The accumulation of salts (particularly sodium salts) is one of the main physiological threats to ecosystems. Salt disturbs plant development by limiting its nutrient uptake and reducing the quality of the water available to the plant. It affects the metabolism of soil organisms, leading to severely reduced soil fertility. High levels of salinity in soils provoke the withering of plants as a result both of the increase in osmotic pressure and the toxic effects of salts.

An excess of sodium results in the destruction of the soil structure, which, due to the lack of oxygen, becomes incapable of sustaining either plant growth or animal life.

Salinisation increases the impermeability of deep soil layers, making it impossible to use the land for cultivation.

Causes

Factors leading to excessive accumulation of salts in soil may be natural or anthropogenic.

*Environmental (natural)* factors that result in salinisation or sodification:
- geological events, which can increase the concentration of salts in groundwater and consequently in soils;
- natural factors, which can channel salt-rich groundwater to the surface, near the surface or to horizons above the groundwater table;
• groundwater seepage into areas lying below sea level, that is, micro-depressions with little or no drainage;
• waters flooding from areas with geological substrates that release large amounts of salts;
• wind action, which in coastal areas can blow moderate amounts of salts inland.

Natural factors influencing the salinity of soils are climate, soil parent material, land cover, vegetation type and topography.

**Human-induced factors** that may lead to salinisation or sodification:

- irrigation with waters rich in salts;
- rising water table due to human activities (filtration from unlined canals and reservoirs, uneven distribution of irrigation water, poor irrigation practices, improper drainage);
- use of fertilisers and other inputs, especially where land under intensive agriculture has low permeability and limited possibilities of leaching;
- use of wastewaters rich in salts for irrigation;
- salt-rich wastewater disposal on soils;
- contamination of soils with salt-rich waters and industrial by-products.

The most influential human-induced factors are land use, farming systems, land management and land degradation. Inappropriate irrigation practices (such as the use of salt-rich irrigation water) and insufficient drainage both cause salinisation.

Salinisation and sodification are often associated with irrigated areas where low rainfall, high evapotranspiration rates or soil textural characteristics impede the washing of salts out of the soil, which subsequently build up in the surface layers. Irrigation with water that has a high salt content dramatically worsens the problem.

In coastal areas, salinisation may be associated with the over-exploitation of groundwater caused by the demands of growing urbanisation, industry and agriculture. Over-extraction of groundwater can lower the normal water table and lead to the intrusion of seawater.

**Location and magnitude**

Salinity is one of the most widespread soil degradation processes on Earth. In Europe, salt-affected soil occurs in Hungary, Romania, Greece, Italy and on the Iberian Peninsula. In Nordic countries, the de-icing of roads with salts can lead to localised salinisation.

Soil salinisation affects an estimated 1 to 3 million hectares in the EU. It is regarded as a major cause of desertification and is therefore a serious form of soil degradation. With the increases in temperature and decreases in precipitation characteristic of climate in recent years, the problem of salinisation in Europe is getting worse.

![Saline deposition in a soil profile (Hungary)](Mollic Solonet - World Reference Base for Soil Resources 2006) (Source: Gergely Tóth)
Links with other soil degradation processes and/or environmental issues

Salinisation greatly reduces soil quality and vegetation cover. Due to the destruction of the soil structure, saline and sodic soils are more easily eroded by water and wind. When land degradation occurs in arid, semi-arid and subhumid areas it is known as desertification. Salinisation induces desertification effects such as loss of soil fertility, soil structure destruction and compaction, and soil crusting.

Further reading

http://soco.jrc.ec.europa.eu
Fact sheet no. 4: Salinisation and sodification

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Conservation agriculture

What is conservation agriculture and why is it useful?

Conservation agriculture (CA) encompasses a set of complementary agricultural practices:

• minimal soil disturbance (through reduced or no-tillage) in order to preserve soil structure, soil fauna and organic matter;
• permanent soil cover (cover crops, residues and mulches) to protect the soil and contribute to the suppression of weeds;
• diversified crop rotations and crop combinations, which promote soil micro-organisms and disrupt plant pests, weeds and diseases.

Conservation agriculture aims to boost agricultural production by optimising the use of farm resources and helping to reduce widespread land degradation through the integrated management of available soil, water and biological resources combined with external inputs. Mechanical tillage is replaced by biological mixing of the soil, whereby soil micro-organisms, roots and other soil fauna take over the tillage function and soil nutrient balancing. Soil fertility (nutrients and water) is managed through soil cover management, crop rotations and weed management.

Disc harrow used for reduced tillage operations (Germany) (Source: Stephan Hubertus Gay)
Implementation

Conservation agriculture is typically implemented through the following steps, each of which lasts for two or more years.

- **First phase.** Inversion ploughing is stopped, and reduced or no-tillage techniques implemented instead. At least a third of the soil surface has to remain covered with crop residues, and cover crops should be introduced following the harvest of the main crop. Disc, spike or rotary harrows are used (direct drills in case of no-tillage). Yield reduction may occur.
- **Second phase.** Natural improvement of soil conditions and fertility occur thanks to the organic material originating from the natural degradation of residues. Weeds and pests tend to increase and must be controlled, chemically or by other means.
- **Third phase.** Diversification of the cropping pattern (crop rotations) may be introduced. The overall system stabilises progressively.
- **Fourth phase.** The farming system reaches an equilibrium and yields may improve in comparison with conventional farming. This reduces the need to use chemicals for weed and pest control, or to supplement fertility.

Farmers need training for each phase. Experience may be acquired in the field but yields and profits may be lower in the short term. The system is unsuitable for compacted soils, which may first require loosening.

Benefits

Several benefits arise from the application of CA, some of which (improved yields, biodiversity, etc.) become obvious once the system reaches stability.

- The organic carbon stock, biological activity, above- and below-ground biodiversity and soil structure are all improved. Higher biological activity results in the formation of well-connected, mostly vertical soil macro-biopores that increase water infiltration and resistance to severe packing. Soil degradation – in particular soil erosion and run-off – is greatly reduced, often leading to increased yields. Reduced soil and nutrient losses, in combination with more rapid pesticide breakdown and greater adsorption (due to the higher organic matter content and biological activity) also result in improved water quality. Carbon dioxide ($CO_2$) emissions are lowered as a result of the reduced use of machinery and increased accumulation of organic carbon. CA practices could sequester between 50 and 100 million tonnes of carbon annually in European soils, the equivalent of the emission of 70-130 million cars.
- Labour and energy inputs related to land preparation and weeding are greatly reduced.
- Fertiliser requirements and soil restoration interventions are reduced.

Drawbacks

- Typically there is a transition period of five to seven years before a conservation agriculture system reaches equilibrium. Yields may be lower in the early years.
- If seasonal factors are not taken into account, the inappropriate application of chemicals may increase the risk of leaching due to the more rapid movement of water through the biopores.
Sustainable agriculture and soil conservation
Soil-friendly farming systems and practices

- If crop rotations, soil cover and/or crop varieties are not adjusted to optimal levels, more chemicals may be needed to control weeds and pests.
- Nitrous oxide (N\textsubscript{2}O) emissions increase in the transition period.
- Farmers need to make an initial investment in specialised machinery, and need to have access at a reasonable cost to cover crop seeds that are adapted to local conditions.
- Farmers need extensive training and access to skilled advisory services. Compared to conventional farming, a fundamental change in approach is required.

Success stories

In Europe, no-tillage accounts for up to a tenth of Finland and Greece’s utilised agricultural area (UAA), and up to five percent in the Czech Republic, Slovakia, Spain and the United Kingdom. Reduced tillage is being implemented on almost half of the UAA in Finland and in the United Kingdom, and on a quarter of the UAA in Portugal, Germany and France. In the Midi-Pyrénées region (France) in 2006, on average three quarters of the winter crops and one quarter of the spring crops were under reduced tillage. In the same year, cover crops accounted for a fifth of the spring crops area, three times higher than in 2001.

Further reading

http://soco.jrc.ec.europa.eu
www.fao.org/ag/ca/
www.fao.org/ag/catd/
www.ecaf.org/First.html
http://kassa.cirad.fr/
www.sowap.org/

Corn cultivated under no-tillage: residues from the previous crop are still visible under the corn canopy, covering the soil (Germany) (Source: Jana Epperlein, Gesellschaft für konservierende Bodenbearbeitung e.V., Germany)
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Soil-friendly tillage practices

Soil-friendly tillage practices can help to achieve a better protection of soil resources. The main types are intercropping, subsoiling, and contour farming, each of which is discussed below.

**Intercropping**

**What is intercropping and why is it useful?**

Intercropping involves growing two or more crops in alternating rows on adjacent strips of variable width or in different layers (under-sown crops) on the same piece of land, during the same growing season. It thus promotes a favourable interaction between different plant species or varieties.

**Benefits**

The competition and complementarity between appropriately selected, intercropped plants enhances the overall stability of the system, including a significant resilience against pests, diseases and weeds. This practice has positive effects on soil porosity, soil biodiversity, supports nutrient cycles and results in increased yields. Overall it leads to a better use of available resources.

**Drawbacks**

Combinations of crops in intercrop systems must be carefully chosen. Intercropping may result in reduced yields compared to stand-alone crops if it leads to excessive competition for resources. Costs for the purchase of seeds and seedbed preparation can be rather high.

**Success story**

**Intercropping in the Svratka river basin (Czech Republic)**

This area has a high risk of soil degradation. Intercropping (under-sown crops) is one of the main ways of successfully dealing with this risk and is widely used in the area, especially in organic farming. Under-sown crops (like grass or lucerne) are sown while the main crop (e.g. wheat) is still growing. These crops thus have the capacity to prevent soil erosion and nutrient losses after the main crop is harvested, and also to increase above-ground biodiversity. Overall, intercropping mitigates water and wind erosion, organic matter decline, diffuse soil contamination and off-site damage in the area. The practice is supported under agri-environment measures, providing motivation for farmers to apply it.

*Source: SoCo case study in the Czech Republic*

(Intercropping of wheat, maize and flax on sloping land (France) (Source: Solagro, France))
Subsoiling

What is subsoiling and why is it useful?

Long-term ploughing and the continued use of heavy machinery can create deep hardpans and compacted soil layers. These may hinder root growth and infiltration of water and nutrients. Subsoiling aims at restoring the lost soil properties and involves loosening compacted soil layers below the ploughing depth, without inverting them. The working depth of the subsoiler should be decided according to the degree of compaction and the soil moisture content at this depth.

Benefits

Subsoiling leads to improved root growth and water and nutrient infiltration. It thus helps to reduce surface run-off and boost yields.

Drawbacks

Subsoiling requires a high input of energy. This practice is of a remedial character: which means that if the causes of compaction and poor soil structure are not removed, compacted layers may well reappear in the short term. Subsoiling is less effective at reducing shallow surface compaction resulting from inappropriate livestock management on pasture.

Success story

Subsoiling in the village of Belozem (south Bulgaria)

Salinisation is one of the major soil degradation processes in southern Europe. There are more than 35 000 hectares of salt-affected soils in Bulgaria. In Belozem 40% of the land is affected by salinisation. Periodic subsoiling (up to 40-45 cm) has been proven to remedy compaction and salinisation on heavy soils. It increases water infiltration and decreases the upward capillary movement of underground water with high salt content. It also improves soil drainage and can facilitate the leaching of excess salts from the upper part of the soil. However, the effect of this practice is short-lived unless measures to improve the soil are introduced.

Source: SoCo case study in Bulgaria
Contour farming

What is contour farming and why is it useful?
Contour farming involves carrying out field activities such as ploughing, furrowing and planting along contours (at right angles to the normal flow of run-off, and not up and down the slope). It aims to create water-retention storage within the soil surface horizon and to slow down the run-off rate, giving water the time to infiltrate into the soil.

Benefits
Contour farming increases the soil's infiltration capacity and reduces water loss and erosion due to tillage.

Drawbacks
On slopes steeper than 10 %, contour ploughing should be combined with other measures, such as terracing or strip cropping. The effectiveness of contour farming for water and soil conservation depends on the design of the systems, but also on such factors as soil, climate, slope aspect and land use of the individual fields.

Success story

Contour farming in the Guadalentín basin (Murcia, Spain)
Water erosion has traditionally been considered as the major soil degradation process in this region. Contour tillage, the restriction of row crops on steep slopes and reduced tillage are the main preventative practices adopted. Contour tillage has been widely used since its inclusion in the Code of Good Farming Practices (2001), and has been mandatory for this region under cross compliance since 2005. Contour tillage is highly effective at mitigating water erosion.

Source: SoCo case study in Spain

Further reading
http://soco.jrc.ec.europa.eu
Fact sheet no. 6: Soil-friendly tillage practices

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  – Fact sheet no. 6: Soil-friendly tillage practices;
  – Fact sheet no. 7: Soil-friendly farm infrastructure elements;

– Soil-relevant policies:
  – Fact sheet no. 8: Requirement to keep land in good agricultural and environmental condition (GAEC);
  – Fact sheet no. 9: Agri-environment measures;
  – Fact sheet no. 10: Advisory services.

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Soil-friendly farm infrastructure elements

Farm infrastructure elements can help to achieve better protection of soil resources. Buffers (in their many forms) and terraces are discussed below.

Buffers

What are buffers and why are they useful?

Buffers are areas or strips of land maintained under permanent vegetation cover. They can be used along streams, lakes, contours, field borders, or even within fields. The following are examples of buffers.

- Grass strips are herbaceous areas used to trap sediment and pollutants from adjacent fields before they can reach waterways or sensitive areas.
- Hedgerows are strips of bush-like plants used to indicate property borders or provide a stock-proof fence. They may also play a role in filtering sediment and pollutants from adjacent fields or in preventing the drift of pesticides, particularly when spraying high crops.
- Grassed waterways are broad, shallow, saucer-shaped vegetated channels designed to move surface water across farmland without causing soil erosion. The herbaceous plants slow down the flow of water and protect the channel surface from rill and gully erosion, especially when the contributing watershed surface is relatively large.
- Windbreaks consist of rows of trees or shrubs. They aim at reducing wind speed and wind erosion, and thus protect young crops and control the drifting of snow and soil.
- Riparian buffers are zones of grass, trees or shrubs adjacent to watercourses that filter pollutants.

Implementation

Establishing buffers may involve planting grass strips, hedgerows or tree lines, or a combination of these. Maintenance is generally required in order to ensure filtering efficiency or limit excessive growth that could damage crop production. In some European countries, buffer strips are compulsory at the edges of croplands that border water bodies.

Benefits

Buffers may reduce the effects of water and wind erosion. Accordingly, they can significantly reduce the volume of sediment and nutrients transported by agricultural run-off to water bodies, or prevent the drift of pesticides from fields into water bodies, roads or other areas. Windbreaks, in particular, can halve the wind speed over a distance equal to twenty times the trees’ height, and intercept the drift of aerial pollutants and soil particles. They thus help to reduce costs of cleaning operations (such as sediment removal). Buffers can alter the shape of landscape. They may evolve over time into semi-natural habitats, hosting a variety of wildlife on farmland, and creating a network of...
Fact sheet no. 7: **Soil-friendly farm infrastructure elements**

**Terracing**

**What is terracing and why is it useful?**

Bench terraces consist of a series of level or nearly level platforms built along contour lines at suitable intervals, and generally sustained by stone walls. Terracing is generally used to allow agriculture on slopes, where the gradient and soil depth would normally prevent the cultivation of crops, and to limit run-off or increase the water-retention capacity of the soil.

**Implementation**

The slope is cut along the contour lines and soil is moved in order to form a level bench for cultivation. An embankment, generally made of stones, is constructed to support the terrace. As a large amount of cutting and filling is required per unit area, bench terraces may not be the optimum practice on soils that are easily eroded. Terracing was very much used in the past and is retained as part of the cultural heritage in some areas.

**Benefits**

Terracing facilitates cultivation on slopes, and leads to reduced run-off and improved water retention. More commonly, the maintenance of old terraces in good condition prevents erosion and ensures the continued existence of traditional landscapes.

**Corridors for the movement of fauna and flora.**

They are most effective if planned as part of a comprehensive resources conservation system. Buffers may also provide useful commodities (fruits, wood, fodder, etc.), and thus contribute to a more diverse production on the farm.

**Drawbacks**

Under certain circumstances buffers can result in the loss of productive land. Plants in the buffer may compete with crops for available resources (especially in the case of tree windbreaks), and the available space for machinery to manoeuvre is reduced. Maintenance is required, so additional costs are incurred. Finally, buffers address the impact but not the cause of soil degradation; for example, they filter soil particles transported by run-off, but do not prevent erosion.

**Success stories**

Several types of buffers are common across Europe. Ireland and the UK have the densest network of hedgerows in the EU-27. Windbreaks are widespread in many of the extensive European plains, and grassed waterways are widely used in France.
**Drawbacks**

Construction of new terraces requires a high input of labour and energy. It also involves the movement of a considerable amount of soil and thus impacts heavily on the landscape and the environment in general. Terraces require a high level of maintenance and, if abandoned, may be subject to erosion. Furthermore, they are often located in remote or inaccessible areas, from which a skilled workforce and the rural population in general have disappeared. Terracing is generally not suited to farming that uses large and heavy machinery.

**Success stories**

Terraces cover large areas in the Mediterranean region (Spain, Portugal, Greece, Italy, southern France, Cyprus, Malta), where they are generally used for vineyards and olive groves. Terraces are preserved as significant cultural heritage features in many national Rural Development Programmes.

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**Further reading**

- [Buffers](http://www.fao.org/docrep/W2598E/W2598E00.htm)
- [Terracing](http://www.fao.org/docrep/T0321E/T0321E00.htm)
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Sustainable agriculture and soil conservation

Soil-relevant policies

Background

Cross compliance is part of the Common Agricultural Policy and has manifold implications for soil conservation. Cross compliance is a control and sanctioning mechanism leading to the reduction of direct support in the case of non-compliance with standards established in the field of environment, public, animal and plant health, and animal welfare. Furthermore, cross compliance refers to the requirement to maintain land in good agricultural and environmental condition (GAEC). What this implies is defined by Member States at national or regional level according to a common framework.

Cross compliance applies to direct income payments as well as to most environmental payments applied under Rural Development. Cross compliance refers to the ‘baseline’ or ‘reference level’ for voluntary agri-environment measures (fact sheet no. 9), under which payments are granted to farmers who undertake environmental commitments going beyond mandatory requirements, including cross compliance standards.

Effect on soil degradation processes

The GAEC requirement refers to a range of standards that relate to protection against soil erosion, maintenance of soil organic matter and structure, avoidance of the deterioration of habitats, and water management. Minimising the area of bare soil and retention of terraces directly contribute to the prevention of soil erosion, whereas crop residue management and crop rotation help to maintain organic matter in the soil. Compliance with management requirements that target habitat and water quality such as the retention of landscape features, the establishment of buffer strips along watercourses, or the avoidance of encroachment may help to control water erosion and are likely to contribute to soil biodiversity. Retaining land as permanent pasture has the additional advantage of maintaining soil organic matter. Finally, appropriate use of irrigation water helps in the control of salinisation and sodification.

In general, cross compliance has increased farmers’ awareness of soil degradation, as well as the environmental reasons for introducing standards to prevent it.

Cover between vine rows that is also used as green manure (Rheinland-Pfalz, Germany)
(Source: Geertrui Louwagie)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Compulsory standards</th>
<th>Optional standards</th>
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<tbody>
<tr>
<td>Soil erosion: protect soil through appropriate measures</td>
<td>Minimising the area of bare soil</td>
<td>Retain terraces</td>
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<tr>
<td></td>
<td>Adequate land management reflecting site-specific conditions</td>
<td></td>
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<tr>
<td>Soil organic matter: maintain soil organic matter levels through appropriate practices</td>
<td>Arable stubble management</td>
<td>Standards for crop rotation</td>
</tr>
<tr>
<td>Soil structure: maintain soil structure through appropriate measures</td>
<td>Retention of landscape features, including (where appropriate) hedges, ponds, ditches, trees in line, in groups or isolated, and field margins</td>
<td>Appropriate machinery use</td>
</tr>
<tr>
<td>Proper level of maintenance: ensure a proper level of maintenance and avoid deterioration of habitats</td>
<td>Minimum livestock stocking rates or/and appropriate regimes</td>
<td>Establishment or retention of habitats</td>
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<tr>
<td></td>
<td>Avoiding the encroachment of unwanted vegetation on agricultural land</td>
<td>Prohibition on grubbing up olive trees</td>
</tr>
<tr>
<td></td>
<td>Retention of permanent pasture</td>
<td>Maintenance of olive groves and vineyards in good vegetative condition</td>
</tr>
<tr>
<td>Protection and management of water: protect water against pollution and run-off, and manage the use of water</td>
<td>Establishment of buffer strips along watercourses</td>
<td>Compliance with authorisation procedures where use of water for irrigation is subject to such</td>
</tr>
</tbody>
</table>

**Prohibition on stubble burning (Finland)**  
(Source: Geertrui Louwagie)

**Tree line along grassland (County Sligo, Ireland)**  
(Source: Geertrui Louwagie)
Success stories

The following practices (related to GAEC standards) have proven to be successful in addressing diverse aspects of soil degradation.

Targeting water erosion
- Minimise the area of bare soil
  On agricultural land and forest area with under-planted crops, green cover (planted or spontaneous) between 15 November and 1 March is required, except during soil preparation work for new crop cultivation (Portugal).
- Adequate land management reflecting site-specific conditions
  On parcels with high risk of soil erosion, except for terrace plots or plots in areas integrated into flood plains, neither the planting of temporary crops nor of new pasture is allowed. The improvement of natural permanent pastures is allowed only when the soil is not tilled. Planting new permanent crops is only allowed in situations considered to be technically adequate by the responsible authority (Portugal).
  On sloping ground with clear signs of erosion (such as widespread presence of rills), temporary channelling of surface water by means of drainage furrows is required directly after sowing (Italy, in particular the ‘Provincia Autonoma Bolzano/Bozen’ and Calabria).

Targeting soil organic matter and soil biodiversity decline
- Arable stubble management
  Some Member States extend this standard beyond arable land and also prohibit burning of crop residues (stubble, straw, dead grass, hay) on grassland (natural or sown) and pastures (Italy, in particular the ‘Provincia Autonoma Bolzano/Bozen’ and Calabria) or on all agricultural land (Estonia).

Practices to improve soil quality on arable land more generally
- Farmers must complete an annual ‘Soil Protection Review’ (SPR), which consists of a simple assessment of the risk of damage to soil structure, loss of organic matter, and erosion, and identifies remedial measures to be implemented (England, UK). The SPR allows the choice of the management options that are appropriate under varying local conditions and requires an annual update to reflect changing circumstances.

Source: SoCo survey on EU policy implementation and SoCo case studies

Further reading
http://soco.jrc.ec.europa.eu

Riparian margin (County Sligo, Ireland)
(Source: Geertrui Louwagie)
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Agri-environment measures

Background

Rural development policy in the European Union provides funding for a wide range of measures that Member States or regions use to support the sustainable development of their respective rural areas. Member States establish their Rural Development Programmes (RDP) at national or regional level, in accordance with their needs and reflecting their respective National Strategy Plans. Rural Development Programmes are co-financed by the EU and the Member States.

Rural development measures are arranged under the three themes of the policy, known as ‘thematic axes’: competitiveness, environment and the countryside, and quality of life and economic diversification. Measures under all three axes may address soil degradation on agricultural land. These measures include training, farm modernisation, natural handicap payments, agri-environment payments, non-productive investments, agroforestry, and afforestation.

Agri-environment measures in particular encourage farmers to protect, maintain and enhance the environmental quality of their farmland. Agri-environment measures can be designed at the national, regional, or local level and so are adapted to particular farming systems and specific environmental conditions. In supporting actions going beyond legal and compulsory requirements, agri-environment measures complement the GAEC approach (see fact sheet no. 8).

Concrete menus of agri-environmental commitments are agreed between the implementation authority and the farmer through contracts for periods of between five and seven years. Agri-environment payments are calculated on the basis of cost incurred and income foregone as a result of specified agri-environment commitments.
Effects on soil degradation processes

Agri-environment measures which target soil protection, conservation or improvement, address in particular water or wind erosion, soil contamination, or certain physical, chemical, and biological soil properties. Schemes that primarily target the preservation of water, biodiversity, or landscape may work through the adoption of soil conservation practices. Instead of focussing on single soil conservation practices, agri-environment measures may also focus on the adoption of environmentally benign farming systems such as conservation agriculture and organic farming.

Targeting water erosion
- Conservation tillage practices such as no-tillage, in particular on areas with high biodiversity value in order to support soil biodiversity; or mulch-sowing in combination with no- or reduced tillage: that is, leaving crop remains (mostly straw) on the field (usually during the winter months) and drilling seeds directly under the mulch; or direct sowing and non-inversion tillage
- Green cover crops during winter time
- Installing and maintaining grass buffer zones, grass corridors or erosion ponds and dams
- Building or rebuilding soil retention structures, such as terraces or walls, on the boundaries of sloping fields under irrigation

Targeting organic matter and biodiversity decline
- Use of exogenous organic matter in arable farming, such as manure, green cover, straw, etc.
- Conservation agriculture techniques, such as no-tillage, in areas of high biodiversity value under annual crops
- (Conversion to) organic farming, in particular through input reduction, crop rotation and extensification of livestock. Positive side-effects on local and diffuse soil contamination are expected.

Source: SoCo survey on EU policy implementation
The organic agriculture agri-environment scheme (Murcia, Spain)
This measure aims at preserving ecosystems, maintaining or increasing soil fertility and organic matter content, producing crops free of chemical residues and reducing chemical pollution from agricultural sources. It has existed in Spain since 1992; the implementation in Murcia started in 2001. Under the current programme (2007-2013) farmers sign a contract for 5 years and payments differ between crops. It is the most important agri-environment scheme in the region, consuming 57 % of the budget, and foresees support for 1 500 farms or 30 000 ha, aiming at a 25 % increase in the area under organic farming in the region, and focusing on nature protection areas.
The prescriptions of the scheme for individual measures are designed by the regional government, in consultation with the regional council for the regulation of organic agriculture, and agricultural organisations. The latter play an important role in helping farmers with the administration of the measure, and also act as advisors.
This measure has considerable potential to address soil degradation problems in the region, and is mainly relevant in irrigated areas. Other positive features are its adaptation to regional conditions and its continuity over time; its importance guarantees continuity into the future too. The measure is well known and fairly popular among farmers, despite its heavy administrative burden and limited funding for participants.

Source: SoCo case study in Spain

Agri-environment measures proved to be successful in generating soil benefits, for example:
• Hedge-planting measures in Piemonte (Italy) had a significant impact on soil erosion.
• In Austria, direct sowing techniques for maize resulted in a 40 % reduction in soil erosion.
• Organic farming practices in Umbria (Italy) helped to reduce soil erosion on average by 6.8 t/ha/yr. Conversion of arable land to grassland resulted in a reduction in erosion by 30 t/ha/yr.
• In Flanders (Belgium), calculations indicated that green cover reduces soil erosion by at least 50 %.

Source: Mid-term evaluation RDP 2000-2006

Further reading
http://soco.jrc.ec.europa.eu

Use of pheromones in viticulture, which allows reduced pesticide use (Rheinland-Pfalz, Germany)
(Source: Geertrui Louwagie)
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Advisory services

Background
Advisory services aim at helping farmers to improve the overall performance of their holding. They may also support the protection, maintenance and improvement of the soil resource. The Common Agricultural Policy makes it compulsory for Member States to set up a farm advisory system. The setting up and use of such services can be supported under the EU’s Rural Development Policy; national or regional schemes may also encourage such initiatives.

Effect on soil degradation processes
Most advisory initiatives take a range of soil degradation processes into account, and have their focus on farming systems rather than individual farming practices.

Targeted information helps farmers to protect soil and water (Czech Republic)
In the Czech Republic, a sophisticated advisory programme is in place to support the implementation of the Nitrates Directive. This has involved a series of regional workshops, the distribution of leaflets, and the provision of information on appropriate management. The information can be accessed through the Land Parcel Information System (LPIS), a database in which areas and the demarcation of agricultural parcels are recorded. Developed in 2004, the Czech LPIS is innovative in the way it integrates environmental data with the standard LPIS. Registered users can access information on the requirements related to the Nitrates Directive (for example, restrictions concerning the use of fertilisers, and crop rotation requirements) which is precise, specific and targeted at individual parcels. The system is accessible via the internet and used by farmers, farm advisors and inspectors. The LPIS has been combined with detailed soil data and a digital terrain model, which forms the basis for a precise calculation of soil erosion. Specific anti-erosion measures have thus been designed, including anti-erosion balks, ditches, grass strips and retention polders. It has also been used to locate 100 000 hectares for conversion to grassland or the implementation of specific agronomic measures.

Source: SoCo case study in the Czech Republic
Addressing soil erosion in the Midi-Pyrénées region (France)

Current agricultural land use and farming practices in the Midi-Pyrénées show a high erosion risk. Technical advisors have a central role in dealing with agricultural development and taking this degradation process into account. For over 20 years, the Regional Chamber of Agriculture has been leading work groups on erosion control, and since 2000 conservation agriculture has become the core working focus. A regional work group looking into the most advanced forms of conservation agriculture has been established for the period 2007-2012. It is based on a partnership between the Chambers of Agriculture, technical institutes and farmers’ associations, which constitute between them a network of showcase farms and a research programme. The objectives are:

• the development of simplified tillage techniques (reduced or no-tillage) adapted to the soil and climate conditions of southwestern France;
• assessment of the agronomic, economic and environmental benefits of these techniques;
• definition of the required conditions, in order to pass this information on to farmers and extension advisors.

Meanwhile, private companies are promoting simplified tillage techniques in the Midi-Pyrénées. These meet the need for farmers to increase their margins as well as better addressing soil degradation processes in their farm management. Farmers pay a fee of EUR 90/ha for this locally adapted advice.

Perceived severity (sum of individual scores on a scale 0-5) of soil degradation before and after implementing conservation agriculture (CA) on 14 farms in the Midi-Pyrénées region (France)

Source: SoCo case study in France
Catchment-sensitive farming initiative (CSF) (England)

CSF (2006-2011) is a partnership initiative run by Defra (the Department for the Environment, Food and Rural Affairs in England) and two governmental environmental organisations (the Environment Agency and Natural England). The government provides the funding, with GBP 25 million allocated in the initiative's first two years, including GBP 5 million for the Capital Grants Scheme. It aims to encourage early voluntary action by farmers to reduce diffuse water pollution and to improve soil and land management practices in 40 priority catchments, thereby contributing to a number of policy objectives, including the implementation of the Water Framework Directive. The emphasis is on information provision, advice and capacity building.

The measures have been successful in generating greater awareness among farmers of a range of diffuse pollution issues, and the soil management practices connected with these issues. By financing advisory staff on the ground, capacity to address soil management has increased, sharpening the focus of other measures including Environmental Stewardship, which is the main agri-environment measure in England, and the farm Capital Grants Scheme. Although the scheme has only been in operation for a short time, its take-off phase has been very successful. Under the scheme, over 14 000 farm-specific recommendations have been made, including a large number relating to appropriate soil management. The scheme has the potential to fill an important gap in the suite of policies available to tackle diffuse water pollution and soil pollution from agriculture, and to have considerable stakeholder support.

Source: SoCo case study in the United Kingdom
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