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Addressing soil degradation in EU agriculture: relevant processes, practices and policies

Report on the project 'Sustainable Agriculture and Soil Conservation (SoCo)'

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Preface

In 2007, the European Parliament requested the European Commission to carry out a pilot project on 'Sustainable Agriculture and Soil Conservation through simplified cultivation techniques' (SoCo). The European Parliament considered that 'in Europe, soil degradation and erosion is probably the most significant environmental problem' and underlines the importance of conservation agriculture as being a 'set of soil management practices which minimise alteration of the composition, structure and biodiversity of the soil, safeguarding it against erosion and degradation'. While stating that 'Rural development planning action for 2007 to 2013 affords a unique opportunity to make headway with these techniques', the European Parliament underlined that the project should 'foster knowledge of these techniques so that future European legislation can be easily applied'.

The SoCo project was designed in a close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). It has been implemented by the JRC's Institute for Prospective Technological Studies (IPTS) and Institute for Environment and Sustainability (IES). Further information about the SoCo project is available on the website: http://soco.jrc.ec.europa.eu

The SoCo project is structured around four work packages. This report presents the findings of a stock-taking of the current situation with respect to soil degradation processes, soil-friendly farming practices and relevant policy measures within an EU-wide perspective (work package 1). The following institutes contributed to this report: the JRC-IPTS, the JRC-IES, Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V. and SOLAGRO.

This report has been reviewed by the SoCo Steering Group, comprising representatives of several DG AGRI Units, the JRC-IPTS, the JRC-IES, DG Research and DG Environment, as well as by the SoCo Scientific Advisory Board: Arnold Hermanus Arnoldussen, Štefan Bojnec, Floor Brouwer and Pierre Dupraz. We thank all involved for their support to the work.

Executive summary

Agriculture occupies a substantial proportion of the European land, and consequently plays an important role in maintaining natural resources and cultural landscapes, a precondition for other human activities in rural areas. Unsustainable farming practices and land use, including mismanaged intensification as well as land abandonment, have an adverse impact on natural resources. Having recognised the environmental challenges of agricultural land use, the European Parliament requested the European Commission in 2007 to carry out a pilot project on 'Sustainable Agriculture and Soil Conservation through simplified cultivation techniques' (SoCo). The project originated from a close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). It was implemented by the Institute for Prospective Technological Studies (IPTS) and the Institute for Environment and Sustainability (IES).

The overall objectives of the SoCo project are: (i) to improve the understanding of soil conservation practices in agriculture and their links with other environmental objectives; (ii) to analyse how farmers can be encouraged, through appropriate policy measures, to adopt soil conservation practices; and (iii) to make this information available to relevant stakeholders and policy makers in an EU-wide context.

This report presents the findings of a stock-taking of the current situation with respect to soil degradation processes, soil-friendly farming practices and relevant policy measures within an EU-wide perspective. This overview includes the results of the survey on the national/regional implementation of EU policies and national policies, a classification of the described soil degradation processes, soil conservation practices and policy measures, and finally the outcome of the Stakeholder Workshop which took place on 22 May 2008 in Brussels.

The current findings and the data received from the stock-taking of the policies do not provide sufficiently detailed insight into the investigated links and are thus too limited to allow policy recommendations. In order to clarify the context-specific links between soil degradation processes, farming practices and policy measures, SoCo therefore conducted ten case studies, spread over three macro-regions within the EU. The methodological details and results of the case studies as well as an overall assessment of the effectiveness of the policy framework as regards soil protection, conservation or improvement will be presented in the SoCo Final report.

Nature, localisation and magnitude of soil degradation related to agriculture

Soil is defined as the top layer of the Earth's crust and is composed of mineral particles, water, air and organic matter, including living organisms. It is a complex, mutable, living resource which performs many vital functions: food and other biomass production, storage, filtration and transformation of substances including water, carbon and nitrogen. Soil further serves as a habitat and a gene pool, and provides a basis for human activities, landscape and heritage, and the supply of raw materials.

Soil is also subject to a series of degradation processes. Six of the soil degradation processes recognised by the Commission (water, wind and tillage erosion; decline of soil organic carbon; compaction; salinisation and sodification; contamination; and declining soil biodiversity) are closely linked to agriculture. Within SoCo, the magnitude of the related soil degradation risks was estimated at EU level and areas where these risks are most likely to occur were identified. The degree of 'risk' of soil degradation is established as a function of the underlying pre-disposing factors, and does not indicate the actual occurrence of degradation processes in particular areas.

Due to the loss of topsoil, the soil becomes less fertile and the aquatic ecosystem contaminated. Erosion in agricultural areas could result in undercut slopes which remove the slope base, causing landslides. The major drivers for water erosion are intense rainfall (particularly pronounced in clay soils after long droughts), topography, low soil organic matter content, percentage and type of vegetation cover and land marginalisation or abandonment. Following the geographical distribution of these major drivers, several areas with a high risk of erosion (including some hotspots) are located in the Mediterranean regions. Erosion risk is also observed across western and central Europe. Even though the risk is relatively limited in e.g. France, Germany and Poland, water erosion can still be a substantial problem here. On the other hand, the analysis shows hilly to mountainous areas (Pyrenees, Apennines and the Alps) with very low or no erosion risk. These are largely forest areas with soils stabilised through tree roots.

Wind erosion, involving a removal of predominantly the finest soil particles, results in an ongoing decrease in soil fertility, so that the effects of wind erosion on agricultural productivity are detectable only after years or decades. A soil’s susceptibility to wind erosion is determined by its erodibility (mainly soil texture and organic matter content) and the climate’s erosivity (mainly wind velocity and direction and precipitation). Wind erosion is additionally influenced by the interactions of various components (such as land use) resulting in a high temporal variability in the actual wind erosion risk of a particular site. The highest number of erosive days on bare soil per year (calculated over the last 30 years) is found across the sand belt covering southeast England, the Netherlands, northern Germany and Poland. Additionally, the areas exposed to high wind speed along coastlines show elevated levels of wind erosion. However, the outcome of the modelling exercise might be influenced strongly by lacking data (e.g. detailed info on soil, climate and land management) and scale effects.

Soil organic carbon is a source of food for soil fauna and contributes to soil biodiversity. Soil organic carbon supports the soil’s structure, which improves the physical environment for roots to penetrate through the soil, enhances the water retention capacity, and supports drainage (thus reducing run-off and erosion). A loss in organic carbon content can limit the soil’s ability to provide nutrients for sustainable plant production. Apart from soil characteristics (such as soil texture) and soil type, the soil organic carbon content is determined by land use, climate (mainly temperature and precipitation) and soil hydrology. Risk related to soil organic carbon decline is defined in terms of the potential of soils to lose organic carbon (removal of carbon from the soil) compared to rates of accumulation of soil organic carbon. The climate factor explains the existence of a north-south climatic gradient, with high soil organic carbon levels in the colder humid northern part of Europe and in mountainous areas, and lower levels in the warmer semi-arid southern part. The model results show that agricultural soils in Europe have very different actual soil organic carbon levels and are subject to different risk levels of soil organic carbon decline. Maintaining and optimising organic carbon levels (as a specific objective of land management) is important in contributing to climate change mitigation.

Compaction can create significant damage to the soil infiltration rate, redistribution of water and nutrients, root development, and the direction and depth of root growth. As the degree of compaction increases, cultivation becomes more difficult demanding more energy as well as decreasing crop yields and productivity. The natural susceptibility of soils to compaction mainly depends on soil texture, with sandy soils being least and clayey soils being most susceptible. Human-induced compaction is caused by soil use and management (e.g. heavy machinery used under wet conditions). European soils used for agricultural and pastoral purposes have a predominantly low or medium natural susceptibility to compaction. Agroforestry and permanently irrigated land (mainly on light sandy soils) -with the exception of rice fields, mostly on clay soils with a high water table- are least susceptible to compaction.

Salinisation leads to an excessive increase of water-soluble salts in the soil, whereas sodification concerns an increased content of exchangeable sodium (Na^+). High levels of salinity in soils provoke the withering of plants both due to the increase of osmotic pressure and the toxic effects of salts. Salinisation increases the impermeability of soil layers, eliminating the possibility to use the land for cultivation. When alkalinity takes place, the high pH level does not, in most cases, permit plant life. Excess sodium on the exchange complex results in the destruction of the soil structure that due to a lack of oxygen, cannot sustain either plant growth or animal life. Alkaline soils are easily eroded by water and wind. The main natural factors influencing soil salinity are climate, the salt contents of the parent material and groundwater, land cover and topography. The most influential human-induced factors are land use, farming systems, and land management, such as the use of salt-rich irrigation water and/or insufficient drainage. Saline soils have developed in most arid regions, where climate is the determining driver. Salinity of local groundwater or substrata is causing problems of salinity too. The countries most affected are Spain, Hungary and Romania. Other countries show localised occurrence of these conditions, which could have a devastating effect locally. Particular types of soil, such as acid sulphate soils may be at risk of salinisation under certain environmental conditions.

SoCo has not been able to produce comprehensive risk assessments of the degree of soil contamination (by heavy metals and pesticides; excess of nitrates and phosphates) or declining soil biodiversity due to a lack of data.

Heavy metal input in agriculture may be caused by human activities, such as fertilisation and amendment practices, used to increase soil productivity. High concentrations of heavy metals in soils can be toxic for living organisms, resulting in biodiversity decline and groundwater pollution. Heavy metals together with excessive nitrogen inputs are regarded as the main sources of contamination in agricultural soils with significant effects on water quality.

Soil biodiversity tends to be greater in forests (compared to grasslands) and in undisturbed natural lands (compared to cultivated fields). Agricultural land use and management practices can have significant positive (liming in grasslands or low levels of disturbance) and negative (ploughing, overuse of agrochemicals or organic wastes) impacts on different components of soil biodiversity. Soil tillage operations modify the soil’s architecture (soil structure, porosity, bulk density, and water-holding capacity), the distribution of crop residues and organic carbon content. The adoption of organic farming and low-input farming can reduce the impact of agricultural activity on soil biodiversity. Changes in biodiversity alter ecosystem processes and change the resilience of ecosystems to environmental change.

The macro-assessment of the soil degradation processes provided in this report represents EU-wide estimates only and should not be interpreted with the same accuracy as field measurements. Risk was assessed through parametric and empirical models, using the European Soil Database and Corine Land Cover Database. Given the general EU-wide character of the evaluation and despite using the best available data, important drivers for actual soil degradation at the local level (e.g. land use and land use change, farming practices, farming systems) could not be taken into account. Also, these data show serious differences and gaps in quality, comparability and geographical distribution. To create a more complete picture, improved data collection would be required, ideally through the development of a harmonised monitoring system across Europe and through additional research on EU-wide soil degradation processes.

Relevant farming practices for soil protection, conservation and improvement, their uptake and related environmental objectives

SoCo focused its review on two specific farming systems, namely conservation agriculture and organic farming, along with a range of farming practices.

Farming systems

Conservation agriculture comprises a combination of practices which minimise alteration of the composition and structure of the soil, safeguarding it against erosion and degradation, and preserving soil biodiversity. No-tillage and reduced tillage, in combination with permanent soil cover (cover crops, crop residues) and crop rotation, are essential practices in conservation agriculture. Crop rotation involves growing a range of crops in the same space in sequential seasons to avoid the build-up of pathogens and pests that often occur when a species is continuously cropped. Uptake of no-tillage varies from 4.5 to 10 % (of total arable land) in Finland and Greece and from 2.5 to 4.5 % in the Czech Republic, Slovakia, Spain and the United Kingdom. Reduced tillage is practised on 40 to 55 % of the arable land in Finland and the United Kingdom, and on 20 to 25 % in France, Germany and Portugal. All mentioned practices minimise the risk of soil degradation by increasing the organic carbon stock, thus improving biological activity, soil fertility, soil structure and the water-retention capacity of soils, thus reducing soil erosion and nutrient run-off (with positive effects on water quality), and improving soil resistance to compaction. As for crop rotations, in addition to erosion control, the interaction between distinctive crops within a crop rotation can increase the yields, especially for the first consecutive crop. An example is the positive effect of legumes on the subsequent yields of a grain crop. On the economic side, significant cost savings with respect to labour and fuel consumption are reported. Reduced tillage and no-tillage can potentially reduce the need for labour hours by 30-40 and 50-75 % respectively, depending on the geographical location (northern or southern Europe). Similarly, consumption of fuel can realistically drop by 10-20 % and 15-25 % for reduced tillage and no-tillage respectively. Nevertheless, switching to conservation agriculture might require significant capital investment (for example, in sowing equipment) and greater attention in the use of chemicals (that is for weeding). Furthermore, conservation agriculture is a complex, site-specific farming system, requiring training of farmers and adaptation to local circumstances before maximum economic benefits can be obtained. The practices forming the basis for conservation agriculture are also (individually) used in other farming systems (e.g. conventional, organic).

Organic production is an integrated system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes (FAO, 2008b). Organic farming plays a dual societal role, on the one hand responding to consumer demand for organic products, and on the other hand delivering public goods through the protection of the environment and animal welfare, and thus contributing to rural development (Regulation (EC) 834/2007). Over the period 1998-2005, the area under organic farming (including conversion areas) certified under Council Regulation 2092/91/EEC increased by 130 % in the EU-15, and by 2005 it amounted to 4 % of the total Utilised Agricultural Area in the EU-25. However, there is considerable variation between Member States. Organic farming, although different from conservation agriculture, has similar positive effects on soil organic carbon content and soil biodiversity. Energy consumption is reduced and beneficial effects are reported on water quality, in particular with respect to pesticides (which are strictly limited in organic farming), and on above-ground biodiversity (in particular species abundance and/or richness) and landscape. Net returns depend on yields, with some variation according to the crops.

Farming practices

Ridge tillage, i.e. cultivating crops on pre-formed ridges, alternated with furrows protected by crop residues, has positive effects on moisture-holding capacity, soil fertility maintenance (including organic carbon content) and biological activity and thus on water erosion and nutrient run-off. Evidence suggests that ridge tillage can be an economically viable alternative to conventional tillage with higher net returns and lower economic risk. Ridge tillage has only been studied in experiments in most parts of Europe.

Contour farming involves activities, such as ploughing, furrowing and planting, carried out along contours instead of up and down the slope. It aims at creating detention storage in the soil surface horizon and slowing down the rate of run-off. Contour farming thus increases the soil's infiltration capacity, may have positive effects on organic carbon content, and results in controlling water and tillage erosion. However, climate, soil type, slope aspect and land use should be taken into account when judging the suitability of this practice. Data on cost-benefit analyses are scarce.

Subsoiling involves loosening deep hardpans in soils, thereby improving the soil's infiltration rate and root penetration. In particular, it has a beneficial effect on infiltration rate and capacity, but shows variable effects on nutrient cycling. The effects of subsoiling are influenced by many other parameters such as a combination of practices, type of crop and soil, (micro-)climate, period of soil cultivation, etc.

Intercropping is the growth of two or more crops in proximity in the same field during a growing season to promote the interaction between them. As in any biodiverse ecosystem, the interaction between complementary plants enhances the overall stability of the system, including a significant resilience against pests, diseases and weeds. This practice increases soil porosity and supports organic carbon and nitrogen cycles; there are indications of positive effects on soil biology and biodiversity too. Studies highlight the variability in net returns for a number of intercrops.

Maintenance and establishment of permanent grassland (grass sward over five years) and temporary grassland (grass sward less than five years) can improve soil protection. Permanent grassland covers 32 % of the European UAA with important differences between the Member States: e.g. in the United Kingdom, Ireland and Slovenia, permanent grassland covers at least 60 % of the UAA. Both permanent and temporary grasslands have undergone a gradual decline over the past 25 years, having been converted into cropland or forest, returned to fallow land or abandoned. However, the 2003 CAP reform introduced the obligation to maintain permanent pastures in order to prevent massive conversion into arable land. This resulted, in 2006 and 2007, in a limited increase in permanent pasture in most Member States. Permanent grasslands significantly contribute to aggregate size and stability and soil biology (from micro- to macro-organisms). They also support the cycling of nutrients (organic carbon, nitrogen, phosphorus and potassium) in the soil. The continuous vegetative cover reduces the erosion risk by water and wind.

Agroforestry refers to land use systems and technologies where woody perennials (trees, shrubs) are deliberately combined with agricultural crops, either in some form of spatial arrangement or temporal sequence. Agroforestry has positive effects on soil fertility maintenance, water-holding capacity, erosion control, biodiversity, carbon sequestration and control of nitrate leaching. However, its environmental effects are highly variable, depending on biophysical conditions, management intensity, and choice of crops and tree species. Research has shown that the long-term economic profitability of silvo-arable agroforestry systems relative to that of conventional arable farming is not clear-cut; when the profitability of the latter is high, the overall economic performance of agroforestry depends on the proportion of farm land planted, tree density and land quality.

Buffer strips (filter strips, field borders, windbreaks, grassed waterways, riparian buffers, etc.) at the edge of arable lands can significantly reduce (by 70-90 %) the volume of suspended solids, nitrates and phosphates transported by agricultural run-off to water bodies. Depending on the type, they can reduce wind erosion and contribute to biodiversity and aesthetics of the landscape. On the economic side, buffer strips lead to a retraction in the productive area and investment in their establishment (seeding, planting). In return and depending on local conditions, they may replace or reduce the need for other nature restoration activities.

Bench terraces consist of a series of (nearly) levelled platforms built along contour lines, at suitable intervals and generally sustained by stone walls. Terracing has a particularly beneficial effect on the soil's infiltration rate and capacity and thus on controlling water erosion. However, the high maintenance required, coupled with the high cost of labour and the significant changes in the socio-economic structure of the agricultural population over the last decades, has led farmers to abandon terraces. In turn, many authors report adverse effects of terracing once they are badly maintained or even abandoned. A simple cost-benefit analysis of terracing is often not sufficient to establish its profitability.

Review of the regulatory environment and policy instruments that address conservation agriculture and soil conservation practices

The review of the regulatory environment and policy instruments is based on three forms of data collection. Firstly, a review of the existing, relevant EU legislation; secondly, a review of impact assessments, evaluations and research projects relating to EU policies; and thirdly, a survey monitoring national and regional implementation. The results from the policy survey are not exhaustive, i.e. they do not reflect all existing policies in the EU-27 with a soil protection, conservation or improvement potential.

To date, soil protection is not a specific objective of any EU legislation but it features in some legislation as a secondary objective. To close this gap, the Commission proposed a Soil Framework Directive in September 2006. Reviewing existing legislation from a soil protection point of view requires considering all stated objectives and their expected effects on soil quality. In many cases other environmental objectives (e.g. water protection and waste management) contribute to some extent to soil protection, although not always effectively.

In the framework of the Cardiff Process, environmental objectives are to be integrated into EU sectoral policies, including the Common Agricultural Policy (CAP). The CAP comprises two principal headings of budgetary expenditure: market price support and direct income payments (Pillar 1), and a range of selective incentive payments targeting rural development (Pillar 2).

Cross compliance, a horizontal tool for both pillars and compulsory since 2005 (Council Regulation (EC) 1782/2003), plays an important role in soil protection, conservation and/or improvement. Under cross compliance rules, the receipt of the Single Farm Payment and payments for eight rural development measures under axis 2 is conditional on a farmer's compliance with a set of standards. The Statutory Management Requirements (SMRs) create synergies between the direct payments scheme and the need to ensure compliance with a number of relevant EU environmental directives, including the Nitrates Directive. The requirement to keep agricultural land (whether in productive use or not) in good agricultural and environmental condition (GAEC) aims at preventing land abandonment and ensuring a minimum maintenance of agricultural land. The elements of GAEC specifically target protection against soil erosion, maintenance or improvement of soil organic matter, and maintenance of a good soil structure.

Within Pillar 2 (Regulation (EC) 1698/2005), a wide range of measures can be supported and is potentially relevant to soil protection/conservation/improvement. Member States or regions are obliged to spread their rural development funding across three thematic axes: (1) competitiveness; (2) environment and land management; and (3) economic diversity and quality of life; with minimum spending thresholds applied per axis. 'LEADER' is a horizontal axis complementing the three thematic axes. The axes contain measures which offer Member States the possibility of supporting actions to reduce soil degradation on agricultural land when such a need has been identified in their territories, in particular:

- Axis 1: Vocational training and information actions (Art. 20 (a) (i)); Use of advisory services (Art. 20 (a) (iv)); Setting up of farm management, farm relief and farm advisory services (Art. 20 (a) (v)); Modernisation of agricultural holdings (Art. 20 (b) (i)); Restoring agricultural production potential damaged by natural disasters and introducing appropriate prevention actions (Art. 20 (b) (vi)).
- Axis 2: Natural handicap payments in mountain areas and payments in other areas with handicaps (Art. 36 (a) (i-ii)); Natura 2000 payments and payments linked to Directive 2000/60/EC (Art. 36 (a) (iii)); Agri-environment measures (Art. 36 (a) (iv)); Support for non-productive investment (Art. 36 (a) (vi)); First afforestation of agricultural land (Art. 36 (b) (i)); and First establishment of agroforestry systems on agricultural land (Art. 36 (b) (ii)).

Axis 2 measures are of particular interest within the scope of soil quality, since both environmental improvement and preservation of the countryside and landscape encompass soil degradation processes. Also, the listed measures can stimulate specific farming practices and farming systems such as organic farming and conservation agriculture. Measures should be well targeted and focussed on actions above the reference level. As such, a range of rural development measures provides the Member States or regions with possibilities for encouraging farmers to go voluntarily beyond the reference level of soil quality, established through the requirements under SMRs, GAEC, minimum requirements for fertilisers and plant protection products and other relevant mandatory requirements established by national legislation. However, in most cases, it is impossible to conclude at the EU level to what extent the measures focus on soil quality, since the required level of detailed information, in particular the link between farming practices and specific soil degradation processes, can only be obtained at the programme level.

Currently the most relevant EU environmental directives with respect to soil quality are the Nitrates Directive and the Water Framework Directive. Others, such as the Birds and Habitats Directives, the Sewage Sludge Directive and the Plant Protection Products Directive, are expected to have beneficial effects on soil quality, but to a lesser extent owing to a more focused set of objectives.

- The Nitrates Directive (91/676/EEC) is designed to protect the Community's waters against nitrates from agricultural sources, one of the main causes of water pollution from diffuse sources, and is thus primarily targeting water quality. However, it is expected to have positive effects on local and diffuse soil pollution by nitrates (and phosphates). Also in particular cases, soil compaction might be positively affected, as fertiliser spreading is banned in the winter period (with prevailing wet or water-saturated soils).
- The Water Framework Directive (2000/60/EC), including its daughter directives such as the new Groundwater Directive (2006/118/EC), is primarily focused on water quality and mitigating the effects of floods and droughts. Because of the link between water and soil quality, measures taken under these directives may contribute to reducing diffuse soil contamination, with expected positive side-effects on soil biodiversity.
- Avoiding pollution or deterioration of agricultural soils is regarded as an implicit precondition for the protection or recovery of habitats under the Birds Directive (79/409/EEC) and Habitats Directive (92/43/EEC). Soil biodiversity is likely to benefit from the (extensive) farm practices implemented under these directives. Positive effects on (local and) diffuse soil contamination are expected too. A coherent European ecological network known as 'Natura 2000' is integrating the protected areas of both directives.
- The Sewage Sludge Directive (86/278/EEC) addresses the decline of organic matter and soil contamination, through regulating the use of sewage sludge on agricultural land, while encouraging its correct use.
- The Plant Protection Products Directive (91/414/EEC) addresses risks resulting from the actual use of pesticides (mainly plant protection products and biocides). Both pieces of legislation are expected to have repercussions for soil contamination and soil biodiversity.

Given the socio-economic and environmental importance of soils, the Sixth Environment Action Programme called for the development of a Soil Thematic Strategy, published by the Commission in 2006. Its overall objective is the protection and sustainable use of soil, based on the prevention of further soil degradation, preserving soil functions and restoring degraded soils to a level of functionality consistent with current and intended use. The proposed Soil Framework Directive (COM(2006) 232) requires Member States to identify areas at risk of soil degradation processes, as well as to set up an inventory of contaminated sites. Subsequently Member States have to adopt measures, which could be built on measures already implemented in national and Community contexts. However, Member States are free to decide upon the level of ambition of their soil policy, to set their own targets and to decide how and by when to achieve them. The European Parliament adopted its first reading decision on the proposed Directive in November 2007, endorsing the proposal and calling for a Directive on soil protection. In the Environment Council meeting of 20 December 2007, despite the support and call for legislation from 22 Member States, there were five Member States (France, Germany, United Kingdom, Austria, the Netherlands) that voted against the compromise text prepared by the Portuguese Presidency, thus creating a blocking minority. The proposal is still under discussion in the Environment Council.

The United Nations Convention to Combat Desertification (UNCCD) (United Nations, 1994; into force since 2006) and United Nations Framework Convention on Climate Change (UNFCCC) (United Nations, 1992) are two multilateral international agreements going beyond the EU borders that have potential for soil quality protection, maintenance and improvement.

SoCo conducted an extensive survey of policy implementation at Member State and regional levels across the EU-27. The results indicate that the existing policy measures have the potential to address all recognised soil degradation processes across the EU-27, even though not all policy measures are implemented in all Member States or regions. Measures are implemented using the flexibility provided within the legislative framework of the EU. Adaptation to local conditions influences the implementation but not always to the desired degree. The link between available policy measures, implied soil conservation practices and soil degradation processes can be either two-stage, by supporting or requiring a specific farming practice which positively affects soil quality, or one-stage with a direct link to soil quality and a free choice of farming practices. Typically, the two-stage policy intervention is either through support for beneficial farming practices, or through the prevention or prohibition of damaging practices. Especially with regard to voluntary incentive-based measures (VIBM), it is important to monitor the uptake, as this provides an indication of their relevance to the social, economic and natural environment of farms and of their expected effect. Compliance with prescriptions (mandatory measures) and levels of uptake of voluntary incentive-based measures, in particular, are both strengthened through increasing awareness and advice.

Establishment of a classification of soil degradation processes, soil conservation practices and policy measures

SoCo established a classification of soil conservation practices and related policy measures. It provides a schematic representation of the (expected) effects of farming systems (organic and conservation agriculture) and farming practices on soil degradation processes and related environmental issues, as well as indicating which policy measures encourage the adoption of such practices. The earlier-presented information on the impacts of farming practices on soil degradation processes is based on the scientific literature, which mostly concerns observed effects under particular geo-climatic conditions and farming characteristics such as farming type and tradition. On the contrary, the survey on the implementation of EU policies at Member State or regional level did not illuminate the extent to which the links between farm technical requirements and soil degradation processes are based on actual measurements. Given differences in the use and implementation of policy measures, these hypothesised cause-and-effect models may not reflect what happens on the ground in the diverse and more complex agri-environment reality. However, a lack of monitoring and of a (quantitative) database hinders a comprehensive evaluation of the impact, effectiveness and efficiency of the different policy measures at the present time.

Summary of stakeholder workshop in May 2008

A stakeholder workshop at EU level (involving farmers, land owners, actors affected by soil degradation, policy makers, policy-implementing institutions, relevant NGOs, etc.), jointly organised by the Joint Research Centre and DG Agriculture and Rural Development, was held on 22 May 2008, in Brussels, and brought together about 120 stakeholders. Its aim was twofold: (i) informing stakeholders on the SoCo study and establishing a platform for project cooperation, and (ii) gathering stakeholder opinions and experience in the area of soil conservation.

Marian Fischer-Boel, Commissioner for Agriculture and Rural Development, recalled in her welcome address the importance of soil protection and informed the audience about the objectives of the project to investigate good soil conservation practices and analyse how policy can best be used to encourage farmers to adopt such practices. Member of the European Parliament (MEP) Stéphane Le Foll introduced the background of SoCo, initiated as a pilot project from the European Parliament within the 2007 budget. The idea was born from the need to rethink agriculture; in his view, the discussion surrounding agriculture has remained the same in Europe, although the worldwide context has rapidly and fundamentally changed.

The first results of the project were then presented in a session on the 'Agricultural soil conservation context'. Stakeholders discussed how to move from the strategic to the operational level. The importance of suppliers in adopting new farming practices was stressed.

An overview of 'Soil conservation practices – agricultural perspective' provided insight into different farming approaches to remedy soil degradation processes. Stakeholders also emphasised the importance of standards and indicators for good agricultural practice. The diversity of agricultural systems and agro-climatic conditions throughout Europe was highlighted and a case-by-case approach (cf. site-specificity) recommended as regards developing and adopting solutions. Agri-environment measures and organic farming were advocated as enabling such site-specific approaches.

In the session on 'Costs and benefits of soil conservation practices', some caution about 'conservation agriculture' was voiced during the discussion. Stakeholders expressed the opinion that the CAP should leave room for a range of systems and models, including other relevant agricultural techniques.

The final session 'Existing policy framework' provided an overview of the current stage of the EU policy frame and made some references to other regions. During the discussion, the importance of involving farmers in the policy making and implementation process was stressed by several stakeholders. Support for the training of farmers in order to help them dealing with the technical complexity of farming techniques was reiterated. The issue of property rights was also mentioned as private ownership of land may limit public intervention. There was a general call for enough flexibility for Member States and for regions in the implementation of EU policies, allowing them to maintain the diversity of Europe by taking into account the local agri-environmental conditions.

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1 Introduction

Agriculture occupies a substantial proportion of the European land, and consequently plays an important role in maintaining natural resources and cultural landscapes, a precondition for other human activities in rural areas. Unsustainable farming practices and land use, including mismanaged intensification and land abandonment, have an adverse impact on natural resources.

Having recognised the environmental challenges of agricultural land use, the European Parliament requested the European Commission in 2007 to carry out a pilot project on 'Sustainable Agriculture and Soil Conservation through simplified cultivation techniques' (SoCo). The European Parliament considered that 'in Europe, soil degradation and erosion is probably the most significant environmental problem' and underlines the importance of conservation agriculture as being a 'set of soil management practices which minimise alteration of the composition, structure and biodiversity of the soil, safeguarding it against erosion and degradation'. While stating that 'Rural development planning action for 2007 to 2013 affords a unique opportunity to make headway with these techniques', the European Parliament underlined that the project should 'foster knowledge of these techniques so that future European legislation can be easily applied'. The project will include knowledge dissemination activities.

The SoCo project was designed in a close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). It has been implemented by the JRC's Institute for Prospective Technological Studies (IPTS) and Institute for Environment and Sustainability (IES). Further information about the SoCo project is available on the website: http://soco.jrc.ec.europa.eu.

The overall objectives of the SoCo project are: (i) to improve the understanding of soil conservation practices in agriculture and links with other environmental protection objectives, (ii) to analyse how farmers can be encouraged to adopt soil conservation practices through appropriate policy measures, and (iii) to make this information available to relevant stakeholders and policy makers in an EU-wide context.

The SoCo project is structured in four work packages (WP):

WP 1: Stock-taking of the current situation within an EU-wide perspective

WP1 reviews the existing literature on agricultural conservation practices, in relation to the main soil degradation processes (erosion, loss of soil organic matter, compaction, salinisation and sodification, contamination, and soil biodiversity decline), and provides a stock-taking of the current situation regarding policy measures that address (or contribute to) soil conservation within an EU-wide perspective.

WP 2: Case studies on soil/land management and policy measures

WP 2 comprises 10 case studies in the EU-27 taking into account territorial coverage, farm structures, typical agricultural soil degradation processes, farming systems and practices, existing policy measures and institutional conditions.

WP 3: Conclusions and recommendations

WP 3 sums up and synthesises the findings, and translates them into conclusions and recommendations. WP 3 brings the results from the case studies (WP 2) back to the EU-wide perspective and links them with the results of WP 1.

WP 4: Dissemination

The SoCo project focuses on six soil degradation processes related to agriculture: soil erosion (water, wind or tillage); soil organic carbon decline; soil compaction; soil salinisation and sodification; soil contamination: heavy metals and pesticides, excess of nitrates and phosphates; and declining soil biodiversity. The review of sustainable farming practices includes eleven individual farming practices and two farming systems (conservation agriculture and organic farming).

Understanding the behaviour of farmers with respect to soil management is central to the project. There are many factors affecting farmers' decisions: farmers use soil management practices according to their business objectives and particular conditions (natural and economic), traditions and knowledge, market conditions (commodity prices, role of the retail industry, etc.) and policies (mandatory regulations, incentive-based measures, recommendations and good practices, etc.). There is a long history of regulating farming practices with respect to natural resources. There are various policy frameworks for the protection of natural resources; major natural resources protection measures are interlinked and, thus, there is a regulatory and policy-incentive system in place, at national and EU levels, influencing soil-relevant farming practices.

Overview of soil degradation processes in connection to agriculture

Soil is defined as the top layer of the earth's crust and is composed of mineral particles, water, air and organic matter, including living organisms. It is a complex, mutable, living resource which performs many vital functions: food and other biomass production, storage, filtration and transformation of substances including water, carbon and nitrogen. Soil further serves as a habitat and gene pool, and provides a platform for human activities, landscape and heritage, and the supply of raw materials[1]. However, despite being a non-renewable resource, soil can be protected against negative pressure, maintained and/or improved in its current status given it is properly used (e.g. by choosing a suitable soil function, appropriate farming practices, etc.).

Sustained economic growth is based on fertile agricultural ecosystems and good soils. If large parts of European soil are, in the future, no longer suitable for agricultural production, due to pollution, loss of organic matter, erosion, salinisation, sodification or compaction, important economic activities can no longer be sustained (EEB, 2006).

Soil structure is affected by cultivation and livestock activities. Agriculture can have positive effects on the state of soils. For instance, land management practices like organic and integrated farming or extensive agricultural practices in mountain areas, can maintain and enhance organic matter in the soil and prevent landslides. However, the measures working in favour of soil protection, conservation and improvement are spread across many areas, and are designed in many cases to safeguard other environmental media or to promote other objectives. Agricultural activity may increase the possibility of erosion in general but also decrease the risk of erosion. This depends on the type of cultivation and on soil coverage and will be discussed in more detail throughout this project. When the humus or topsoil is eroded by water or wind, soil fertility diminishes, with resulting lower yields. Soil erosion in an upstream area can lead to downstream dams being blocked by sediments. This means a loss of water-holding capacity downstream, which can also cause floods. A good soil structure with an appropriate organic matter content contributes therefore to helping prevent or reduce the

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[1] Source: http://ec.europa.eu/environment/soil/index_en.htm

impact of flooding in a flood-exposed watershed by holding the water for as long as possible higher up in the watershed.

Carbon sequestration is considered an option for mitigating climate change and combating organic carbon loss from agricultural soils. Both organic and conventional agriculture systems can fix carbon: organic systems up to 4 000 kg CO_2/ha and conventional systems up to 1 000 kg CO_2/ha. However, farming often contributes to greenhouse gas (GHG) emissions by causing loss of organic matter and through high inputs of fertilisers (EEB, 2006). A loss in organic carbon content can limit the soil's ability to provide nutrients for sustainable plant production. Soil organic matter provides the physical environment for roots to penetrate the soil and for excess water to drain freely from the soil. Organic matter can hold up to 20 times its weight in water, contributing to the water retention capacity of soils. A healthy level of organic carbon in a soil will contribute to a good agricultural productivity of that soil (EEB, 2006).

High levels of salinity in soils cause the withering of plants due to both the increase of osmotic pressure and toxic effects of salts. When alkalinity processes take place, the high pH level does, in most cases, not permit plant life. Excess of sodium, on the exchange complex, results in the destruction of the soil structure that, due to insufficient oxygen, is not capable of sustaining either plant growth or animal life. Alkaline soils are easily eroded by water and wind. Salinisation increases the impermeability of deep soil layers, eliminating the possibility to use the land for cultivation (Van Camp *et al.,* 2004).

Compaction can create significant damage to soil functions (mainly infiltration rate, redistribution of water and nutrients), root development, direction of root growth as well as economical damage by decreases in crop yields and soil productivity (DeJong-Hughes *et al.*, 2001). Compaction reduces rooting depth and plant growth resulting in a lower harvest. Cultivation becomes more difficult demanding more energy. This can cause soils not to be economically viable.

Although soils themselves generally do not travel, the causes and impacts of soil degradation often do. The uptake of contaminants by agricultural food products poses a health threat as most of these products are transported and consumed throughout Europe. The impact of soils on other media like water, air and biodiversity is considered of common importance, e.g. transboundary pollution of rivers or groundwater coming from polluted soils (pesticides, excess of phosphates, heavy metals etc.). Polluted or degraded soils can also lead to lower soil biodiversity (insects/food chain) (EEB, 2006) influencing the breakdown of nutrients and agricultural production. Last but not least, climate change aspects affect soils across country borders; they are equally addressed (e.g. mitigation, adaptation) at a supranational level.

Overview on the European policy frame regarding soil protection

European environment policy has evolved significantly since the 1970s. It has given the EU cleaner air and water and a better understanding of our dependence on a healthy environment. Many environmental problems go beyond national and regional borders and can only be resolved through concerted action at EU and international level. From an initial focus on single pollutants and impacts, the policy has moved into an integration phase, with emphasis on understanding and addressing the pressures on the environment and examining the effects of different policies and behaviour patterns.

Different Community policies contribute to soil protection, particularly environment (e.g. air and water) and the Common Agriculture Policy (CAP) (Rural Development and Cross-compliance, i.e. linking a farmer's eligibility for agricultural subsidies to environmental conditions).

The Sixth Environment Action Programme (6th EAP) sets out the framework for environmental policy-making in the European Union for the period 2002-2012 and outlines actions that need to be taken to achieve them. The priorities of the 6th EAP are climate change, nature and biodiversity, health and quality of life, and natural resources and waste. The 6th EAP calls for the development of seven thematic strategies, including a strategy on the protection of soil. The Soil Thematic Strategy comprises three elements:

- a communication laying down the principles of Community soil protection policy;
- a legislative proposal for the protection of soil, comprising a proposal for a Soil Framework Directive;
- an analysis of the environmental, economic and social impacts of the Strategy.

Related research projects and institutions

Results derived from research projects are incorporated in the stock-taking within an EU-wide perspective to the extent that they give answers to the project's research questions. In order to give an idea of the active players and topics in the fields covered, a non-exhaustive list of European Commission funded research is provided in Annex 1.2. Results of many of these projects have been utilised to prepare these report among them the CC Network, ITAES, ENVASSO.

Also, the following governmental and non-profit institutions form a reliable source of information related to the general topic of this project. While many environmental or agricultural institutions include soil degradation within their analyses[2], several international and/or European organisations dedicate themselves specifically to soil[3]. Amongst other similar institutions, the International Soil Reference and Information Centre (ISRIC; http://www.isric.org/), the European Society for Soil Conservation (ESSC; http://www.essc.sk/), the European Conservation Agriculture Federation (ECAF; www.ecaf.org), and, the International Federation of Organic Agriculture Movements – European Regional Group (IFOAM-EU; http://www.ifoam.org) specifically aim at increasing and disseminating knowledge on sustainable land use and soil conservation practices through research projects, establishment of databases and development of best practices. The European Confederation of Soil Science Societies (ECSSS: www.ecsss.net), a European umbrella organisation founded in 2004, organises quadrennial conferences on soil conservation issues. The European Soil Bureau Network (ESBN; http://eusoils.jrc.it/esbn/Esbn_overview.html), located at the Joint Research Centre (JRC) of the European Commission, Ispra, was created in 1996 as a network of national soil science institutions. Its main tasks are to collect, harmonise, organise and distribute soil information for Europe. European Cities and Municipalities have formed in 2000 the European Land and Soil Alliance (ELSA), based on a common manifesto and the already existing climate alliance. ELSA defines itself as a 'network of European local authorities which jointly pursue the aims of sustainable urban development - in particular the promotion of a sustainable utilisation of soils - in the sense of Agenda 21' (http://www.soil-alliance.org/en/index2.htm).

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[2] For example, the European Environment Agency (EEA; http://www.eea.europa.eu/) dedicates a chapter to soil degradation in its environmental assessment report (European Environment Agency, 2003).

[3] The European Society for Soil Conservation published in 2005 a list of regional and national organisations and persons working on soil. (European Society for Soil Conservation (ESSC), 2005).

Generally, it is possible to distinguish between institutions with a broader scope, such as soil degradation, and specialised ones that exclusively tackle particular aspects of soil degradation and sustainable soil use. Their organisational form ranges from advocacy groups, non-academic think-tanks to local, national and regional groups, some of them further specialised on one of the soil issues. Depending on their origin and mandate, these institutions either stress the environmental, agro-economical, technical or political aspect of soil degradation and sustainable soil use.

Structure of this report

This report contains the findings of WP 1 (Stock-taking of the current situation within an EU-wide perspective). Chapter 2 focuses on the nature, localisation and extent of soil degradation processes. Chapter 3 provides information on soil conservation practices in agriculture, their environmental effects as well as economic costs-benefits and where available, their uptake. Chapter 4 provides a review of the regulatory environment and policy measures for soil protection, conservation and improvement in EU and national/regional implementation. Chapter 5 links the three preceding chapters to establish an EU-wide classification of farming techniques and policy measures addressing soil degradation processes. This is followed in Chapter 6 by the summary report of the stakeholder workshop on 22 May in Brussels and leads into an outlook on the further work of the SoCo project.

Outlook and further work

The following linkages are of particular importance to the SoCo study:

i) the link between farming practices and the state of soils, i.e. how soil characteristics (indicators of soil states) are affected by individual farming practices and systems;
ii) the link between policy measures and farming practices;
iii) the link between the policies for soil protection, conservation and/or improvement actually applied and the state of soils;

In order to be able to establish these linkages and to analyse their mechanisms so as to formulate appropriate policy recommendations, the project initially collected the required data through taking stock of relevant policies and measures related to soils within the EU-27.

However, the current findings and the data received from the stock-taking of the policies do not provide sufficiently detailed insight, since several indicators and data-sets are not available at EU level, or are too general or indirect to be utilised.

It is, therefore, necessary to conduct further data collection. Considering the level of precision required from the data and taking account of the conclusions and recommendations expected, this can only be achieved at the case study level. Case studies are also needed to check the theory against the practice and clarify context-specific links between soil degradation processes, farming practices and policy measures.

The case studies envisaged in the SoCo project had to be representative of the situation within the European Union as well as respond to the data needs of the project. Consequently, ten case studies were selected; they were located in three different macro-regions:

i) The Northern and Western European region: Belgium (West-Vlaanderen), Denmark (Bjerringbro and Hvorslev), and United Kingdom (Axe and Parrett catchments);
ii) The Mediterranean region: Greece (Rodópi), Spain (Guadalentín basin), France (Midi-Pyrénées), and Italy (Marche);

iii) The Central and Eastern European region: Bulgaria (Belozem), Czech Republic (Svratka river basin), and Germany (Uckermark).

The case studies followed a common outline:

i) Developing a common agri-environmental framework.
ii) Developing a common framework for policy analysis.
iii) Conducting the case studies according to the same analytical and methodological framework.
iv) Case study workshops to present and discuss the main results with relevant stakeholders.
v) Identifying which measures, and under which conditions, have provided better or worse results and assessing the underlying reasons.

The methodological details and results of the case studies as well as an overall assessment of the effectiveness of the policy framework as regards soil protection, conservation or improvement are provided in a forthcoming SoCo report.

2 Soil degradation processes across Europe

Soil degradation is accelerating, with negative effects on human health, natural ecosystems and climate change, as well as on our economy. In order to achieve the objective of the SoCo project which is to encourage farmers to adopt 'simplified cultivation techniques' that enhance agricultural sustainability, a European-wide assessment needs to be made of the agricultural soil degradation processes. The diversity of European soils, climate and agricultural practices produce both widespread and localised degradation problems which require site-specific measures to enable the continuation of agriculture as will be discussed in chapter 4. The nature, localisation and magnitude of the following agricultural soil degradation processes are reviewed:

- erosion (water, wind and tillage);
- decline in organic carbon content;
- compaction;
- salinisation and sodification;
- contamination (heavy metals and pesticides; excess of nitrates and phosphates);
- decline in biodiversity.

Links with soil conservation practices and related environmental issues (as e.g. water quality, air quality, biodiversity) are explored as well.

The soil degradation processes have been analysed using the best available data. However, available data show serious gaps in quality, comparability and geographical distribution. To create a more complete and qualitatively better picture, data improvements need to be pursued. Ideally, this would be done by developing a harmonised monitoring system across Europe. Furthermore, additional research is needed to complete and update the knowledge on EU-wide soil degradation processes. As these needs vary depending on the different degradation processes, the research needs will be specified in the respective paragraphs.

A summary of all assessment methods with corresponding input and output indicators for each of the described soil degradation processes is presented in Annex 2.17.

2.1 Erosion

2.1.1 Water erosion

Soil particles are detached by raindrop impact and flow traction and transported by overland water flow. Physical factors like climate, topography and soil characteristics are important in the process of soil erosion. Also land abandonment can result in increased erosion, for example through the collapse of old terraces.

Indicators of water erosion are the presence of rills, gullies and the accumulation of sediment at obstructions or where the land levels out.

Erosion is a natural process, but is intensified and accelerated by human activities such as deforestation for agricultural purposes, changes in hydrological conditions, overgrazing and inappropriate cultivation techniques and/or cropping practices. The impact of raindrops causes the breakdown of soil aggregates into smaller parts, which are re-deposited between aggregates on and close to the surface, forming ‘soil crusts’. Soil crusts seal the surface, limit infiltration and increase run-off. Bare soils are more vulnerable since the raindrops are not intercepted by vegetation and are subject to the full impact of the raindrops. With the loss of topsoil, the soil becomes less fertile and the aquatic ecosystem contaminated. Erosion in agricultural areas could undercut the base of slopes, causing landslides. With a very slow rate of soil formation, any soil loss of more than 1 t/ha/yr can be considered as irreversible within a time span of 50 - 100 years (Van-Camp *et al.*, 2004).

The Mediterranean region is particularly prone to erosion as it is subject to long dry periods, followed by heavy bursts of erosive rain, falling on fragile soils on steep slopes. It is clear that water erosion is irreversibly degrading the soils in many parts of Europe. In both cases off-site impacts are as damaging as on-site effects (Table 2.1). Erosion mitigation and prevention can be obtained through conservation tillage, using an increased percentage of soil cover, reduced or no-tillage. Land abandonment should be prevented where there is a risk that it will result in land degradation. In husbandry it is important to bring stocking densities in line with the ecological capacity of the area to prevent soil compaction and erosion.

Table 2.1: On-site and off-site damages due to soil erosion

Kind of erosion	On-site damage	Off-site damage
Water	• Loss of organic matter • Soil structure degradation • Soil surface compaction • Reduction of water penetration • Supply reduction to water table • Surface erosion • Nutrient removal • Increase of coarse elements • Rill and gully generation • Plant uprooting • Reduction of soil productivity	• Floods • Water pollution • Infrastructures burial • Obstruction of drainage networks • Changes in watercourses shape • Water eutrophication

Source: Giordano, 2002

'An estimated 115 million hectares or 12 % of Europe’s total land area are subject to water erosion, and 42 million hectares are affected by wind erosion' (COM(2006) 231). It is estimated that at present water erosion in the Mediterranean region could result in the loss of 20/40 t/ha of soil after a single cloudburst, and in extreme cases the soil loss could be over 100 t/ha. Besides soil loss, the financial aspect is also substantial; the Impact Assessment of the Thematic Strategy states that the cost of soil erosion for the EU-27 is EUR 0.7 - 14.0 billion.

Methodology

At European level, many models have been applied for soil erosion risk assessments. To date, PESERA provides the only Europe-wide estimates of water erosion that are based on a harmonised approach and standard data sets (Kirkby *et al.*, 2004). PESERA is a physically based and spatially distributed model, combining the effect of topography, climate and soil into a single integrated forecast of run-off and soil erosion. Four main datasets are required to run the PESERA model: climate, soils, land cover and topographic data. PESERA uses the simplest possible storage, or 'bucket' model to convert daily rainfall to daily overland flow run-off. Run-off is estimated by subtracting Threshold storage from Rainfall. The threshold depends on factors related to the soil, vegetation cover, tillage and soil moisture status. The MARS database (Monitoring of Agriculture with Remote Sensing – MARS project, JRC) provides daily time series of rainfall, temperature and potential evapotranspiration, interpolated to a 50 km grid for Europe. These data have been further interpolated at a 1 km resolution, using an inverse-spline mathematical procedure, to provide the monthly data layers for the model.

Version 2.0 of the European Soil Database (ESDB, 2004) has been used to provide soil erodibility (run-off to erosion rates conversion), soil water storage capacity (maximum storage capacity of the soil before run-off) and crustability (sets the lower limit of storage capacity for a crusted soil in areas lacking vegetation), on a consistent basis at 1 km resolution across Europe.

Land use is based on the CORINE Land Cover at 250 m resolution for 1990, and these data are combined with cereal planting dates to provide the parameters for a crop or natural vegetation growth model. A 30 second (1 km) digital elevation model available from EROS (Earth Resources Observation and Science) has provided the topographic basis for the PESERA erosion map (Kirkby *et al.*, 2004).

The diagram of the PESERA concept is given in Figure 2.1.

The scale of the data used for the PESERA model is mentioned in the diagram. The data refers to a continental scale and the final output is a grid with a 1 km cell size (100 ha) (Figure 2.2). The PESERA model excludes Finland and Sweden, mainly due to a lack of topographic data. This is due to the fact that the SRTM (Shuttle Radar Topography Mission) data don't cover the area above 60 degrees latitude.

In order to have a complete picture of the soil erosion risk in all 27 member states, the Revised Universal Soil Loss Equation (RUSLE) was applied for Finland and Sweden; the model is explained in Box 2.1. Annex 2.2 gives the combined soil erosion risk assessment map for the EU27 (based on the PESERA and RUSLE models).

Figure 2.1: Diagram of model concept for PESERA

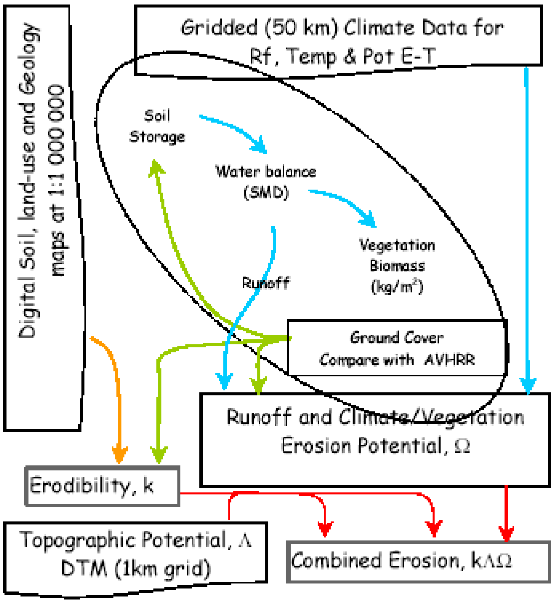
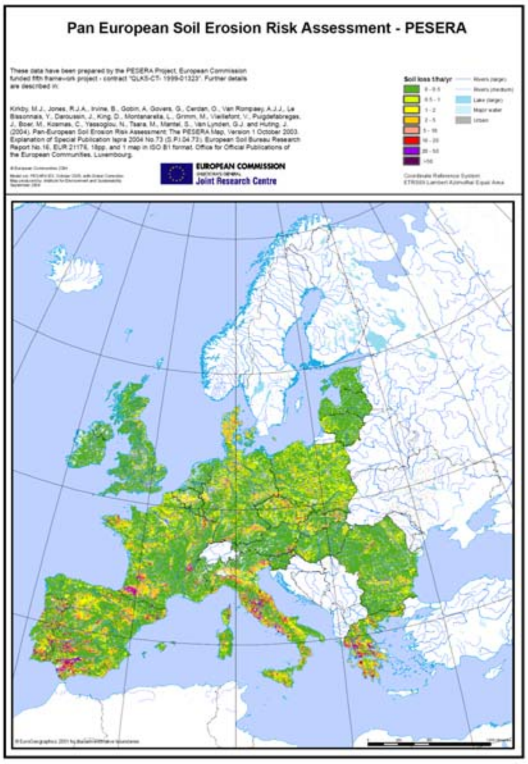


Figure 2.2: PESERA map



Box 2.1: RUSLE approach for Finland and Sweden

RUSLE estimates erosion by means of an empirical equation:

$$A = R * K * L * S * C * P \text{ ; with:}$$

A = (annual) soil loss (t/ha/yr)
R = rainfall erosivity factor (MJ mm/ha/h/yr)
K = soil erodibility factor (t h/MJ/mm)
L = slope length factor (dimensionless)
S = slope steepness factor (dimensionless)
C = cover management factor (dimensionless)
P = Support practices factor (dimensionless)

As no spatial information regarding practices (reflecting the impact of support practices on the average annual erosion rate) was available, the P factor was given value 1 and, thus is not taken into consideration. The outcomes of the SoCo project will include the information referring to the conservation agricultural practices which will make it possible to adjust the P factor.

The data used for the RUSLE model are as follows:

- climate, R factor, monthly precipitation from MARS database ;
- Soil, K factor, Soil Geographical Database of Europe 1:1 000 000;
- Topography, L and S factor, SRTM and for the area of Finland and Sweden not covered by SRTM data, a DTM was used with a resolution of 90 m derived from topographic maps (see following Figure B.1).
- Land cover, C factor, CORINE Land Cover 2000 (Suri *et al.*, 2002).

The main changes in the data elaboration compared to the RUSLE standard methodology are related to the calculation of the R factor and L factor. The available MARS climatic data are not detailed enough in order to apply the R factor according to methodology proposed by Wischmeier (1959). The definition of R factor for Finland and Sweden has been prepared using with empirical algorithms. Many of them, e.g. Arnoldus (1980), Yu and Rosewell (1996), are tested for those areas and the most suitable is Renard and Freimund (1994) using the Fournier Modified Index.

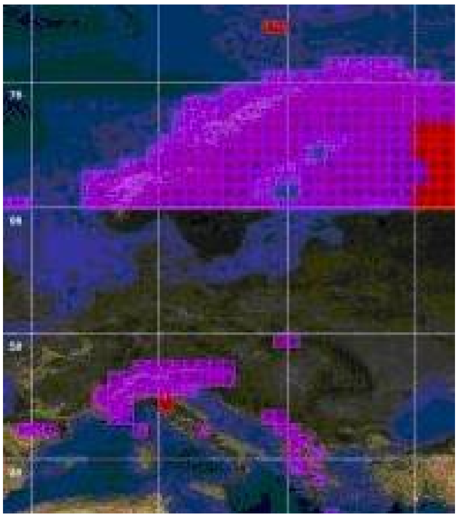
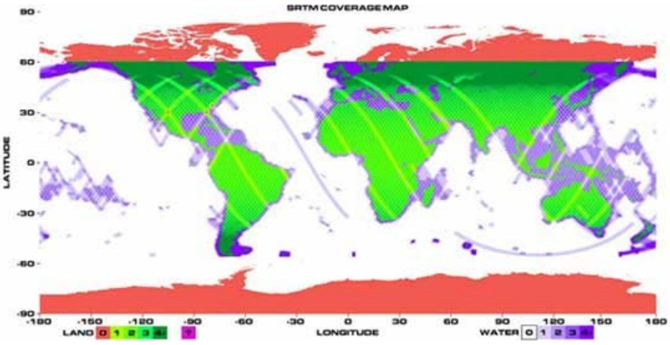
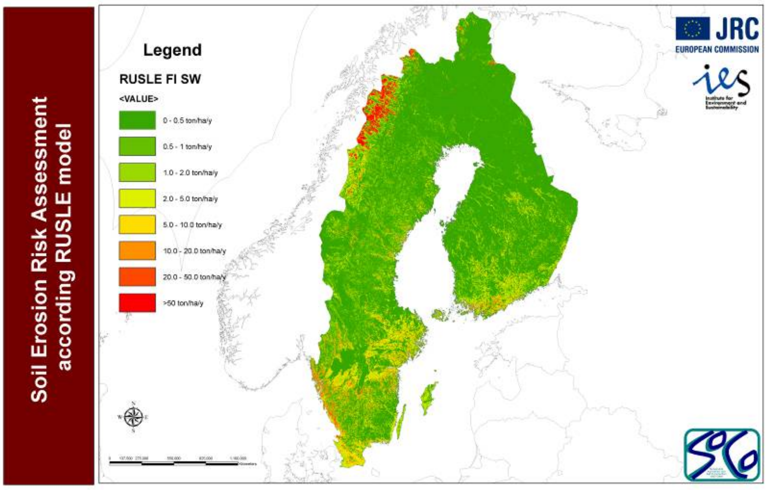


Figure B.1: Area covered by SRTM (below) and data derived by topographic map (left)



The output of the RUSLE model for Finland and Sweden is a grid with a 100 m resolution. The final result is shown in the following Figure B.2.

Figure B.2: Soil erosion risk assessment for Finland and Sweden

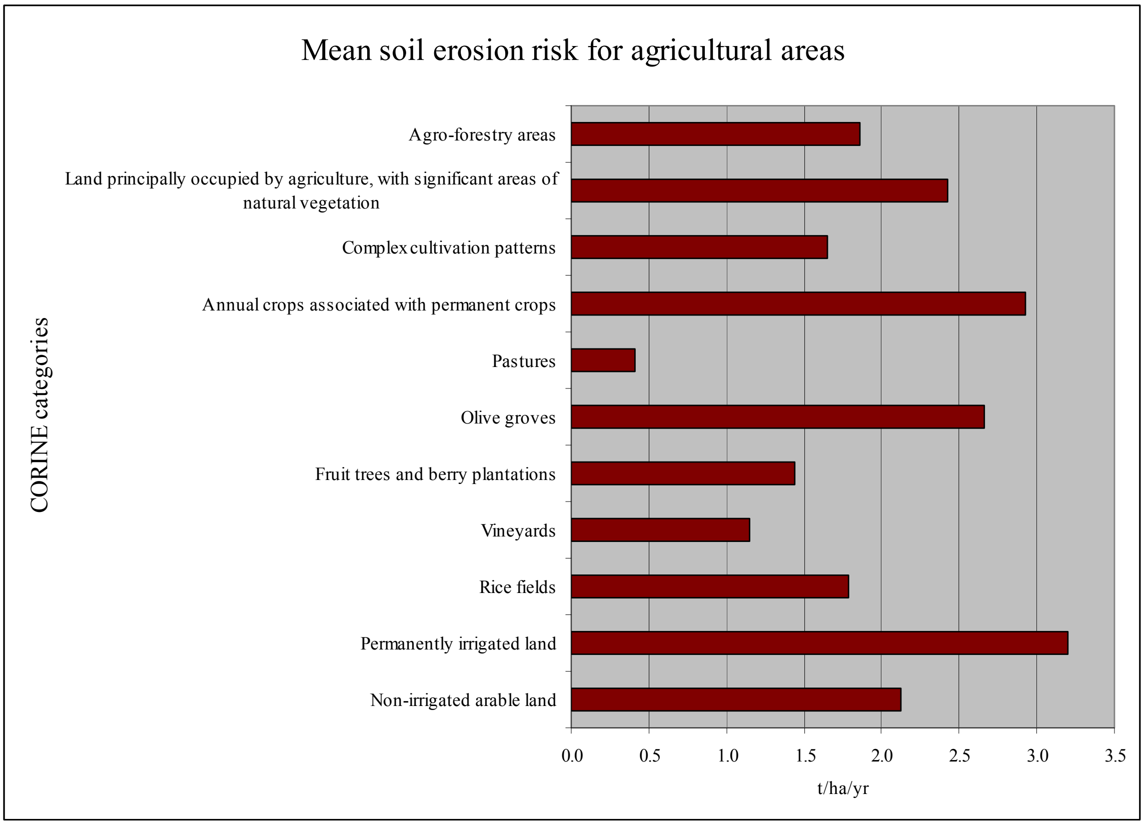


When analysing the results for Finland and Sweden, it has to be noted that the RUSLE equation gives an overestimation of the soil erosion risk for the northwestern part of Sweden. This is mainly due to topographical and land cover factors (L, S and C factor). The C factor (the effect of cropping and management practices on erosion rates) is evaluated according to CORINE Land Cover, at more than 0.5. This implies that the actual soil erosion risk is estimated as just half of the potential soil erosion.

The SoCo project focuses on sustainable agriculture and soil conservation. The soil degradation processes are analysed in relation to the agricultural land. The agricultural areas are identified using the CORINE Land Cover 2000 data and correspond to class 2 of the first level of the CORINE Land Cover classification (see Annex 2.3).

The positive effects of agricultural conservation practices on soil are well known, but at a European level it is quite difficult to identify areas where those practices are applied. The first step in portraying the soil erosion risk in agricultural areas is to define the magnitude of the problem. A straightforward evaluation is to use the average of the soil erosion risk, expressed in t/ha/yr, for agricultural land as defined through the CORINE Land Cover 2000 (Figure 2.3).

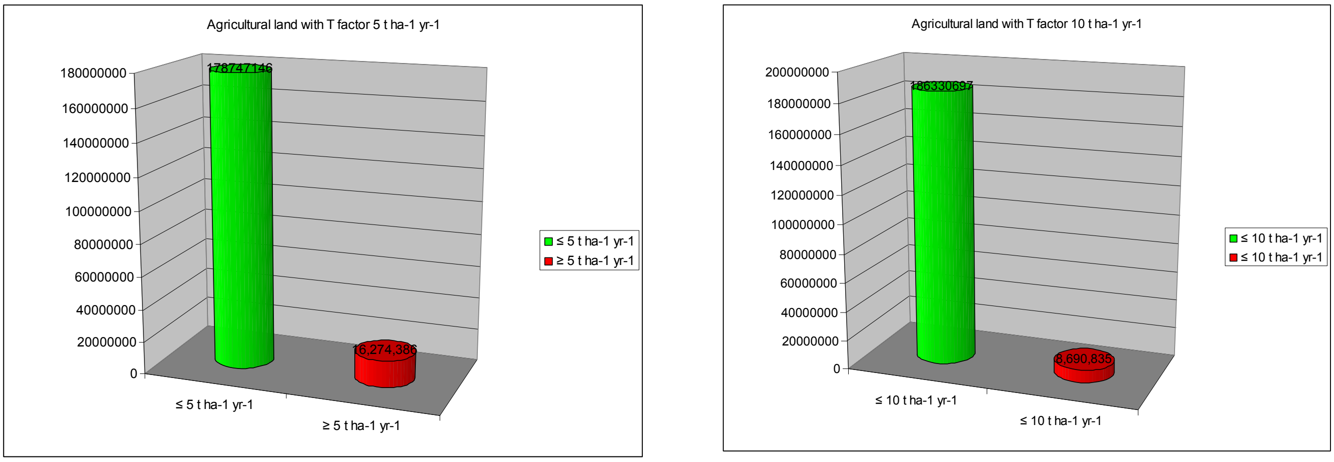
Figure 2.3: Mean value of soil erosion risk for agricultural areas



Results and analysis

According to the PESERA (and RUSLE for Sweden and Finland) analysis the average soil erosion risk for agricultural areas is relatively low. In these models it is not possible to take give an equal importance to all factors that influence erosion. When using models the results have to be interpreted taking into account the limitations of a model. Some factors, such as run-off for example, are at risk of being overestimated. Whether rain becomes run-off or infiltrates into the soil, depends on the condition of the soil. The model does not include the infiltration rate, but instead focuses on the available water capacity. For example, a clay soil in summer may be very dry which makes the PESERA model expect this soil can absorb a lot of rainwater. Instead the soil has dried out so much, a crust has developed preventing water to infiltrate and thus all rain becomes run-off. The model will still show this soil to have a low erosion risk, while field observations show the opposite. Flat areas are generally expected to have a low risk of run-off. PESERA shows a high erosion risk for the Po Valley, indicating that in this area other factors have a greater influence on the erosion risk assessment than slope. When excluding all agricultural land with no slope from the analysis, the average soil erosion risk increases. These results have to be compared with the 'T factor' (the soil loss tolerance). Soil loss tolerance represents the maximum rate of soil loss that can occur while still permitting crop productivity to be sustained economically (Renard *et al.*, 1997). The USDA (United States Department of Agriculture) fixed the soil loss tolerance between 2 to 10 t/ha/yr, depending on soil type. Based on this information the mean erosion risk for all agricultural land use categories (CORINE) is below the soil loss tolerance limit (Figure 2.4). Following this criterion the total agricultural area with a T factor more or equal to 10 t/ha/yr is 8.7 million hectares. Taking 5 t/ha/yr as the upper limit of the T factor, the agricultural area at risk encompasses 16.3 million hectares. Soils with a T factor of 2 t/ha are generally not used for cultivation as they are shallow and very vulnerable.

Figure 2.4: Agricultural areas with a T factor above 5 t/ha/yr (left) and 10 t/ha/yr (right)



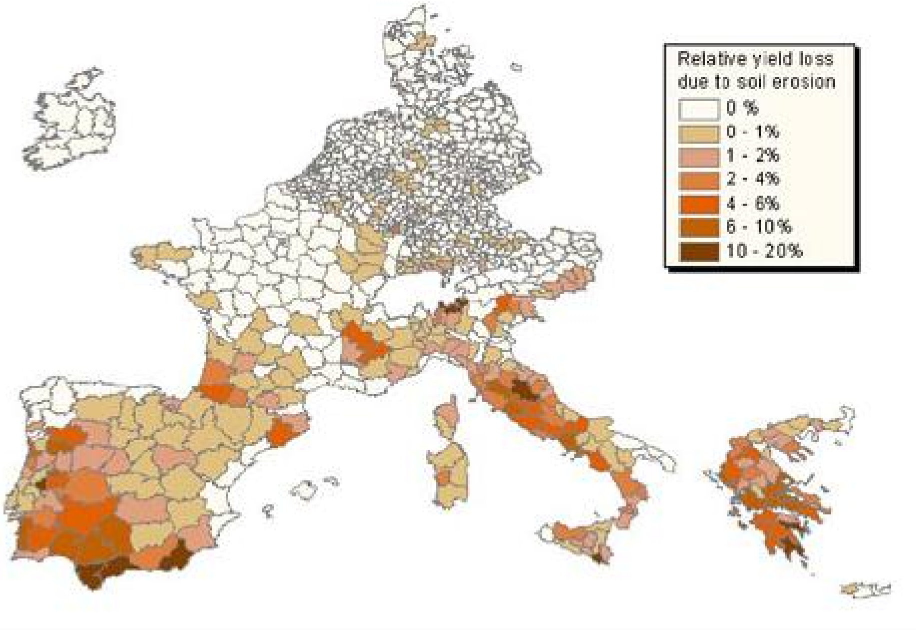
Classes	In %	Hectares agricultural Areas
≤ 5 t/ha/yr	91	178 747146
≥ 5 t/ha/yr	9	16 274 386

Classes	In %	Hectares agricultural Areas
≤ 10 t/ha/yr	95	186 330 697
≥ 10 t/ha/yr	5	8 690 835

In many cases statistical data on agriculture (farms structure, livestock, crops, mechanization, etc.) including management practices, refer to an administrative level. Even if it is impossible to geo reference the data, it could be useful to analyse them in comparison with the soil erosion risk at the same NUTS level (Nomenclature of Territorial Units for Statistics). Therefore the soil erosion risk map was mapped at NUTS 2 and 3 (Annex 2.5 and 2.6).

Bakker *et al.* (2007) have investigated the effect of soil erosion on yield loss. These results (Figure 2.5) are at NUTS 3 level and correspond to the results in Figure 2.3. Locations with highest yield losses correspond to areas with highest erosion risk on the PESERA-RUSLE map (Annex 2.2).

Figure 2.5: The relative loss in wheat yields due to soil erosion in 100 years calculated for NUTS 3 units and based on the UNEP yield scenario (Bakker *et al.*, 2007)



Conclusions and needs for future research

The analysis demonstrated that the spatial resolution of the soil erosion risk map is suitable to make evaluations and analyses at European level using simple indicators like mean risk of soil erosion for agricultural areas.

According to what can be expected from the geographical distribution of the major drivers for soil erosion (intense rainfall and long droughts, topography, low soil organic matter content, vegetation cover, marginalisation/land abandonment) in the Mediterranean countries several areas can be observed with a high risk of erosion, emphasising the hotspots in need of attention. Figure 2.2 (and Annex 2.2) also shows a widespread erosion risk across among others France, Germany and Poland. This risk may be at the lower range but can amount to a substantial problem. Unexpectedly, the map shows hilly to mountainous areas (Pyrenees, Apennines and the Alps) with very low or no erosion risk. These are largely forested areas by which soils are stabilised.

One of the main challenges is how to create a link between the soil erosion risk and the management factors and land use. Unfortunately these data are not organised and easily applicable into the models used. Much more efforts and research are needed in order to calibrate and validate the prediction model for soil erosion risk; a better link with the management practices (human-induced soil erosion) is needed too.

A possible approach is to consider the agro-ecological zones in Europe. Climate, soil and terrain relationships decide the potential and/or limitations of agricultural production. A set of management factors will help to optimise sustainable production. National policy and support measures need to be adapted to these facts. This will prevent cropping systems being established under unsuitable conditions (e.g. ploughing extensive grazing fields to replace these by barley).

2.1.2 Wind erosion

Wind erosion is the transport of soil particles by wind and forms part of the degradation process on arable land by segregating the soil particles. The removal of mainly the finest soil particles results in a gradual decrease in the soil fertility, so that the effects of wind erosion are detectable only after years or decades. The Global Assessment of Soil Degradation (GLASOD) found 42 million hectares or 4 % of the European territory to be affected by wind erosion (EEA, 2003). Three different modes of particle transport, which depend on particle size, can be defined: creep (>500 µm along the surface, event), saltation (70 - 500 µm, event), short term suspension (20 - 70 µm, hours) and long term suspension (<20 µm, days, >100 km transport) (Shao, 2000).

Wind erosion occurs when two conditions coincide: favourable meteorological conditions (e.g. high wind velocity) and favourable ground conditions (loose particles on a susceptible surface and lack of surface protection by crops or plant residues). Wind erosion itself is a natural phenomenon, but might be accelerated by human influence, especially cultivation or overgrazing. The climate’s erosivity and the soil’s erodibility determine the extent of wind erosion and are additionally influenced by the interactions of various other components resulting in a high temporal variability of the actual erodibility of a particular site (Lyles, 1988; Warren and Bärring, 2003). The climate’s erosivity depends on the interactions between intensity, frequency and duration of wind velocity and wind direction, amount and distribution of precipitation, humidity, radiation, snow depth and evaporation (Funk and Reuter, 2006). The soil’s ability to resist erosive meteorological conditions mainly depends on soil texture and organic matter content, which influence the water-holding capacity and the ability of the soil to produce aggregates or crusts (Chepil, 1955). Other influencing parameters are vegetation cover, roughness, field size, which are further discussed in Funk and Reuter (2006).

Measures against wind erosion are manifold and can be divided into measures to increase the resistance of the soil surface and measures to reduce the surface wind speed, whereas some measures against wind erosion meet both. Creating a rougher surface stimulates the turbulence of air masses, which increases the dissipation of the kinetic energy of the wind at the surface thereby slowing down the wind velocity (Stull, 1988). This is valid at all scales, from landscapes to single particles. Secondly, at field level, arranging hedges perpendicularly to the prevailing wind direction can give a protection of up to 25 times their height (Nägeli, 1943). The creation of shelterbelts is a very expensive long-term strategy, and becomes effective only after a number of years. Additionally, by creating larger soil clods (e.g. by applying no or reduced tillage), more area is sheltered because the leeward side of clods or furrows is shielded against wind action and particle impact (Potter and Zobeck, 1988). Soil cover is the best measure against wind erosion. Wind erosion risk is greatly increased on soils that are covered for less than 10 % (Morgan and Finney, 1987; Funk, 1995; Sterk, 2000). Soil cover greater than 10 % reduces wind erosion rapidly, and complete prevention occurs when the soil cover is over 40 %. Other measures like surface fixations with slurry exist.

Other considerations appropriate at field level are water table management using drainage and irrigation systems, and crop management according to good farming practices. For example, the increase in maize of recent decades has resulted in an increased susceptibility to wind erosion; the reduced plant cover combined with the longer duration of bare soil are responsible. At regional level, the roughness of the landscape can be described according to the size and distribution of its elements. The greater the heterogeneity of a landscape (e.g. a mixture of forest and agricultural area), the greater is its roughness, which results in a lower susceptibility to wind erosion.

Wind erosion decreases soil fertility by removing the finest, more nutrient-rich top layers of the soil (van Lynden, 1995). It impacts on air quality, which in turn influences the global climate due to changes in atmospheric radiation balance by aerosols (Shao, 2000; EEA, 2003; Goossens, 2003). It damages crops to the point where arable land has to be taken out of production (Schroeder and Kort, 1989; Jönsson, 1992; Veen *et al.*, 1997) and pollutes adjacent areas. Wind erosion removes soil organic matter, thereby decreasing the aggregate stability of the soil, which negatively affects the denitrification potential (removal of nitrogen by micro-organisms) for biomass productivity, and even decreases soil organic matter storage in terms of climate change mitigation.

Methodology for defining wind erosivity

A first approximation of wind erosivity across different years can be made by summarising wind integrals (hourly, daily) for the texture of different soil surfaces depending on wind velocities thresholds (Beinhauer and Kruse, 1994). The Wind Force Integral (WFI) defines the potential transport capacity of the wind at the soil surface as a function of the wind force and the surface moisture content, providing that the following conditions are met:

(i) precipitation < 0.3mm in that time step (e.g. no rain event),
(ii) precipitation (m) < evaporation (m), and,
(iii) average wind speed (u) in m/s > the soil textural threshold (u_{thr}) in m/s:

$$WFI = \sum_{1}^{n} (u - u_{thr}) \times u^2$$ for the time steps (n) per month or per year.

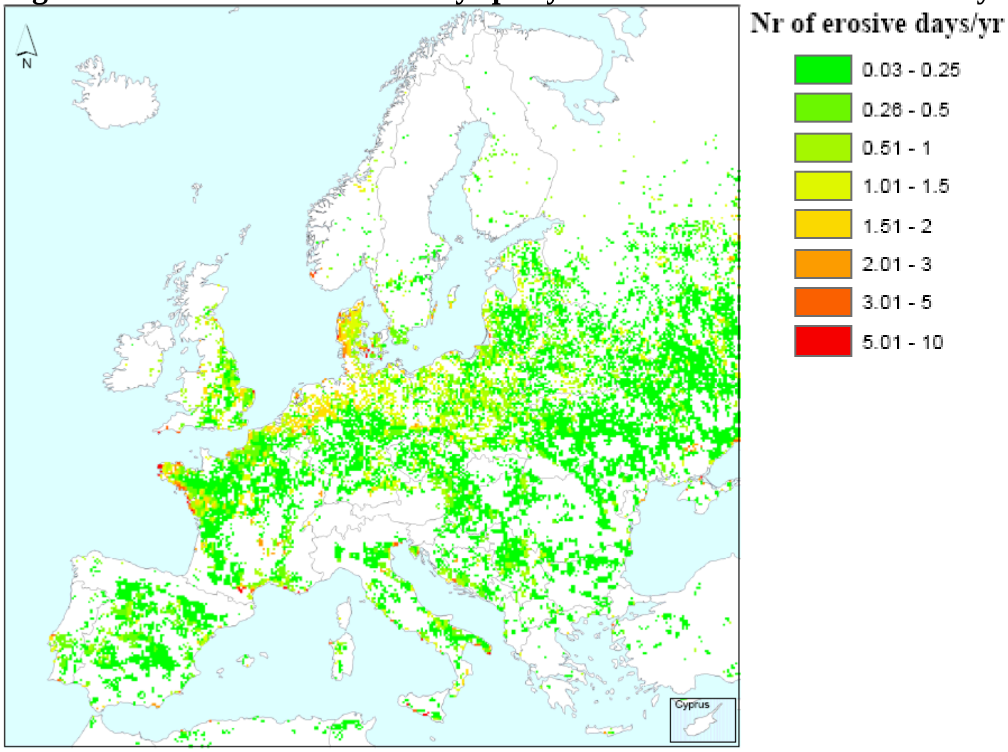
Climate data used in the presented analysis are provided by the FP5 research project PRUDENCE (http://prudence.dmi.dk), which provides high resolution downscaled climate scenarios. The soil textural threshold has been derived based on the dominant soil surface texture from the European Soil Database (ESDB, 2004). Soil textural data from Zobler (1986) were used as an additional information layer in areas where no data were available in version 2.0 of the European Soil Database. It is assumed that only agricultural areas under cultivation are prone to wind erosion. Agricultural areas have been extracted from the CORINE Land Cover 2000 database or from the Global Land Cover Database (GLC) 2000 (Bartholomé and Belward, 2005). No information on plant cover, seeding times or field size has been used, as a consistent dataset with sufficient resolution and harmonised methods is not available for Europe.

Results and analysis

The map in Figure 2.6 evaluates the erosivity of the climate according to climatic conditions (e.g. wind velocity) and the soil erodibility (e.g. soil texture). It shows the 30-year average number of erosive days for bare soil conditions (enlarged version in Annex 2.6). The daily, monthly and yearly variability of wind erosivity in Europe shows a strong spatially diverse pattern over the years. The maximum number of erosive days, observed over the whole area modelled, varies between 11 and 24 days over the period 1961-1990. The northeastern part of the UK experienced quite severe erosion conditions in 1983 and 1987; whereas only limited erosion was observed in the years in between. A similar observation can be made for northeastern Germany. A changing pattern in extent and distribution of wind erosion potential should be expected as climate conditions and the soil surface are interacting differently from year to year (month or day).

Using the present data, it appears that areas with high potential for wind erosion coincide with the sand belt (e.g. areas in northeastern UK, Denmark, northern Germany, Poland, parts of Russia). Certain countries (e.g. Sweden and Norway) do not show any wind erosion risk, even if these countries contain agricultural areas and are known to observe wind erosion (Jönsson, 1992). However, the information currently contained and used for the threshold friction velocity is based on the European Soil Database, which may not represent sufficiently the current conditions and hence may need updating.

Figure 2.6: Number of erosive days per year calculated over the last 30 years



Conclusion and needs for future research

The map in Figure 2.6 provides an overview of the geographic spread of areas prone to wind erosion. For this evaluation the soil is assumed to be bare, since land cover and management are not incorporated into the model. The omission of soil cover is a limiting factor in this analysis and the interpretation of the results should take that into account. The highest number of erosive days on bare soil per year (calculated over the last 30 years) can be found across the sand belt that covers southeast England, the Netherlands, northern Germany, and Poland. Additionally, the areas exposed to high wind velocities at coastlines show elevated levels of wind erosion. However, these areas might be influenced strongly by scale effects of the modelling exercise. These scale problems can only be overcome if more detailed information about soil, climate and land management is available for modelling. The hotspots for wind erosion on bare ground may have a different distribution when the data allow the cell size to be smaller than the 100 km^2 used here. The hotspots on coastlines will certainly disappear if a wind erosion assessment is performed that includes soil cover and/or management factor. To specify hotspots of wind erosion for policy purposes the evaluation needs more (soil cover and land management) and more detailed data.

Some progress has been achieved in wind erosion research in recent years. The transfer of detailed field-scale results, as provided by WEELS (Wind Erosion on European Light Soils; http://www2.geog.ucl.ac.uk/weels/) or the WELSON (Wind Erosion and Loss of SOil

Nutrients in semi-arid Spain; Gomes *et al.*, 2003) project, to larger scales should be the next Europe-wide challenge. Micro-topography measurement techniques like 3D, LIDAR-based approaches have already been developed, but still need to be implemented. A time series of meteorological data is needed for any erosion risk assessment to give at least an idea of how the risk is related to time.

2.1.3 Tillage-related erosion

Two other erosion processes should be mentioned in relation to human influence; tillage erosion and soil loss due to harvesting.

Tillage erosion is the displacement of the cultivation layer due to cultivation. Slope and the tool used for tillage have quite a strong influence (Lindstrom *et al.*, 1992; Govers *et al.*, 1999). Tillage erosion is not just soil loss (as is the case with water erosion, where sediments are washed into river and streams), but rather a translocation of soil in the landscape. Tillage erosion can be generally be influenced by (van Oost and Govers, 2006):

i) reducing tillage speed and depth,
ii) ploughing on consolidated instead of pre-tilled soils and
iii) ploughing along contour lines.

Erosion rates often exceed 10 t/ha/yr (Govers *et al.*, 1994; Poesen *et al.*, 1997; Tsara *et al.*, 2001; de Alba, 2003); however, no Europe-wide assessment has been performed.

A second type of tillage-related erosion is the loss of soil due to crop harvesting. The literature (e.g. Auerswald and Schmidt, 1986; Eichler, 1994; Poesen *et al.*, 2001) reports rates of around 2 t/ha/yr for potato and 9 t/ha/yr for sugar beet, therefore similar to water and tillage erosion values. A first attempt to quantify the effects of soil loss through harvest has been performed by Ruysschaert *et al.* (2006); however more reliable information across all Member States is strongly needed.

2.2 Organic carbon decline

The soil organic carbon content includes all carbon-containing constituents like undecomposed organic vegetation residues, soil fauna and humus. It is not a uniform material but is made up of very heterogeneous mixtures of both simple and complex substances containing carbon (C). Soil organic carbon (SOC) can be divided into different pools based on composition and ease of decomposition.

Firstly, the labile pool includes easily decomposable organic materials that stay in the soil for fairly short periods, from a few days to months. They are important as food and energy sources for soil organisms, as a source of plant nutrients (nitrogen and phosphorus) and for promoting the stability of large soil aggregates. This pool also includes micro-organisms, many of which are involved in the actual decomposition and recycling processes. Because these materials stay in a soil for only a short time, they are not taken into account in this report. Secondly, the slow pool includes well decomposed and stabilised organic materials, often referred to as humus. They stay in the soil for many years and are important for stabilising soil structure (micro-aggregates), improving water-holding capacity and retaining plant nutrients, e.g. cations. Thirdly, the inert pool includes biologically very resistant organic materials which are thousands of years old in soils. Chemically they are similar to charcoal and because of their charge properties and porous nature they can retain cations and improve soil physical properties.

For a healthy soil, the three pools of organic carbon are all present and are needed to serve different functions of the ecosystem. Therefore SOC is a good indicator of soil health. Not only total SOC but also the proportions of the different pools are also indicative of the health status of the soil. Organic carbon inputs can thus restore and increase soil health.

Many degraded soils lack labile and slow pools of organic carbon. To restore soil health, it would be necessary to add organic C materials that can replenish both the labile pool (to increase the food source for soil microbes and provide available nutrients for plants) and the slow pool (to improve soil structure and soil physical properties) (Chan, 2008).

Soil organic carbon (SOC) accounts for more than 95 % of the total carbon accumulated in pastures and perennial crops and nearly 100 % of the total carbon accumulated in arable land. SOC enhances the resilience of agricultural ecosystems. In addition, soil is among the mandatory carbon pools to be reported for agricultural land use under the Kyoto Protocol, and it is certainly one with the highest potential, both in terms of enhancement of the C sink and reduction in C emissions. SOC can be a source of greenhouse gases through the formation of CO_2, CH_4 and N_2O. It can be also a sink through C sequestration under an organic form (Van-Camp *et al.*, 2004).

Soil type and properties (e. g. soil texture) are important and contribute to an explanation of the initial carbon content. Sandy soils are normally low in organic matter (OM); in contrast many soils rich in clay (e.g. Luvisols) or amorphous products (e.g. Andosols) can accumulate OM in a stable form (humus).

SOC is a dynamic characteristic that is mostly affected by land use, climate and the hydrological situation. Climate (mainly temperature and precipitation) has a critical influence on carbon mineralisation or accumulation. This influence explains the existence of a climatic gradient from north to south, with high carbon content in the cold, northern part of Europe and in mountainous areas and lower concentrations in the hot, semi-arid southern part (Mediterranean). Another influencing factor is the soil hydrology: organically rich soils (e.g. peats) are normally formed in anaerobic and wet conditions, which favour accumulation of undecomposed vegetation residues. Considering the whole of Europe, 22 million ha of soils have more than 6 % organic carbon; in contrast, 74 % of the soils in the southern part of Europe have less than 2 % organic C (Van-Camp *et al.*, 2004).

Under appropriate long-term agricultural practice, the SOC content can be kept in equilibrium with climate, temperature and precipitation, due to the nature of the crop residues and organic matter management. Recent trends in land use and climate change resulted in SOC loss at a rate equivalent to 10 % of the total fossil fuel emissions at pan-European scale (Janssens *et al.*, 2004). A survey of Belgian croplands (210 000 soil samples taken between 1989 and 1999) indicated a mean annual SOC loss of 76 g C/m^2 (Sleutel *et al.*, 2003). A large-scale inventory in Austria revealed that croplands were losing 24 g C/m^2 annually (Dersch and Boehm, 1997). Carbon losses from soils across England and Wales in 1978-2003 were about 13 million tons of carbon annually (Bellamy *et al.*, 2005). Grassland is seen as a net C sink in most European countries. The overall mean C sink is 60 g C/m^2 annually.

However, the uncertainty of this estimate is high (Vleeshouwers and Verhagen, 2002). SOC enhancement in agriculture can be achieved either through a reduction in soil disturbance and a decrease in the rate of SOC mineralisation (e.g. reduced or zero tillage, set-aside land, growth of perennial crops, etc.) or through an increased input of organic materials into the soil (e.g. application of manure, crop residues, fertilisation, etc.) or both (Lal, 2004). Several studies have evaluated the capacities of the different modifications in land use and land management to increase the SOC stocks in the EU (Liski *et al.*, 2002; Freibauer *et al.*, 2002; Smith *et. al.*, 2005, 2006). However, these studies do not explicitly relate SOC enhancement measures to diversity of soil types. This indicates a need to synthesise the existing knowledge on the SOC dynamics in agricultural soils with a view to developing a methodology for identifying areas and magnitudes for potential changes of SOC over time.

Following the framework for risk area identification (Eckelmann *et al.*, 2006), the risk is defined as the probability of SOC loss (removal of carbon from the soil) or SOC gain (accumulation of carbon in the soil). A loss in SOC content can limit the soil's ability to provide nutrients for sustainable plant production. SOC is a source of food for soil fauna and contributes to soil biodiversity. SOC supports soil structure, which improves the physical environment for roots to penetrate through the soil, enhances the water retention capacity, supports excess water to drain freely from the soil (thus reducing overland flow and erosion), etc.

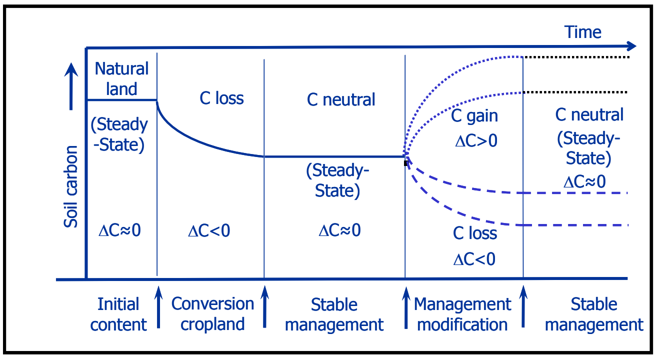
2.2.1 Methodology

Concepts

There are several theories explaining SOC content and dynamics (e.g. Turin, 1965; Orlov, 1990; Stevenson, 1994). In this analysis, the following assumptions are adopted:

1. The amount and the quality of the SOC content are specific parameters for a given soil typological unit (STU). These parameters depend on a combination of soil-forming factors. In a steady state ecosystem (either native vegetation or an agricultural system under constant management practices) a quasi-equilibrium SOC level is obtained since C losses from soil eventually equal C inputs into soil.
2. The above-mentioned STU-specific quasi-equilibrium in SOC content in cropland depends on the land management (Turin, 1965; Goulding *et al*., 2000). For a homogeneous bioclimatic region, the actual, minimum and maximum threshold values of the SOC can be estimated based on the observed SOC content. These threshold SOC values allow for the interpretation of the SOC status in terms of potential to gain/lose SOC (Figure 2.8), and (using the derived limited and high SOC thresholds) areas can be classified as having limited, enhanced or high risk of SOC loss or probability of SOC gain (Figure 2.9). The dynamic aspects are illustrated in Figure 2.7.

Figure 2.7: Conceptual model of SOC changes due to cultivation and land use modifications in agricultural soil



Source: modified from Johnson, 1995

The initial SOC content in the steady state shows a neutral C balance (ΔC≈0). The conversion into cropland shifts the C balance towards C loss (ΔC<0). Stable management returns the C balance to the neutral path (ΔC≈0), which results in a new steady state for SOC. Further management modification might lead either to positive C balance and C gain (ΔC>0) or to negative C balance (ΔC<0) and C loss.

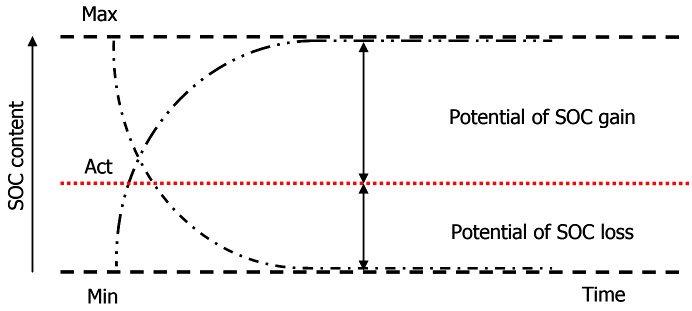
Model description

SOC content can be characterised by three critical threshold values (Figure 2.8):

1. The actual SOC (Act SOC) levels are the available data on C amounts (kg/m or t C/ha), which are either physically observed or model-derived for the Soil Typological Unit within a bioclimatic region These data originate from pedotransfer rules for the EU (Jones *et al*., 2004). For any STU, the Act SOC content coincides with bioclimatic conditions and land use practices (see assumption 1 above). The Act SOC is calculated from the equation: Act SOC = C*BD*Depth*(1-Frag), where C is the percentage of SOC content, BD is the bulk density of soil (in kg/mor t/ha), Depth is the thickness of a soil layer (in m) and (1-Frag) is the content of stones (as a percentage).
2. The minimum SOC (Min SOC) content is the lowest Act SOC amount that a soil can absorb. The Min SOC content can be associated with biologically 'inert' organic carbon. There are several models for identifying the value of the Min SOC content (Falloon *et al*., 2000). We assume that for the STU under homogeneous bioclimatic conditions the variation of SOC content depends on different land use practices. The distribution of SOC content is assumed to be normal. Setting the Min SOC at about -2 standard deviations from the mean SOC, the Min SOC content accounts for 95.45 % of the SOC observations.
3. The maximum SOC (Max SOC) content for the STU, under homogeneous bioclimatic conditions, illustrates that the variation of the Act SOC content depends on different land use practices. The Max SOC content is selected as being the maximum observable Act SOC content for the STU within a bioclimatic region.

These thresholds determine the potential of SOC loss and gain (Figure 2.8) of an STU within a bioclimatic region.

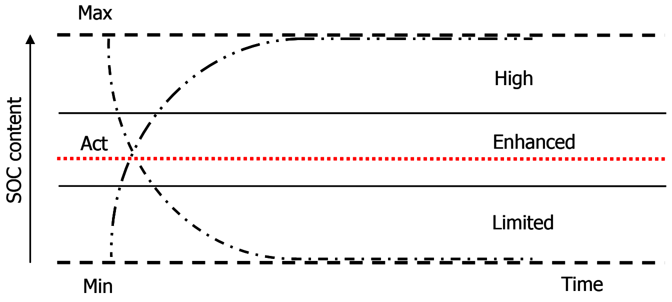
Figure 2.8: Critical threshold values for SOC



Act (red dotted line) is the actual SOC content, Min (the lower horizontal dashed line) refers to the steady minimum, and Max (the upper horizontal dashed line) is the steady maximum contents. The exponential curve (dashed line with one dot) illustrates SOC loss. The exponential curve (dashed line with two dots) demonstrates SOC gain. The difference between Max and Act content shows the potential to gain SOC. The difference between Act and Min content displays the potential to lose SOC.

The kinetics of the SOC changes follow an exponential curve that shows a declining rate of SOC accumulation/loss with time when soil approaches either the maximum or minimum SOC content (Figure 2.9). These kinetics allow for the suggestion that the probability of SOC gain is higher for carbon unsaturated soil; and the risk of the SOC loss is higher for carbon saturated soil. These assumptions are phrased above as the '***risk of SOC loss***'. For practical reasons, the threshold intervals are equally distributed and computed as (Max SOC – Min SOC)/3.

Figure 2.9: Risk and probability zones for the SOC loss (indicated by horizontal lines)



In the zone of limited risk, the soil is close to the Min SOC threshold value; in the zone of enhanced risk, the soil is between Min and Max SOC threshold values; and in the zone of high risk, the soil is close to the Max SOC threshold value.

Main equations

1. Act SOC = measured SOC density;
2. Max SOC = maximum SOC value from all observations;
3. Min SOC = Mean SOC value - 2δ;

4. Potential SOC loss = Min SOC – Act SOC[4];
5. Potential SOC gain = Max SOC – Act SOC;
6. SOC threshold interval = (Max-Min)/3;
7. Limited SOC threshold = Min SOC + (Max-Min)/3;
8. High SOC threshold = Min SOC + 2(Max-Min)/3.

Input parameters

The computation of the soil organic carbon (SOC grid) is performed for each dominant Soil Typological Unit (as defined in the Soil Geographical Database) for all agricultural land use types (as defined in CORINE 2000 v6) and for each climatic region (as defined in soil regions v2). The spatial resolution of the grid (map) is 1 km.

2.2.2 Results and Discussion

SOC critical threshold values

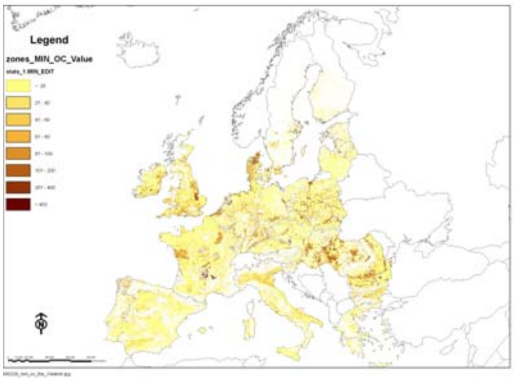


Figure 2.10: Min SOC content (Annex 2.7)
This map shows that the Min SOC contents vary from 20 - 40 t C/ha (yellow) for most of the EU. Distribution of the high values (more than 80 t C/ha) of the Min SOC content is sporadic. The general picture of Min SOC does not follow any geographical pattern which is explained by the close link of the Min SOC contents with soil texture and mineralogy of the parent material.

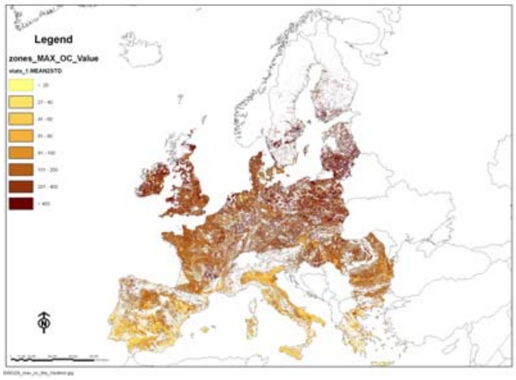


Figure 2.11: Max SOC content (Annex 2.8)
The dominating Max SOC values (dark brown) are more than 100 t C/ha. These values are observed in the northern two thirds of the EU territory. This distribution coincides with the bioclimatic zone of temperate forest. This zone has a temperature-precipitation ratio that is favourable for SOC accumulation. A relatively low Max SOC content of less than 100 t C/ha (light brown) is observed in the southern part of the EU and coincides with the extend of the Mediterranean semi-arid climatic zone.

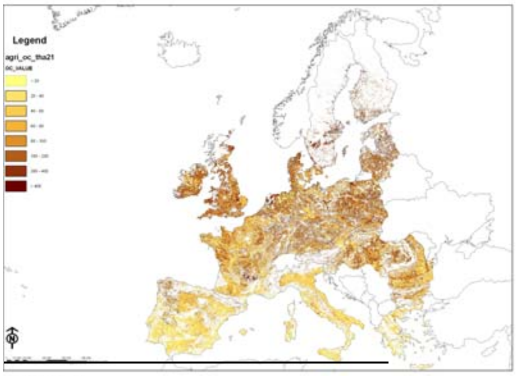


Figure 2.12: Actual SOC content (Annex 2.9)
The distribution of the Act SOC values shows a gradual decrease in SOC content from north to south. This pattern is in line with the bioclimatic gradients. The mosaic variation in the regional Act SOC value is explained by variation in soils and land use practices.

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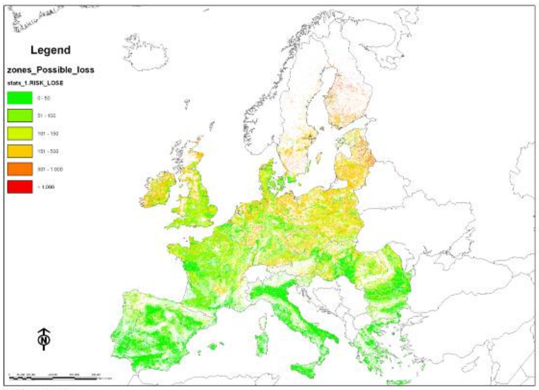
[4] Due to incompleteness of the database the mean (arithmetic average) of Act SOC content is applied in the calculation.

SOC loss

Figure 2.13: Potential SOC loss (t C/ha) (Annex 2.10)

The highest rates of potential SOC loss (more than 150 t C/ha) are found in northern Europe. Central Europe shows a mosaic distribution of the SOC loss potential ranging from less than 50 to more than 150 t C/ha. Southern Europe has a potential SOC loss rate of less than 50 t C/ha.



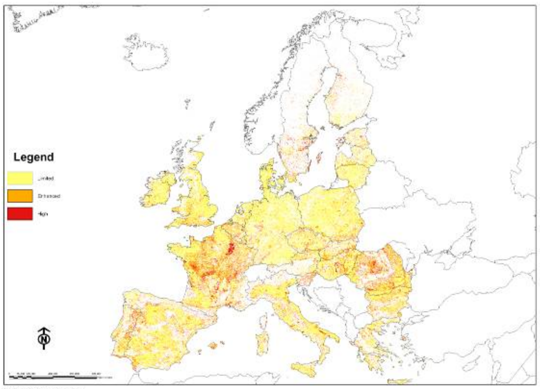


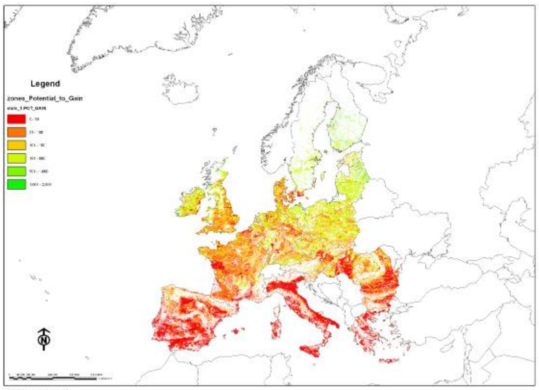
Figure 2.14: Risk zones of SOC loss in the EU (Annex 2.11)

The distribution of the risk zone for SOC loss is patchy. Most of the soils in northern Europe (Scandinavia) have an enhanced risk (orange); western and eastern parts have considerable soil areas at high risk (red). The southern part of the EU has more of a mosaic pattern of regions with limited and enhanced risks of SOC loss.

SOC gain

Figure 2.15: Potential SOC gain (t C/ha) (Annex 2.12)

The highest rates of potential SOC gain (more than 150 t C/ha) are in the north of the EU (green). The central part of the EU has a mosaic distribution of SOC gain potential ranging from less than 50 to more than 150 t C/ha. Southern Europe has a SOC gain potential of less than 50 t C/ha.



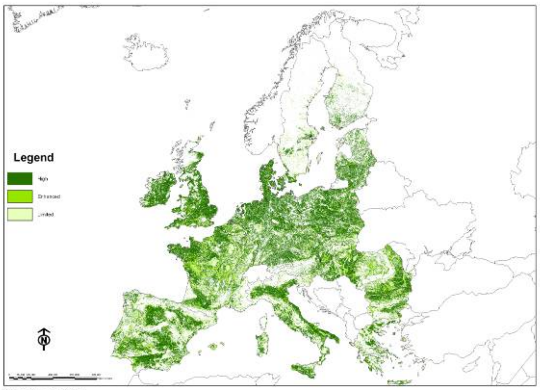


Figure 2.16: Probability zones of SOC gain in the EU (Annex 2.13)

Most of the soils in the north (Scandinavia) have a limited probability of SOC gain (light green). The rest of the EU has a mosaic pattern of regions with a combination of enhanced (green) and high (dark green) probability zones of SOC gain.

Land management is a crucial factor in a soil's SOC content (see Figure 2.7). This issue has been comprehensively reviewed by Freibauer *et al.* (2002). The assessment in this report avoids repeating previous studies and draws attention to the fact that the same change in land management on the same soil type might have a different effect on soils, depending on the actual SOC level. The land management history of the soil provides the explanation for this effect.

However, to lose carbon any soil must have carbon. Observing Figure 2.9, it is easy to recognise that the rate (amount of carbon per unit of time) of SOC loss would be higher for soils that are rich in carbon. This dependence is interpreted as a risk of carbon loss. The same can be said for carbon gain. The indication of the high potential for further carbon gain in the SOC-rich northern regions is an unexpected result.

Another finding is that the zones with a probability to gain carbon do not follow SOC gain potentials. In fact, the rate of carbon gain in the southern regions is higher than that in the northern regions. This finding is supported by field measurements in Piemonte region, Italy (see Toth *et al.*, 2007). The rate of carbon sequestration in soils under 10 years oak plantation was nearly 7 t C/ha/ yr. This is about 4.5 times more than the published average for European cropland (1.5 t C/ha/yr) and more than one order higher than land in conversion from cropland to forest (Smith *et al.*, 2005). In other words, there is faster accumulation of SOC but a lower SOC content in the south compared to a slow rate of accumulation and higher SOC content in the north. The temperature stimulates the decomposition of organic materials, removing SOC from the soil. In colder and wetter areas the decomposition is much slower and results in higher SOC contents as shown in Figure 2.9.

2.2.3 Conclusions and needs for future research

The study illustrates that agricultural soils have very different SOC levels and qualities in terms of potential and risk of soil organic carbon (SOC) changes in Europe.

In the EU there are more than 70 billion tons of organic carbon in the soils. This stock has a considerable impact on climate change mitigation. Indeed, releasing to the atmosphere just a small fraction of the carbon currently stocked in European soils could wipe out all the savings that other sectors of the economy are achieving in order to contain anthropogenic greenhouse gas emissions. It is, therefore, necessary to promote practices that favour maintaining or even increasing soil organic matter levels.

However, the optimisation of SOC content as a specific objective of land management in order to contribute to climate change mitigation is not widely recognised at present. There are a limited number of studies showing that the relationship between SOC and soil productivity is rather complicated and there is an upper threshold of SOC beyond which no further increases in productivity are achieved (e.g. Toth *et al.*, 2007; Carter, 2004). Clearly, for a successful implementation of an optimisation goal of any future post-Kyoto agreement, continually updated knowledge of the SOC status indicators is valuable. Establishing a harmonised monitoring system across Europe and developing an accounting system are essential.

A new quantitative model 'Soil Organic Carbon Status Indicators' (SOCSI) is applied to investigate organic carbon decline risk in the EU. This approach can distinguish between SOC loss/gain and the risk of SOC loss and probability of SOC gain. The SOCSI model provides a spatially explicit diversification of the SOC content. The model also allows actual, maximum and minimum SOC contents to be estimated.

Interpretation of the results can focus on SOC management (SOC stabilisation, enhancement or production) in the framework of conservation agriculture practices (including minimum soil tillage, crop rotation and continuous residue cover). Further research should be focussed on improved soil characterisation which should replace model-derived data by measured parameters. In addition, the SOCSI should be tested in the different environments of the EU.

There is an urgent need to systemise the existing knowledge on the SOC dynamics in agricultural soils with the aim of establishing a methodology for identifying areas and magnitudes for potential changes of SOC over time.

2.3 Compaction

Soil compaction is the rearrangement of soil aggregates and/or particles by reducing or even eliminating voids and pores between aggregates and particles, causing the soil to become denser. When compaction is very intensive the aggregates can be fully destroyed. The porosity of the internal aggregates is also influenced. Direct indicators of soil compaction are the orientation, size and shape of soil aggregates. In compacted soil, aggregates are oriented horizontally (platy structure). Also a plough pan (hard layer) is typically observed in compacted arable soils.

The susceptibility of a soil to compaction is the probability that a soil becomes compacted when exposed to a compaction risk (e.g. the use of heavy machinery). Such susceptibility can be low, medium, high and very high depending on soil properties and the set of external factors such as climate and land use.

There are different causes of soil susceptibility to compaction and thus of actual soil compaction. They are divided into two main types: natural and man-induced; a third type consists of a combination of natural and man-induced compaction occurring simultaneously in the same place.

Soil properties largely determine the natural susceptibility of a soil to compaction. Man-induced soil compaction (or secondary compaction) is exclusively caused by soil use and soil management. In many cases secondary compaction is planned, e.g. in civil engineering, and not necessarily considered to be negative. In forestry and agriculture, soil compaction is considered a negative consequence of improper soil use. In these cases soil compaction is seen as a soil quality issue. Compaction can create significant damage to soil functions (mainly infiltration rate and redistribution of water and nutrients), root development and direction of root growth, as well as economic damage, through decreasing crop yields and soil productivity (DeJong-Hughes *et al.*, 2001), up to the point where agricultural production is no longer economically viable.

Increased use of irrigation causes the soil to be permanently wet. The use of heavy equipment when a soil is wet intensifies compaction. Although these causes can be removed by changing management practices, the problem with compaction is that it becomes irreversible once certain thresholds have been passed. These thresholds depend on the soil type. In general, soil compaction is considered to be a hidden problem in agriculture. This explains why the most important action for combating non-desirable soil compaction is prevention.

Soil compaction can induce or accelerate other soil degradation processes, e.g. erosion or landslides. Compaction reduces the infiltration rate, which increases run-off in sloping areas. Compaction in flat areas can cause water-logging, resulting in the destruction of aggregates and causing crust formation. In sloping areas, the presence of a compacted layer with low permeability can cause the upper part of the soil, once saturated with water and thus heavier, to slide, provoking mass movements and landslides.

The evaluation of man-induced (secondary) susceptibility of soils to compaction focuses primarily on soils that are intensively cultivated, mainly with root crops. These soils are continuously ploughed and the crop requires repeated machinery use among others for the application of fertilisers or pesticides. Secondary susceptibility is expected to be higher in big fields where the use of heavy machinery is indispensable as well as on very small fields where ploughing is done by horse power, very often to the same depth. These assumptions are prone to great inaccuracies and can have major implications for farmers if interpreted inaccurately. Comprehensive information about the use of machinery linked to specific fields is currently not available and therefore a Europe-wide analysis of the issue cannot be attempted.

Finally, livestock can damage soil structure by causing compaction at the surface. In many modern husbandry systems, problems can already arise if cattle are held overnight on relatively small fields. Animals can also affect bigger areas when they are outwintered. In both cases, in combination with wet soil conditions the emergence of irreversible compaction may be the result.

2.3.1 Methodology

The evaluation of natural soil susceptibility is based on the creation of logical connections between relevant parameters, called pedotransfer rules. The input parameters for these pedotransfer rules are taken from the attributes of the European Soil Database (ESDB, 2004). The most important parameters are: soil type, texture, soil water regime, depth to textural change and the limitation of the soil for agricultural use. To increase the accuracy of questionable cases, auxiliary parameters were used: impermeable layer, depth of an obstacle to roots, water management system, dominant and secondary land use. It was assumed that every soil, as a porous medium, could be compacted, meaning that there is no soil without a natural susceptibility to compaction.

In order to create these pedotransfer rules, SoCo evaluated all parameters individually regarding their susceptibility to compaction. Table 2.2 shows the categories for soil compaction.

Table 2.2: Categories for soil compaction

Nr.	Classes	Description
0	no soil	represents water bodies, glaciers and rock outcrops
1	low susceptibility to compaction	
2	medium susceptibility to compaction	
3	high susceptibility to compaction	
4	very high susceptibility to compaction	
9	no evaluation possible	in, towns or soils disturbed by man and marshland

Pedotransfer rules comprise the basic assumption (Table 2.3): If the soil represents a given soil unit (WRB_GRP), with a given soil subunit (WRB_ADJ), and has a specific topsoil texture (TEXT_SRF), and a specific subsoil texture (TEXT_SUB), with a given depth to textural change (TEXT-DEPTH-CHG), and with a given water regime (WR)[1], and depending on whether a limitation to agricultural use (AGLIM)[2] is present or not, THEN the soil has low, medium, high or very high natural susceptibility to compaction.

Table 2.3: Pedotransfer rule acronyms explanation

Acronym	Explanation
WRB_GRP	Main reference soil groups
WRB_ADJ	Soil subunits
TEXT_SRF	Texture for topsoil
TEXT_SUB	Texture for subsoil
TEXT-DEPTH-CHG	Depth to the textural change in soil profile
WR	Water Regime
AGLIM	Primary and secondary limitation to agricultural use

[1] WR can also possibly be evident also from a given water management system (WM1)

[2] AGLIM may be evident also from the depth to impermeable (IL) layer and the depth to the layer having obstacle for roots development (ROO).

Selected parameters of the ESDB have been evaluated according to above mentioned assumption. Simplification occurs in two marginal situations:

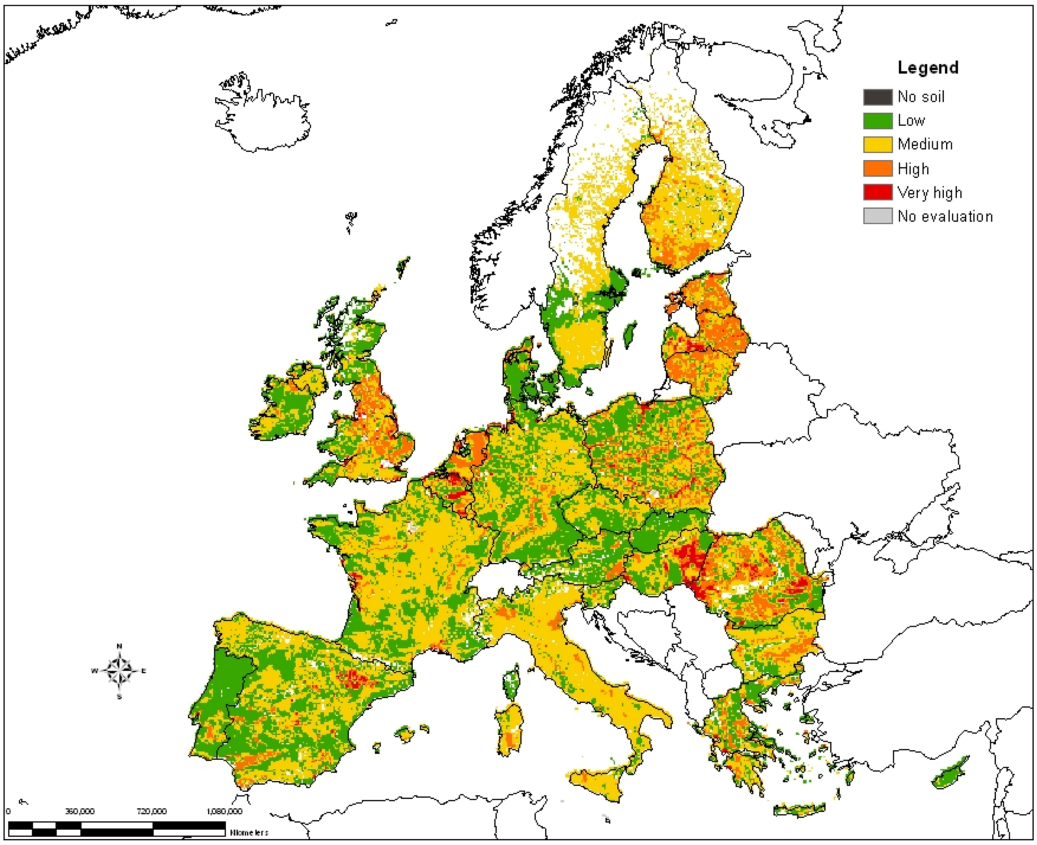
- if all selected parameters show a high susceptibility to compaction, then the soil has very high final susceptibility to compaction;
- if all selected parameters show a low susceptibility to compaction, then the soil has a low final susceptibility to compaction.

All other situations have been evaluated according to the basic assumption and expert knowledge.

2.3.2 Results

Figure 2.17 shows the natural susceptibility of a soil to compaction if it were to be exposed to compaction. Based on soil properties, it gives an idea of the geographic spread of compaction susceptibility and could be used to identify potential hotspots. These data are used to evaluate the natural compaction per agricultural practice (CORINE 2000 v6) (Figure 2.18).

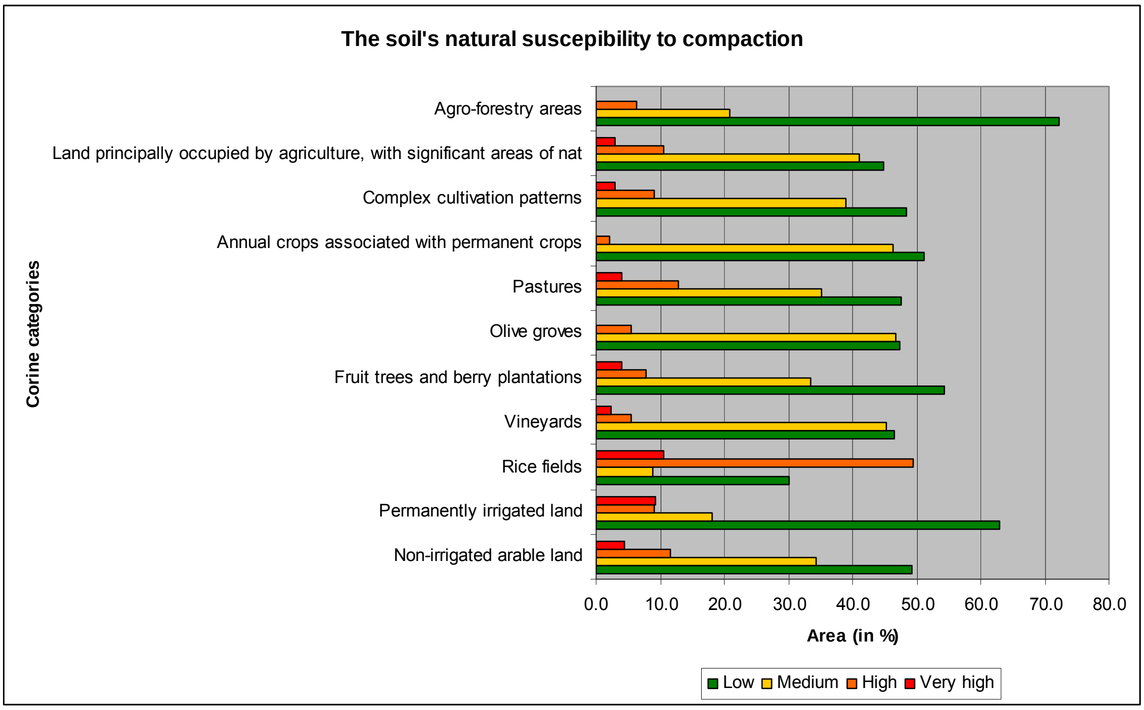
Figure 2.17: Map of natural soil susceptibility to compaction in the 27 Member States of the European Union



According to the results presented in Figure 2.18 European soils used for agricultural and pastoral purposes have a predominantly low or medium natural susceptibility to compaction. Agroforestry and permanently irrigated land show the highest percentages of low susceptibility to compaction. For permanently irrigated lands this is linked to the fact that irrigation is mainly applied on light sandy soils. Exceptions are soils used for rice fields, where soils with high natural susceptibility to compaction predominate. It concerns mostly clay soils with a high water table. When these soils are saturated with water they become more susceptible to compaction.

Cultivation on any type of soil with high and very high natural susceptibility to compaction should focus on proper soil moisture (field capacity) and crop rotation patterns which require few external entries on the field. Root crops are unsuitable for such types of soil.

Figure 2.18: Natural soil susceptibility to compaction in relation to land use



2.3.3 Conclusions

Susceptibility to compaction does not mean that a soil is compacted. It is the likelihood that compaction occurs if subjected to factors that are known to cause compaction. The map shows the conclusion that can be derived from the natural characteristics that influence the soil susceptibility to compaction. The actual status of soil compaction was not evaluated due to a lack of actual data concerning direct measurements.

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) (Woods *et al.*, 1944). This is due to the weight of the soil, the stability of soil structure and the soil's water regime. Clay soils are the heaviest, and the upper parts of the soil compact the lower parts. They have a high water-holding capacity and it is difficult to maintain the proper soil moisture (around field capacity) for their cultivation. They are usually too wet and thus too fragile for the use of heavy machinery.

As mentioned in chapter 2.2, soil structure is improved by soil organic carbon (SOC). Susceptibility to compaction may be reduced (all other factors remaining the same) by an increased SOC content. A higher SOC content improves soil structure, and thereby helps to reduce the susceptibility to compaction. If less compaction occurs, the degradation processes that are induced or accelerated by compaction (such as erosion and landslides) will be reduced as well.

In order to perform more in-depth research on hotspots (i.e. soils with a high or very high natural susceptibility to compaction), further ground validation is needed to verify the results obtained by pedotransfer rules. The evaluation of man-induced susceptibility to compaction is a sensitive issue and will need a lot more detailed data before an attempt can be made to visualise this issue.

2.4 Salinisation and sodification

Salt is a natural element of soils and water. Salt-affected soils result from the accumulation of excess salts. Saline and alkaline soils are soils with a high salt (or salt ion) content. Processes causing the formation of salt-affected soils can be characterised as salinisation and sodification.

Salinisation

Salinisation is the process that leads to an excessive increase of water-soluble salts in the soil. The accumulated salts include sodium, potassium, magnesium and calcium, chloride, sulphate, carbonate and bicarbonate (mainly sodium chloride and sodium sulphate). A distinction can be made between primary and secondary salinisation processes. 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, e.g. with salt-rich irrigation water and/or insufficient drainage.

Sodification

Sodification is the process by which the exchangeable sodium (Na) content of the soil is increased. Na^+ accumulates in the solid and/or liquid phases of the soil as crystallised $NaHCO_3$ or Na_2CO_3 salts (salt 'effloresces'), as ions in the highly alkaline soil solution (alkalisation), or as exchangeable ions in the soil absorption complex (ESP).

High levels of salinity in soils provoke the withering of plants both due to the increase of osmotic pressure and the toxic effects of salts. When alkalinity processes take place, the high pH level does not, in most cases, permit plant life. Excess sodium on the exchange complex results in the destruction of the soil structure that, due to the lack of oxygen, cannot sustain either plant growth or animal life. Alkaline soils are easily eroded by water and wind. Salinisation increases the impermeability of deep soil layers, making it impossible to use the land for cultivation (Van-Camp *et al.*, 2004).

The types of salt-affected soils differ both in physical, chemical, physical-chemical and biological properties as well as in their geographical distribution. The degradation risk of salinisation/sodification reflects the occurrence and the potential occurrence of the salinisation/sodification process due to human activities that adversely affect one or more soil functions.

The main natural factors influencing the salinity of soils are climate, soil parent material, land cover and/or vegetation type, topography and soil attributes. The most influential human-induced factors are land use, farming systems, land management and land degradation. Prevention management practices could include quality control of irrigation water (water coming from areas rich in salts) and stabilisation of the groundwater table.

Soil salinisation affects an estimated one to three million hectares in the enlarged EU, mainly in the Mediterranean regions. It is regarded as a major cause of desertification and therefore is a serious form of soil degradation. With recent increases in temperature and decreases in precipitation, characteristic of the climate in recent years, the problem of salinisation in Europe is getting worse (Van-Camp *et al.*, 2004).

Salinisation and sodification are among the major degradation processes endangering the potential use of European soils. However, no continent-wide assessment of salt-affected soils has been carried out since the compilation of Szabolcs' (1974) map: 'Salt Affected Soils in Europe'. The most up-to-date information on the salt-affected soils with a continental coverage is available in the European Soil Database (ESDB, 2004), which stands as the main general purpose soil database in Europe. Although the ESDB provides information in greater taxonomic detail about the types of salt-affected soils occurring across the continent, the spatial resolution of the ESDB (1:1 million) does not go beyond Szabolcs' map, compiled on a scale of 1:1 million and published on a scale of 1:5 million. Based on the available information on salt-affected soils at European scale, a new map was generated for the delineation of areas threatened by salinisation or sodification in the European Union.

From the environmental risk point of view, a third category of soils can be distinguished: soils with specific characteristics in certain environmental conditions that may be at risk of salinisation such as acid sulphate soils.

2.4.1 Methodology

Two major data sources are available to delineate areas at risk of salt accumulation in Europe: the European Soil Database (ESDB, 2004) and the map of salt-affected soils in Europe compiled by Szabolcs (1974). Szabolcs' map was important and timely in the 1970s because soil salinity and alkalinity were hindering the satisfactory agricultural utilisation of lands in many regions.

To establish an updated map of salt-affected soils in Europe, items from the two databases were selected that have characteristics of salt-affected or potentially salt effected soils. Potentially salt-affected refers to soils that are at present not or to a very low degree saline or alkaline, but where human intervention (irrigation) may cause their considerable salinisation and/or alkanisation/sodification (Szabolcs, 1974).

The information on salinity and alkalinity, available directly or through pedotransfer rules in the ESDB, is described in detail by Baruth *et al.* (2006). In the WRB (World Reference Base) soil names that give information about salinity are Solonchaks, 'salic' horizons, or 'petrosalic' layers. In the definition of Solonchaks, the reference to salinity is given by the presence of a salic horizon within a depth of up to 50 cm. The salic horizon is a surface or a shallow subsurface horizon that contains a secondary enrichment of readily soluble salts, i.e. salts more soluble than gypsum. Analysis of the available information shows that the information from the soil name can be used to characterise the presence of a horizon having saline properties at a maximum depth of 125 cm.

Three classes of salinity are proposed:

• low:	ECse < 4 dS/m (deciSiemens per metre)
• medium:	4 < ECse < 15 dS/m
• high:	ECse > 15 dS/m

where ECse is the electrical conductivity of the soil saturation extract from the root zone.

In the WRB, soils having alkaline characteristics are Solonetz, 'natric' horizons, or 'sodic' properties or soils. In the definition of Solonetz, the reference to alkalinity is given by the presence of a natric horizon occurring within 100 cm from the soil surface. The natric horizon is a dense subsurface horizon with higher clay content than the overlying horizons and that has a high content in exchangeable sodium and/or magnesium. Solonetz, ‘natric’ horizons and soils with ‘sodic’ or ‘endosodic’ properties are considered to have a high alkalinity. ‘Hyposodic’ soils, have medium alkalinity. Analysis of the available information shows that the information from the soil name can be used to characterise the presence of a horizon having sodic properties.

Three classes of alkalinity are proposed for further analysis:

- low: ESP < 6 %
- medium: 6 < ESP < 15 %
- high: ESP > 15 %

where ESP is the exchangeable sodium percentage.

The saline/sodic areas in Europe were determined as follows:

- Digital geodatabases were prepared from Szabolcs' map in the Lambert Azimuthal Equal Area coordination system (‘Digital Szabolcs Map’), using the same projection as the ESDB. Once the databases were in the same reference system, we were able to match the spatial information and explore the semantic characteristics of the data (i.e. verbal description of properties of the data).
- Soil mapping units with saline and/or sodic soils were selected from the ESDB and the percentage share of salt-affected areas of the polygons were calculated. (>50 % and < 50 % for saline and alkaline soils). These polygons were displayed on a separate layer.
- The Digital Szabolcs Map was overlaid by the new salt-affected soil layer of the ESDB.
- On areas where both maps had information on salinity, the information from the ESDB took priority. Areas outside the salinity/sodicity layer of the ESDB were characterised by the ‘Digital Szabolcs Map’.

2.4.2 Results

Following the above-described method we compiled an updated version of the salt-affected soils map (Figure 2.19).

Figure 2.20 shows the area distribution of different land use for those categories where salinity or alkalinity is the spatially dominant feature. The accuracy of the input data only allows the designation of salt-affected areas with a limited reliability (e.g. 50 to 100 % of the area); therefore the results represented in Figure 2.20 should only be used for impressionistic purposes. Salinisation or sodification is not evenly spread across Europe. The definition of the degradation process is based on soil properties and soil-forming factors, and thus depends on the geographic location of the soils.

Figure 2.19: Map of Saline and Sodic Soils in the European Union: Status and Potentials

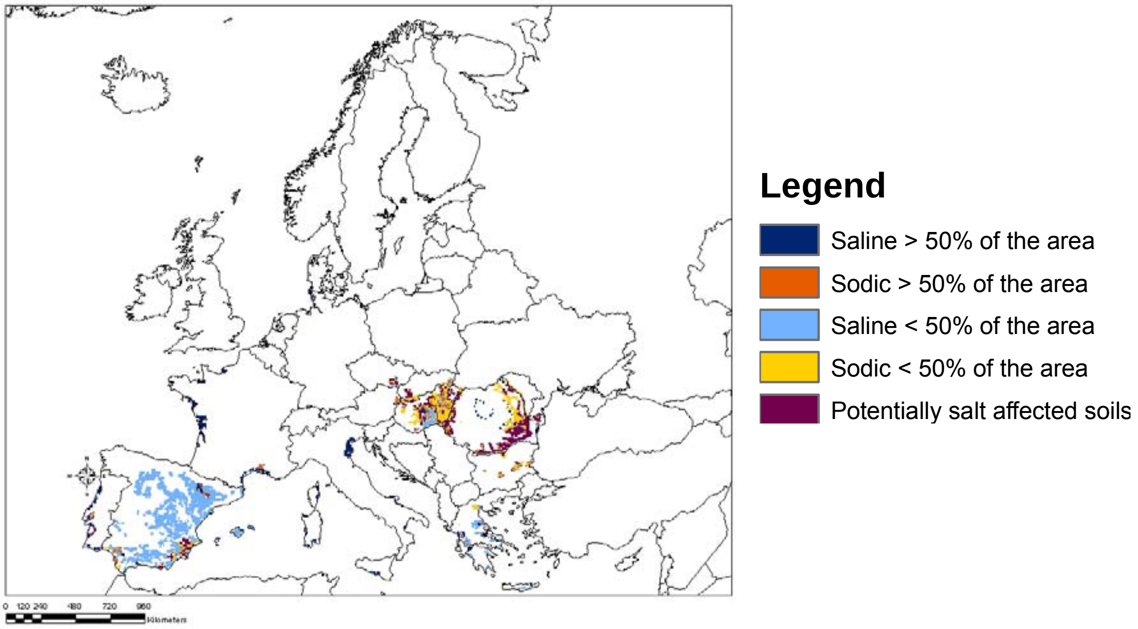
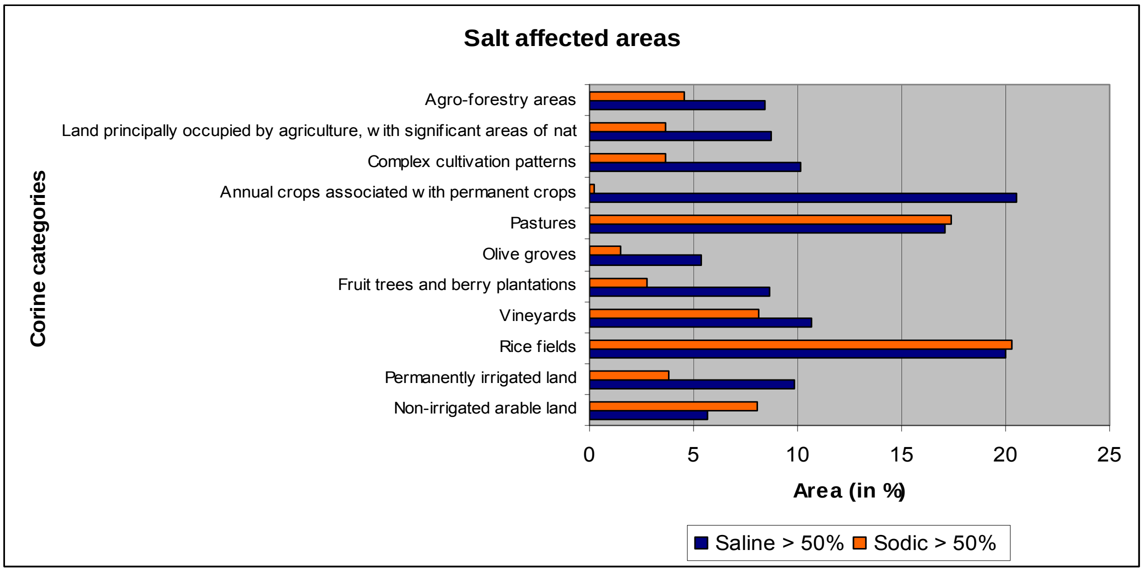


Figure 2.20: Land use in salt-affected areas identified in Figure 2.19.



Human factors influencing salinisation and sodification include:

- irrigation of waters rich in salts;
- rising water table due to activities such as filtration from unlined canals and reservoirs, uneven distribution of irrigation water, poor irrigation practice and improper drainage);
- use of fertilisers and amendments, especially where intensive agriculture is carried out on soils with low permeability and limited leaching capacity;
- 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.

2.4.3 Conclusion and need for further research

Saline soils have developed in the most arid regions. The few exceptions to this rule are caused by salinity of local groundwater or soil-forming substrata (Szabolcs, 1974). The countries most affected as defined by the methodology used in this report are Spain, Hungary and Romania. Other countries show localised occurrence of salinity or sodicity which could have a devastating effect locally.

As the accumulation of sodium salts capable of alkaline hydrolysis is based on different biogeochemical processes, soil sodicity (caused by sodium carbonate) occurs under arid, moderate, and humid climate as well (Szabolcs, 1974).

From the environmental risk point of view, a third category of soils can be distinguished: soils with specific characteristics in certain environmental conditions that may be at risk of salinisation such as acid sulphate soils.

Further research is needed to predict the extent of salt-affected soils with an increased accuracy in comparison to the continental or global geographical soil databases available at the moment. However, the ancillary information currently available on a continental coverage, namely the SRTM-derived digital elevation model for Europe, the European Groundwater Database, and the European Map of Aridity Index were found to be inadequate for increasing the accuracy of the delineations. Salt content information is essential for any further progress.

2.5 Contamination

2.5.1 Heavy metals and pesticides

Soil pollution is recognised among the main soil degradation processes in Europe. It has been estimated that a large proportion of soils in industrialised countries contain higher levels of inorganic pollutants than the corresponding natural background values found in a pristine situation. Moreover, heavy metal concentration in European soils is following an increasing trend.

There are many definitions of the concept of heavy metals. A commonly used definition states that heavy metals are those elements with a specific density of more than 5 g/cm^3. Even if traces of some heavy metals (cobalt, copper, iron, zinc, etc.) are required by living organisms in some metabolic processes, their presence above certain thresholds leads to the apparition of toxicity symptoms. Looking at human health protection, the main concerns of heavy metals in soils and water are linked with the exposure to lead, cadmium, mercury and trace element arsenic.

Heavy metals in soils can come from both anthropogenic and geogenic sources (originating in the soil). However, it is generally recognised that, during recent decades, the input of heavy metals into soils from human activities exceeded the natural inputs due to pedogenesis and atmospheric deposition. Industrial activities, agricultural practices, transport emissions, use of fertilisers and pesticides, waste disposal, oil spills, etc. lead in many cases to high concentrations of heavy metals in soils that can create toxicity problems for living organisms, the decrease of biodiversity and the pollution of groundwater. Heavy metals, together with eutrophication due to high nitrogen and phosphorus inputs, are regarded as the main sources of pollution in agricultural soils. However, heavy metals, unlike many organic compounds and radio nuclides, are considered the most persistent contaminants in soils and they are prone to bioaccumulation.

Sources of heavy metals in agricultural soils

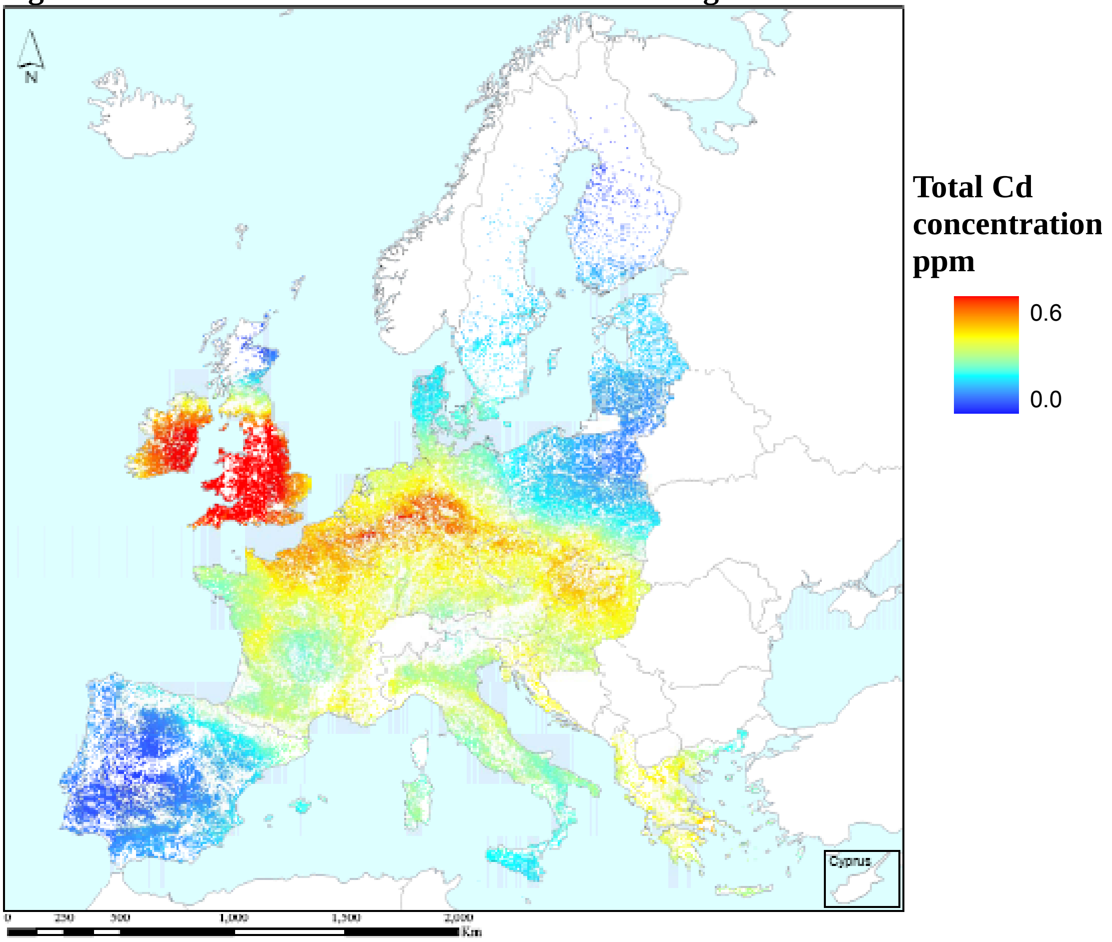
Heavy metal input in agriculture is mainly caused by anthropogenic activities like fertilisation and amendment practices, which are commonly used to increase soil productivity. However, in special situations (e.g. vicinity of volcanoes, presence of mafic and ultramafic substrates, lateritic deposits, hydrothermalism), natural contributions can be also an important source of these elements to soils. It is necessary to determine the natural background values for heavy metals in order to assess the contribution of each source to the overall heavy metal concentration in soils which will help develop and implement adequate policy control measurements to avoid the risks derived from high concentrations of these elements in the environment. This section focuses on the anthropogenic sources of heavy metals.

Mineral, organo-mineral and organic fertilisers

Among mineral fertilisers, phosphate based fertilisers are those that contain the highest concentration of heavy metals (especially cadmium but also chromium, nickel, zinc, lead and arsenic) due to the heavy metal contents already generally found in the crude source mineral (phosphates and apatite). The cadmium concentration in these rocky materials varies widely depending on their origin, ranging between 0.3 and 100 mg/kg. Generally the heavy metal concentration in potassium and nitrogen fertilisers is low because they are derived from ammonia or nitric acid. In addition lime-based fertilisers used to correct the soil pH can contain small amounts of heavy metals as Cd, Cu, Pb and Zn, depending on the origin of the calcium carbonate used in their production.

According to the FOREGS geochemical database for European soils (http://eusoils.jrc.it/foregshmc/), the level of total cadmium concentration ranges between 0.06 and 0.6 ppm. Figure 2.21 shows the estimated concentration of cadmium in European agricultural soils by regression kriging using 1 588 samples from the above-mentioned database.

Figure 2.21: Estimated cadmium concentration in agricultural soils



This map shows that higher cadmium concentrations are found in the UK, Ireland, northern France, Belgium, the Netherlands, central Germany, Slovakia, Czech Republic and Hungary. However, the estimated cadmium values are below the most limiting threshold value of 1 ppm for agricultural soils. More information about the estimated total concentration of other heavy metals in European soils can be found on the FOREGS site.

Pesticides (including 'fungicides', 'insecticides', 'herbicides', etc.)

Pesticides are intensively used in viticulture, fruit farming and horticulture. They can act as an important source of heavy metals like copper, zinc, manganese and tin in the soil. The composition of numerous inorganic fungicides is based on copper (copper sulphur, copper sulphate, industrial Bordeaux mixture, copper oxychloride, copper zinc chromate, copper hydroxide, etc.), while some organic fungicides containing zinc, manganese and tin (dithiocarbamates and organic tin compounds) are resistant to biodegradation and thus can be very persistent in soils. Pesticides based on mercury, nowadays forbidden, were extensively used during the past for the disinfecting and protecting seeds.

Some herbicides, particularly those applied in pre-emergence, can persist for several months in soils and leach down later into the groundwater. It is in particular due to concern about potential contamination of groundwater and/or their strong persistence in the soil that some of the oldest active substances, like atrazine, simazine, trifluralin and diuron, have been withdrawn from the EU market.

Sewage sludge

Sewage sludge may contain high concentrations of heavy metals as it is the product of treated wastewater from varied domestic and industrial sources. The concentrations of heavy metals and organic contaminants like dioxins can reach substantial levels. Sewage sludge may also contain traces of medications like antibiotics and hormones.

Compost and manure

In general, compost has a lower metal concentration. Compost from organic and green waste contains relatively low concentrations of heavy metals (Centemero and Corti, 2000). However, some heavy metals are used in animal nutrition as growth stimulants, and may end up in animal manure. Pig manure may contain high concentrations of, in particular, copper and zinc, since the amount of these metals used as food supplements for pigs can be significant (Mordenti *et al.*, 2001). Only a small percentage of these two elements is absorbed by the animal's digestive system (20 - 28 % of Cu and 4 - 8 % of Zn), while the rest ends up in their waste which is often used as a soil fertiliser.

Atmospheric deposition

The atmospheric deposition of heavy metals, organic and inorganic contaminants to soils and water, can be from both natural and anthropogenic origins. Natural sources of pollutants to the atmosphere include volcanic emissions, natural degasification processes, erosion and combustion processes due to forest fires. These processes can emit large amounts of heavy metals, dioxin, nitrogen and sulphur compounds and organic compounds like dioxins and furanes to the atmosphere. The main anthropogenic emissions are derived from activities like fossil fuel consumption, industrial, activities and electric power production, meaning that agricultural activity is thus not the only source. The heavy metals formed in these processes will return to the earth surface through both dry and wet deposition (Nappi *et al.*, 2003).

Other sources of heavy metals

Many other materials used in agriculture, like fertiliser, may also contain high heavy metal concentrations. They are derived from fossil organic materials (like peat, lignites), agro-industrial residues (waste from sugar beet production, food processing and industries, and from the tannery industry). This last material consists of leather waste produced from skins tanned with products containing chromium, thus containing an elevated level of this element. The waste situation in the tannery industry has improved in recent years. The introduction of tanning alternatives has favoured a reduction of the amounts of chromium employed in the treatment of the skins (Benedetti and Ciavatta, 1998). Ashes from wood coming from bioenergy production can also contain high levels of heavy metals.

Conclusion and needs for future research

Heavy metals and pesticide residues do not only remain in the food chain, but can also be found in soil and water. Although the effect and behaviour of active substances and other components of plant protection products are thoroughly investigated before allowing them to be brought onto the market, the models and calculations used during the risk assessment might not always predict accurately the real behaviour of substances and their residues under particular conditions. Therefore it is very important to measure pesticide concentrations in soil and water (surface and groundwater) in order to verify whether the models and forecasting techniques are correct and whether all risk mitigation measures and use of pesticides according to Good Agricultural Practice do actually lead to acceptable concentrations of these products in the environment (SEC(2006) 895).

Discussion of the risks due to the presence of heavy metals in soils must start by establishing the natural background values to determine whether the concentrations found in soils have a geogenic or anthropogenic origin. In any case, total concentration of heavy metals, their speciation, toxicity, bioavailability and chemical behaviour under changing situations should be fully addressed in environmental impact assessment studies.

2.5.2 Excess nitrates and phosphates

In agriculture, the trend towards greater intensification and higher productivity during much of the past fifty years was accompanied by a significant increase in the use of both inorganic nitrogen (N) and phosphate (P) fertilisers. However, since the mid 1980s, a progressive reduction in fertiliser consumption has been recorded (COM(2007) 120 final).

One of the main sources of nitrate pollution of EU waters from diffuse sources is agriculture, as nitrate leaches through the soil into the water. Codes of good agricultural practice have been set up to reduce pollution by nitrates from this source. Another important source of pollution is the nutrients coming from untreated urban wastewaters. Pursuant to the Nitrates Directive (Directive 91/676/EEC), Member states are required to identify waters that could be affected by pollution, e.g. whether groundwater contains or could contain more than 50 mg/l nitrates.

The third report on the implementation of the Nitrates Directive for the reporting period 2000-2003, submitted by EU-15 Member States, shows improvement in the quality of monitoring and reporting.

With regard to groundwater quality, the overall trend is stable or improving in 64 % of the monitoring sites; whereas an increase in nitrate pollution was observed in 36 % of sites, and 17 % of sites showed nitrate concentrations above 50 mg/l. In surface waters, stable or decreasing nitrate concentrations were observed in 86 % of sites, confirming trends already seen in several Member States in the previous report. However, further data are needed to assess the influence of climatic conditions and urban wastewater treatment improvement on this development. Significant progress has been made in recent years regarding both designation of vulnerable zones and action programmes. Vulnerable zones increased from 35.5 % of EU-15 territory in 1999 up to the 44 % in 2003, with further designations thereafter. However, based on a review of available information on nitrogen pressure and water quality, the Commission considers that there are still gaps in designation that need to be filled (COM(2007) 120 final).

2.6 Biodiversity in agricultural soils

Humans have extensively altered the global environment and caused a reduction in the world's biodiversity. These changes in biodiversity alter ecosystem processes and change the resilience of ecosystems to environmental change. It is estimated that human activities have increased the rates of extinction 100 to 1 000 times (Lawton and May, 1995). In the absence of major changes in policy and human behaviour, anthropogenic effects on the environment will continue to alter biodiversity. Land use change is projected to have the largest impact on biodiversity by the year 2100 (Chapin *et al.*, 2000). With agricultural land covering 38 % of the land surface worldwide (arable land 10.7 %, permanent crops 1 %, pastures 26.5 %), the intensity of agricultural practices and crop management also affect biodiversity (FAO, 2007).

Since the UNCED Conference in Rio de Janeiro 1992, the need to protect biodiversity has been universally acknowledged. The EU had already included biodiversity conservation in its legislation before this date, e.g. the Council Directive 79/409/EEC on the conservation of wild birds and the Council Directive 92/43/EEC on the conservation of natural habitat and wild fauna and flora.

Furthermore several initiatives addressing biodiversity arose from the CBD convention, such as the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) and the Biodiversity Conservation Strategy (ECBS) which were adopted in 1995 and 1998 respectively. The European Strategy for Sustainable Development also indicated that optimisation of agricultural systems is the major way to 'manage natural resources more responsibly to protect and restore habitats and natural systems and halt the loss of biodiversity'.

The Commission's Communication 2006/216 'Halting the losses of biodiversity by 2010 and beyond'[5], represents a milestone in biodiversity conservation policy. The communication focuses on the main threats to biodiversity and on the needs to integrate biodiversity issues more closely into agriculture and rural development policy. The associated Action Plan aims at:

- Reinforcing action to halt the loss of biodiversity in the EU by 2010;
- Accelerating progress towards the recovery of habitats and natural systems in the EU; and
- Optimising the EU’s contribution towards significantly reducing the rate of biodiversity loss worldwide by 2010.

The Action Plan represents an important new approach for EU biodiversity policy; all the relevant economic sectors and policy areas are addressed in a single strategy document and apportioned a share of the responsibility in its implementation.

A summary of the Biodiversity Action plan is provided in Figure 2.22.

Biodiversity plays an important role in agriculture. Indeed, in the ECBS, element of the 5th Environmental Action Programme, it is said that 'biodiversity is essential for maintaining the long term viability of agriculture'. The recent CAP reform represents a continuing effort to integrate environmental aspects into agricultural policy by strengthening agri-environmental measures and introducing cross compliance. It should be noted that the only explicit reference to soil biodiversity is in COM(2002) 179, 'Towards a Thematic Strategy on Soil Protection', where biodiversity decline was identified among the main threats to European soils. However, in point 4 of the preamble to the Commission's 'Proposal for a Directive of the European Parliament and of the Council establishing a framework for the Protection of Soil and amending Directive 2004/35/EC[6], it is stated that 'The current scientific knowledge on soil biodiversity and its behaviour is too limited to allow for specific provisions in this Directive aiming at its protection.'

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[5] http://ec.europa.eu/environment/nature/biodiversity/comm2006/index_en.htm

[6] http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf

Figure 2.22: Summary of the Biodiversity Action Plan

Policy area I: Biodiversity in the EU

Objectives:
1. To safeguard the EU's most important habitats and species
2. To conserve and restore biodiversity and ecosystem services in the wider EU countryside
3. To conserve and restore biodiversity and ecosystem services in the wider EU marine environment
4. To reinforce compatibility of regional and territorial development with biodiversity in the EU
5. To substantially reduce the impact on EU biodiversity of invasive alien species and alien genotypes

Policy area 2: the EU and global biodiversity

Objectives:
6. To substantially strengthen effectiveness of international governance for biodiversity and ecosystem services
7. To substantially strengthen support for biodiversity and ecosystem services in EU external assistance
8. To substantially reduce the impact of international trade on global biodiversity and ecosystem services

Policy area 3: Biodiversity and climate change

Objective:
9. To support biodiversity adaptation to climate change

Policy area 4: the knowledge base

Objective:
10. To substantially strengthen the knowledge base for conservation and sustainable use of biodiversity in the EU and globally

Supporting measures

1. Ensuring adequate financing
2. Strengthening EU decision making
3. Building partnerships
4. Building public education, awareness and participation

Monitoring evaluation and review

In this chapter we aim to give a brief overview of the relationships between agriculture and soil biodiversity.

2.6.1 Biodiversity and soil biodiversity

When considering biodiversity, it is necessary to bear in mind that the expression 'biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD). Biodiversity refers not only to the components of the system but also to the system's structure and to the functional interactions between species within the sytem. The term 'biodiversity' often gets confused with the term 'bio-indicator'. The concept is different but both can be used for environmental assessments. The term 'bio-indicator', coming from 'biological' and 'indicator', refers to a living organism that is able to tell us whether our environment is healthy or unhealthy.

Soil represents one of the most important reservoirs of biodiversity. The biological diversity in soils is several orders of magnitude greater than that above ground (Heywood, 1995) and is seen as the last frontier for biodiversity on earth (Swift, 1999).

Although not generally visible to the naked eye, soil is one of the earth's most diverse habitats and contains one of the most diverse assemblages of living organisms (Giller *et al.*, 1997). In a handful of soil, there are 100 billion bacteria and a large amount of other animal and plant species. In addition, the soil contains tens of thousands of different species that are little known or completely unknown (Loveland and Thompson, 2001; Ritz *et al.*, 2003).

The complex physical and chemical nature of the soil, with its porous structure, immense surface area, and extremely variable supply of organic materials, food, water and chemicals mean that various animal, plant and microbial worlds can co-exist simultaneously and find appropriate niches for their development. This provides a range of habitats for a multitude of fauna and flora ranging from macro- to micro-levels depending on climate, vegetation and physical and chemical characteristics of the given soil. The species numbers, composition and diversity of a given soil depend on many factors including aeration, temperature, acidity, moisture, nutrient content and organic substrate.

Soil biodiversity tends to be greater in forests than grasslands, and in undisturbed natural lands compared to cultivated fields. However, the number and types of organism vary from one system and environment to another and this is strongly influenced by agricultural practices. It is recognised that soil biodiversity can be used as an indicator of soil quality and stable ecosystems (FAO, Soil Biodiversity Portal).

In natural ecosystems such as pastures, earthworms can reach a biomass density of up to 300 g/m^2, whereas in agricultural areas the density of earthworm population is around 40 g/m2. All mechanised activities (ploughing, milling, weeding, harrowing etc.) cause the complete destruction of the niches of the soil fauna in the area treated. The application of pesticides can have harmful effects on earthworms and other animals present in soils in the same way as elevated rates of mineral fertilisation.

It is clear that pilot studies, like the Bio-Bio project (Cenci and Sena, 2006), are necessary in order to understand the biodiversity in agricultural soils. These studies need to take into account the principle components of the soil fauna and the historical, chemical and physical aspects of the soils.

Each soil organism has a specific role in the complex web of life in the soil (FAO, 2001):

- The activities of 'soil engineers' like worms and termites, but also plant roots and ants and other macro-fauna affect soil structure through mixing soil horizons and organic matter and increasing porosity. This directly determines vulnerability to soil erosion and availability of the soil profile to plants.
- The functions of soil biota are central to decomposition processes and nutrient cycling. The rate at which the process operates is determined by small grazers (micro-predators) such as protozoa and nematodes. Larger animals may enhance some processes by providing niches or microbial growth within their guts or excrement. Specific soil microorganisms also enhance the amount and efficiency of nutrient acquisition by the vegetation through the formation of symbiotic associations such as those of mycorrhiza and N_2-fixing root nodules. Nutrient cycling by the soil biota is essential for all forms of agriculture and forestry. Soil biota affect plant growth and productivity as well as the release of pollutants in the environment, for example the leaching of nitrates into water resources.
- Certain soil organisms, like the build-up of nematodes under certain cropping practices, can be detrimental to plant growth. However, they can also protect crops from pest and disease outbreaks through biological control and reduced susceptibility.

- The activities of decomposers, bacteria and fungi (greatly facilitated by mites, millipedes, earthworms and termites), determine the carbon cycle – the rates of carbon sequestration and gaseous emissions (CO_2 and CH_4), and soil organic matter transformation.
- Plant roots, through their interactions with other soil components and symbiotic relationships, especially Rhizobium bacteria and Mycorrhiza, play a key role in the uptake of nutrients and water, and contribute to the maintenance of soil porosity and organic matter content, through their growth and biomass.
- Soil organisms can also be used to reduce or eliminate environmental hazards resulting from accumulations of toxic chemicals or other hazardous wastes. This action is known as bioremediation.

Pimentel *et al.* (1997) investigated the economic benefits of soil biodiversity and found that the most obvious service is the waste recycling, while other services are less evident, such as plant pollination; many species of pollinators in fact, have an edaphic phase in their life cycle.

2.6.2 Soil biodiversity and agriculture

The Millennium Ecosystem Assessment, which was called for by the United Nations Secretary General in 2000 with the objective of assessing the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being, described the state of cultivated systems and their impacts on ecosystem services, as follows:

a) As the demand for food, feed, and fibre is increasing, farmers respond by expanding the cultivated area, intensifying production, or both (Hassan *et al.*, 2005);

b) At the global level, conversion of natural habitat to agricultural use is perhaps the single greatest threat to biodiversity (UNEP/CBD/SBSTTA/13/2, 2007).

The main agricultural practices that impact on biodiversity are the following (COM (2001)162 final):

- unsustainable use of fertilisers and plant protection products (agro-chemicals. pesticides),
- traditional practices giving way to more mechanisation (use of heavy machinery),
- specialisation of production systems and intensification of certain practices (overgrazing, abandonment of mixed cropping systems and of cereals growing in grazing systems),
- reduction in number of species and varieties used,
- conversion of natural ecosystems (wetlands, hedgerows) to agriculture as well as abandonment of farm land,
- re-parcelling (larger parcel size, disappearance of field margins: hedges, ditches, etc.),
- drainage and irrigation (especially when dimensions are not adapted to conditions i.e. overexploiting groundwaters and rivers).

These can result in:

- degradation of site conditions, in particular soil degradation and erosion (affecting soil fauna),
- simplification and homogenisation of ecosystems,
- uncontrolled spread of alien and wild species.

Climate change is another driver whose effects on biodiversity (such as its distribution, migration and reproductive patterns) are already observable. In Europe, average temperatures are expected to rise by 2-6.3° C above 1990 temperatures by the year 2100. This will have profound effects on biodiversity (COM(2006) 216 final).

The impacts of individual agricultural practices on various components of soil biodiversity have been researched for several decades and there have been many reviews (e.g. Andrén *et al.*, 1990; Paoletti *et al.*, 1992; Curry, 1994; Bardgett and Cook, 1998). Agricultural land use and management practices can have significant (positive and negative) impacts on different components of soil biodiversity. For example, ploughing generally reduces diversity while liming tends to increase species richness in nutrient-poor semi-natural grasslands. The overuse of agrochemicals or industrial/domestic organic wastes will, in general, have a detrimental impact on soil organisms. Soil tillage operations deeply modify the soil environment, especially the soil architecture (soil structure, porosity, bulk density, water-holding capacity), crop residues distribution and organic carbon content. Soil environments directly influence the soil micro-arthropod community with respect to numbers and composition (Andrén and Lagerlof, 1983) and, their spatial distribution (Farrar and Crossley, 1983).

In a review that compared the soil biological community in fields with conventional and alternative fertiliser strategies (organic or biodynamic), Ryan (1999) concluded that the total soil microbial biomass and the biomass of many specific groups of soil organisms will reflect the level of soil organic matter inputs. Hence, organic or traditional farming practices, that include regular inputs of organic matter in their rotation, permit larger soil communities than conventional farming practices (Ryan, 1999). Observations on the impacts of agricultural management on communities of micro-arthropods showed that the high input levels of intensively managed systems tend to result in low diversity while lower input systems conserve diversity (Bardgett and Cook, 1998; Siepel and van de Bund, 1988).

Due to the complexity of agriculture and biodiversity, it is very difficult to analyse the links between (the variability of) agricultural production and biodiversity. An appropriate set of biodiversity indicators is a powerful tool for monitoring the biological diversity status and trends in order to evaluate the effects of different farming systems.

The adoption of organic farming and low-input farming can reduce the impact of agricultural activity on biodiversity. These types of agriculture are increasing in Europe: organic and low-input farming areas reached 4 % (2007) and 28 % (2000) respectively of the total agricultural area. Similarly, extensive management of grazing land has proved worthwhile for maintaining diversity of flora, fauna and micro-fauna (COM(2001) 162 final).

2.6.3 Conclusions and needs for future research

At European level, most studies of agricultural areas look at the use of bacteria as leading biological indicator in order to estimate CO_2 production rather than from the point of view of their biodiversity. It is necessary to highlight that the results of such studies are not always comparable, which is principally due to the lack of standardised methods; moreover the presence of organic material in the soil can mask the real state of the soil's health. Specific research on soil biodiversity needs to be carried out, using standardised methods, and covering all member states in order to inform policy makers on the status of the soil fauna.

2.7 Conclusions on soil degradation processes

SoCo's evaluations of soil degradation processes have been performed using models. These models provide EU-wide estimates and should not be interpreted with the same accuracy as field measurements, which are costly and difficult (logistics, harmonised methods, etc.) to collect for such a large area.

Soil properties and thus degradation processes influence each other; the open question is to what extent this occurs. A soil that gains soil organic carbon will improve its structure, which will impact on its susceptibility to compaction. When less compaction occurs, the consequences of compaction (increased run-off and landslides) are lessened and thus soil fertility is maintained. Organic matter absorbs pollutants and micro-organisms help to break these down into harmless elements. A reduction in organic matter means less food for organisms. A reduction in porosity reduces the amount of oxygen and water for organisms, leading to reduced populations, affecting soil health. Insufficient oxygen for plant roots may result in lower yields. A healthy soil means that all these factors are in balance. Priorities for preserving soil quality are site-specific.

A soil monitoring system that evaluates the magnitude of the soil degradation processes needs to be established as a first priority.

3 Soil conservation practices in agriculture

A major objective of this report is to raise awareness of the need for the use of sustainable soil management practices, and to synthesise current knowledge on relevant long-term farming practices (including those relating to livestock management) including their physical, social, economic and environmental charactersitics.

This chapter will focus on a set of sustainable cultivation techniques known as 'conservation agriculture', which are of relatively recent introduction, as well as on some more traditional agronomic measures and organic farming. The information contained in this chapter was derived from a comprehensive review of scientific papers, agronomic literature, research projects, official statistical sources and trustworthy websites. A table summarising the agricultural practices suggested as beneficial for various aspects of soil conservation can be found in Annex 3.1.

3.1 Definition of practices addressing soil conservation, and environmental and economic aspects

Agriculture is found in a variety of forms and management patterns with variable impacts on the environment and on the soil. It is common to distinguish between arable, livestock and mixed farming according to the objectives of production: crops *(sensu lato)*, animals or both.

In arable farming, cultivation methods are defined by the combination of certain objectives, techniques (or means) and tools. A cultivation method usually consists of the following features:

- soil preparation for seedbed,
- weed control,
- plant protection against insects and fungi,
- plant nutrition,
- water supply.

Specific techniques, by their specification of the tools to be used, determine how objectives are met. Each technique has a certain impact on the soil and can serve several purposes. Soil preparation techniques can be classified according to the depth of their actions and to their mechanical effects on soil strata:

- inversion or non-inversion,
- mixing, i.e. a tillage operation whereby soil layers are blended into the soil mass,
- fragmentation.

The combination of these three mechanical effects defines the degree of soil disturbance of a given technique. Table 3.1 below summarises the main techniques applied in agriculture for soil preparation and their impact on soil strata, as well as their respective level of disturbance. Pictures of machinery for each of these techniques are shown in Annex 3.2 and a description of their physical action on the soil is given.

Table 3.1: Classification of soil preparation techniques

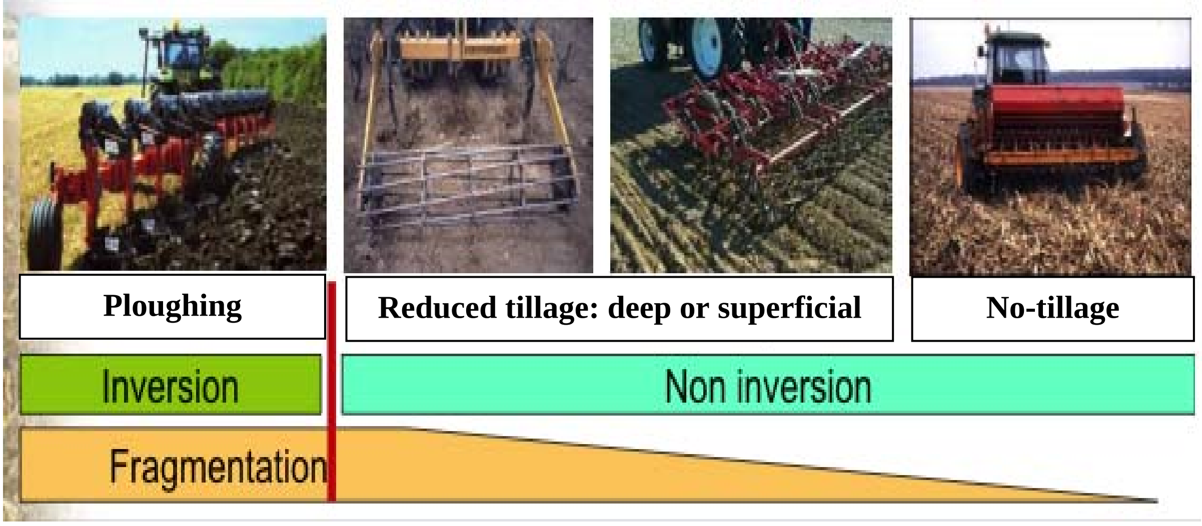
Techniques	Depth of soil preparation (cm)	Inversion	Mixing	Fragmentation	Degree of disturbance
Subsoil tillage (or sub-soiling)	40 - 80	No	No	Yes	Low
Soil decompaction (or decompression)	15 - 40	No	No	Yes	Low – medium
Ploughing	15 - 40	Yes	Yes	Yes	Very high
Deep soil preparation	15 - 30	No	Yes	Yes	High
Reduced tillage	5 - 15	No	Yes	Yes	Medium – Low
No-tillage (or direct sowing)	5	No	No	No	None

3.1.1 Conservation Agriculture

The concept of 'conservation agriculture' covers practices that minimise alteration of the composition, structure and natural biodiversity of soil, safeguarding it against erosion and degradation. These techniques are also referred to as 'simplified cultivation techniques' combining surface working, mulch sowing, direct sowing, non-incorporation of crop residues, crop rotation and vegetation cover (spontaneous vegetation or vegetation resulting from the sowing of appropriate species).

The main difference between conventional cultivation methods (conventional tillage) and simplified cultivation techniques is in the lack of inversion ploughing. Furthermore, fragmentation and disturbance are greatly reduced in simplified cultivation techniques. Soil fragmentation decreases from deep reduced tillage to direct sowing (Figure 3.1).

Figure 3.1: Simplified tillage techniques and intensity of soil fragmentation and soil inversion layers



Source: De Tourdonnet *et al.*, 2007a

In this section the following practices will be described: no-tillage, reduced tillage, cover crop and crop rotation.

No-tillage (FAO, 1993a; Gilliam *et al*., 1997; Boame, 2005; ECAF, 2008a)

No-tillage (NT) is a cultivation technique consisting of a one-pass planting and, if needed, one fertiliser operation. Soil and residues from the previous crop (mulch or stubble) are minimally disturbed. The machines used are normally equipped with coulters, row cleaners, disk openers, in-row chisels or roto-tillers. These penetrate the mulch, opening narrow seeding slots (2-3 cm wide) or small holes, and place the seed and fertilisers into the slots. Weed control is generally achieved with adapted crop rotations and/or herbicides. The entire soil surface remains covered by mulch, or dead sod on more than 50 % of the total surface. This technique is different from the one-passage sowing, where reduced tillage is performed with a combined tool (e.g. drill and rotary harrow).

Reduced Tillage

Deep or superficial reduced tillage without soil inversion represent all the practices where soil tillage is situated between no-ploughing and no-tillage, regardless of the soil cover management. Reduced tillage can be used for different objectives: stubble breaking (crop residues mix with the topsoil), seedbed preparation, mechanical weed control and destruction of soil lumps (for example, after ploughing).

Cover Crop (Sullivan, 2003; FFTC, 2007)

A cover crop is any crop grown to provide soil cover, regardless of the period or soil incorporation. 'Green manuring' involves soil incorporation of any field or forage crop, while it is still green or soon after its flowering. Cover crops and green manures can be annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand, during all or part of the year, generally during or between primary cropping seasons. When cover crops are planted to produce some quick livestock feed or reduce nutrient leaching, at a time when the land would otherwise be left fallow (after a main crop), they are often called 'catch crops'. Mulches are crop residues from cover crops left on the soil surface.

Cover crops are grown primarily to prevent soil erosion by wind and water. Cover crops and mulches help suppress the growth of weeds, provide additional organic matter, and improve the physical and chemical properties of the soil. Furthermore, they physically shelter the soil so that erosion from exposure is reduced. Green manuring is used for soil improvement.

Crop Rotation (USDA, 1996; Grubinger, 1999)

Crop rotation is a planned system of growing different kinds of crops, in the same sequence, on the same land and over three or more years. By exploiting the different ecological niches of crops, crop rotation helps to make a better use of natural resources and, therefore, improve or maintain soil fertility, reduce erosion and the build-up of pests, spread the workload, reduce risks of weather damage and the reliance on agricultural chemicals, and generally increases net profits. To establish a balanced crop rotation, agronomical aspects need to be taken into account prior to the economical ones. Some criteria were established by Viaux (1999). These are listed in hierarchical order (most to least important) in Table 3.2.

Table 3.2: Hierarchy of agronomical criteria necessary to build a crop rotation

	Criteria	Consequences
1	List of the species most adapted to the area(s)	Higher or better development of the crop, due to adaptating to the local pedo-climatic conditions and problems related to local pests and diseases
2	Introduction of a maximum number of different families and species in the rotation	The more genetically unconnected the species are, the fewer common parasites
3	Introduction of at least one legume in the rotation	Free nitrogen (nitrogen fixation) for the following crop and a high protein rate content
4	At least 1/3 of cereal straw content	If straw is not burnt or exported, it maintains soil organic matter
5	At least every three years, introduction of a long intercrop (e.g. a spring crop) integrating winter crops and spring crops	Stale seedbed technique in the intercrop favours the germination of weed seeds, mechanically eliminated later
6	Sow nitrogen demanding winter crops after annual legumes such as peas or a legume cover crop	Following harvest, some crops unload large amounts of nitrogen (such as peas), which will be used by nitrogen demanding crops such as wheat
7	Alternate phosphorus and potash demanding crops, with crops having a small demand of these elements	Same as in nitrogen demanding crops

Source: Viaux, 1999

Beck (2005) proposes six rotation types:

- **Simple rotation,** with only one crop of each crop type in a set sequence: e.g. winter wheat-corn-fallow, wheat-canola, spring wheat-winter wheat-corn-sunflower, corn-soybean, or even winter wheat-corn-pea.
- **Simple rotation followed by a long perennial sequence**: e.g. corn-soybean-corn-soybean-corn-soybean-alfalfa-alfalfa-alfalfa-alfalfa.
- **Compound rotation combining two or more simple rotations** to create a longer and more diverse sequence: e.g. spring wheat-winter wheat-corn-soybean followed by corn-soybean.
- **Complex rotation, where crops within the same crop type vary**, e.g. winter wheat-corn-sunflower-sorghum-soybean or barley-canola-wheat-pea; in this example barley has been substituted for one of the wheat crops, sorghum for corn, and sunflowers for soybean.
- **Stacked rotation,** including rotations where different crops, or crops within the same crop type, are grown in succession (normally twice, following a long break), e.g. wheat-wheat-corn-corn-soybean-soybean or barley-wheat-pea-canola.
- **Crop rotation combining both stacked and normal sequences**, e.g. canola-winter wheat-soybean-corn-corn and spring wheat-winter wheat-pea-corn-millet-sunflower (the latter is designed for cool and dry areas).

A) Soil and environmental impact

No-tillage, reduced tillage and cover crops:

Soil degradation

The use of non-inversion tillage techniques has significant effects on several soil properties that in turn regulate soil behaviour relevant to degradation. Table 3.3 summarises the results of conservation agriculture on physical, chemical and biological soil properties that will be dealt with, hereafter, in more detail.

Table 3.3: Impact of reduced tillage (RT) and no-tillage (NT) on soil properties, compared to conventional tillage (CT)

Soil properties		**Consequence**
Physical properties	Soil porosity	NT: A reduction of total soil porosity (during the first years of NT implementation) and an increase of bulk density NT: A comparable soil porosity after a transition phase RT: No difference in soil porosity between RT and CT NT-RT: Higher macroporosity (mainly resulting from earthworm activity)
	Porosity architecture	NT-RT: Higher macropores with a vertical orientation and high connectivity
	Bulk density	NT-RT: Bulk density of top layer increases a little – for most crops, it does not exceed the optimal condition limits
	Aggregate size	NT-RT: Higher aggregate size in the topsoil layer (0 - 5 cm) RT: + 40 % NT: +100 %
	Aggregate stability	NT-RT: Higher aggregate stability (especially for low clay content soil) RT: + 40 % NT: +100 %
	Structure stability	NT-RT: Higher structural stability
	Soil water	NT-RT: Reduction of water loss by evaporation and higher soil moisture (NT: up to +300 %; RT: up to +35 %) NT-RT: Higher water-holding capacity
Soil flows	Water	NT: Higher infiltration rate
	Gas	NT-RT: Reduction of gas permeability
Chemical properties	N cycle	NT-RT: Higher N content in the topsoil layer NT-RT: Reduction of N mineralisation
	P cycle	NT-RT: Higher P stratification NT-RT: Higher P content in the topsoil layer
	pH	NT-RT: Reduction (< 0.5 pH unit) of the pH of the surface soil layer (0 - 10 cm)
	Soil organic matter	NT-RT: Higher soil organic matter and carbon content in the topsoil layer NT-RT: Higher stratification (decreasing gradient from the surface to the deeper layers) NT-RT: Higher particulate organic matter
Biological properties	Microbial activity	NT-RT: Higher enzymatic activity
	Microfauna	NT-RT: Higher biomass (from +30 % to +100 %)
	Mycorrhiza	NT-RT: More favourable conditions (NT>RT)
	Meso-/Macro-fauna	NT-RT: Higher earthworm population (NT>RT)

Soil erosion

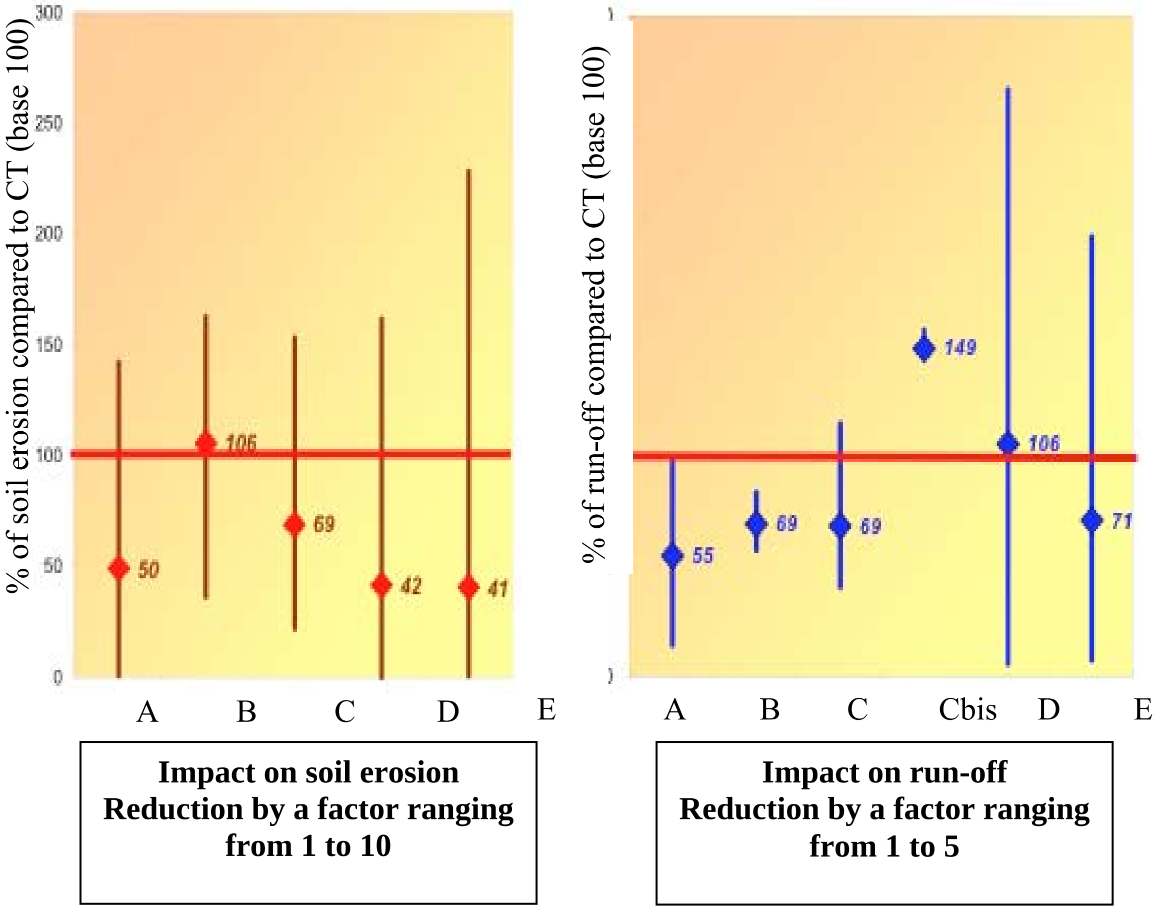
Factors determining soil erosion are analysed in chapter 3. The ability of rainwater to penetrate the soil strongly affects the degree of run-off and erosion (Ancelin *et al.*, 2007). This process is linked to soil permeability, soil porosity (continuity and level) and topsoil compaction. Under simplified cultivation methods, porosity is mainly biological porosity (biopores) due to anecic earthworm burrows (i.e. those feeding on decaying surface litter). These biogenic macropores have a vertical profile, are very resistant to pressure loading and allow a higher rainfall infiltration rate (Tebrügge and Düring, 1999).

Improved aggregate stability means a better resistance to the impact of raindrops and surface sealing. According to many authors, the structural stability (or aggregate stability) is closely linked to the organic carbon rate. As described in the table above, reduced or no-tillage increases the organic carbon rate in the topsoil layer, thereby also increasing aggregate stability.

These results reinforce and confirm evidence that reduced or no-tillage techniques can diminish springtime run-off and erosion, provided the soil is sufficiently covered (with mulch, green manure, catch crops, etc.) and its biological activity is significant (Ancelin *et al.*, 2007). Given certain values of slope, texture, rainfall and so on, the run-off process can be reduced by a factor ranging from 1 to 5 under conservation agriculture compared to conventional tillage methods, and erosion by a factor ranging from 1 to 10, as summarised in Figure 3.2. Simplified tillage techniques are more efficient in reducing erosion than run-off.

However, charts show that there are cases when erosion and run-off can be higher even under simplified cultivation techniques. This seems to occur in connection to the presence of severe soil compaction and soil crusting which tend to reduce or block rainfall infiltration at the soil surface and permeability over the arable soil layer (Ancelin *et al.*, 2007).

Figure 3.2: Comparison of the effectiveness of simplified cultivation methods



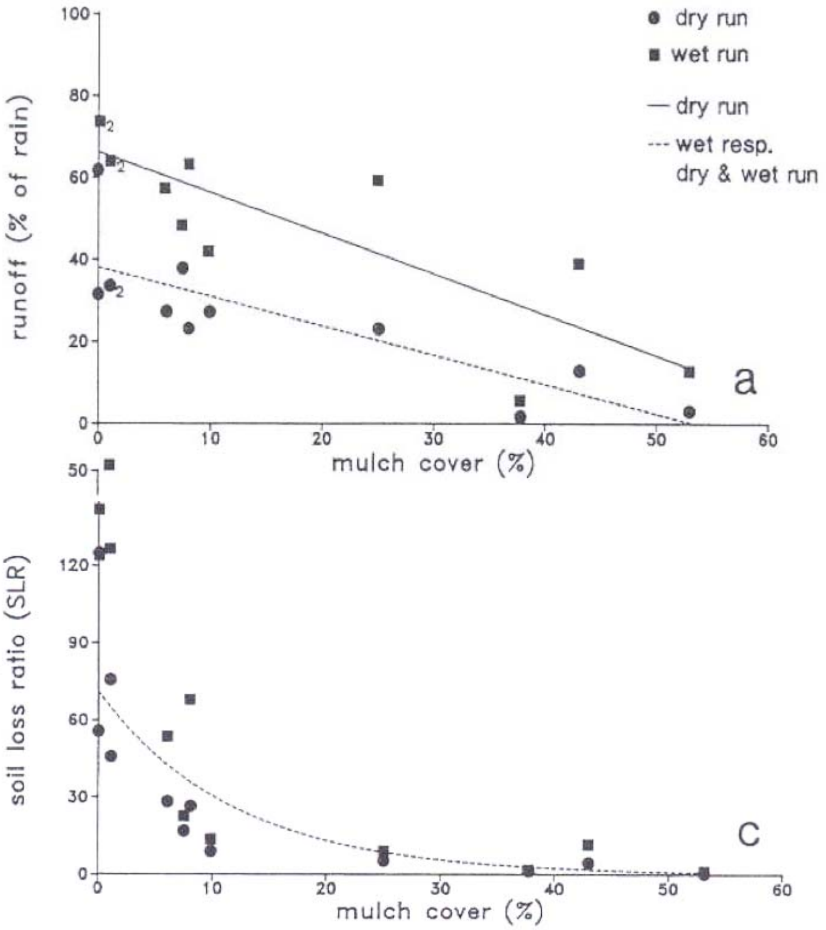
(A, B, C, D, E) on soil erosion and run-off, with ploughing (base 100)
Bar length relates to variability of results, rhombi represent the ponderate average
A = Conventional tillage without mouldboard plough; B = Decompaction; C = Strip till; Cbis = Ridge till; D = Reduced tillage; E = No-till
Source: De Tourdonnet *et al*., 2007a

In European perennial crops (vineyards, olive groves, etc.), 'zero soil cover' combined with 'zero tillage' is currently the most common management method. The intensive weed control (with herbicide or grazing) keeps the soil weed-free and bare, while completely unprotected from water erosion, thus making perennial crops the highest soil loss contributors in agriculture. The implementation of soil cover (permanent or temporary living soil cover) would be the best solution to reduce soil losses and run-off significantly.

However, because of the competition for water between perennial crops and the living soil cover, the use of cover crops is difficult, especially under Mediterranean conditions. The vegetative soil cover between crop rows has to be managed by, for example, use of herbicides or mechanical weed control, or grazing.

It is important to note that whatever the cultivation method – conventional or not – a minimum of 30 % covered soil is effective in reducing run-off by 50 % and erosion by 80 % (Figure 3.3). Cover crops, associated with simplified techniques, allow both a reduction in raindrop impact and a better soil structure (due to better aggregate stability and soil organic matter content).

Figure 3.3: Correlation between mulch soil cover and run-off (upper chart) or erosion (bottom)

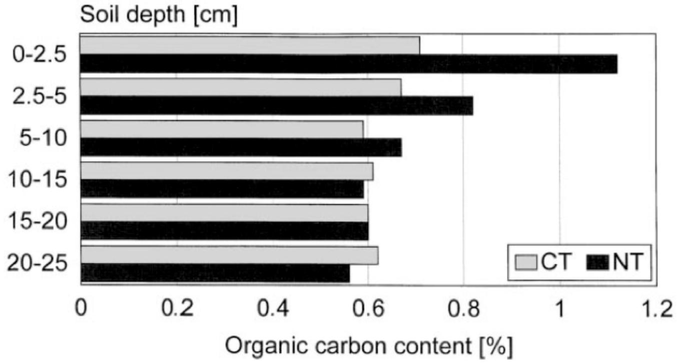


Source: Kainz, 1989 in Labreuche *et al.*, 2007a

Soil organic matter/carbon content

Under conventional tillage, organic carbon distribution is uniform over the first 30 centimetres, as a result of soil turnover by ploughing. When conservation agriculture is applied, soil organic matter originated by crop residues is not buried but accumulates in the topsoil: 75 % of the organic carbon from the crop can be found in the uppermost 5 cm (Labreuche *et al.*, 2007a). Between the surface and the deeper layers, a decreasing gradient of organic carbon occurs. This gradient depends on the duration of reduced tillage or no-tillage practices and on the type of practice: the less the soil is disturbed, the more the gradient is apparent.

Figure 3.4: Effect of long-term tillage systems on organic matter contents in soil, expressed by the content of organic carbon in the topsoil of the Eutric Cambisol



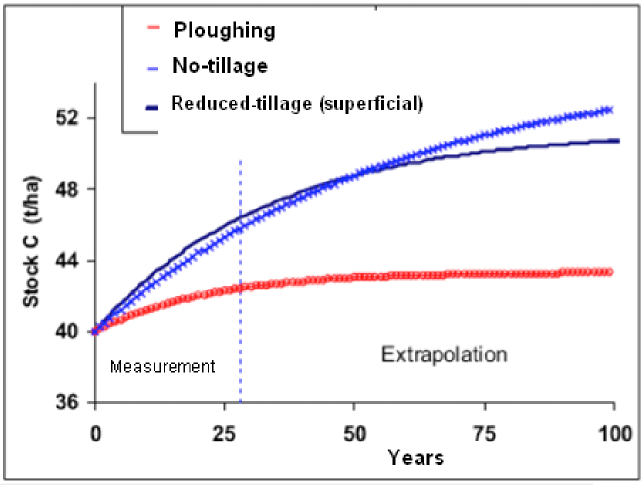
CT: conventional tillage; NT: no-tillage
Source: Tebrügge and Düring, 1999

The actual increase of organic carbon under conservation agriculture is generally between 4 and 120 g C/m^2/yr (Soane and Ball, 1998; Tebrügge and Düring, 1999; Arrouays *et al.*, 2002).

An increase in organic carbon of 50 g C/m^2/yr will increase the organic matter content in the topsoil by 1 % over 30 years (figure calculated on the top 25 cm, a soil density of 1.2 t/m^3 and a carbon content of 50 % in organic matter).

This increase of the organic carbon stock is mainly located in the topsoil layer (the first 10 cm). The process continues until a new balance is reached between accumulation and destruction in the topsoil layer. According to the authors, the time needed to reach this balance is quite variable: a minimum of 10 to 20 years is required (Figure 3.5) (Labreuche *et al.*, 2007a).

Figure 3.5: Simulated evolution of soil carbon content, Boigneville test, France



Source: Balesdent, 2002

On the other hand, this equilibrium is very fragile. The increase of organic carbon stock mainly concerns organic matter with rapid turnover (Oorts, 2006) which is highly sensitive to mineralisation. Therefore, the alternate use of ploughing and conservation agriculture systems can cause the rapid disappearance of all the positive effects of conservation agriculture on organic carbon in soil.

The use of cover crops (during the crop succession period), combined with simplified tillage techniques, can increase the organic carbon stock more rapidly. In the case of a systematic use (every year), the amount of stored carbon can reach 160 kg C/ha/yr (Arrouays *et al.*, 2002).

Conventional ploughing accelerates mineralisation of organic matter by soil micro-organisms because, by destroying soil aggregates, the contact surface between organic matter and soil organisms is increased and so is the availability of nitrogen (Guerif, 1994).

Vice versa, by not destroying soil aggregates, simplified cultivation methods significantly reduce transformation of organic matter into mineral component (K2) (Thevenet *et al.*, 2002), as illustrated in Table 3.4.

Table 3.4: Impact of tillage system on K2 factor

Tillage methods	K2 mineralisation constant
Ploughing (25 cm)	0.046
Reduced tillage (superficial)	0.032
No-tillage	0.017

Source: Balesdent, 2002

In warm climates of southern Europe, where mineralisation processes are rapid, simplified cultivation techniques appear particularly desirable to enhance soil organic carbon content.

Soil compaction

Soil compaction occurs when mechanical pressure is applied, especially in wet conditions. In an agriculture pattern, mechanical pressure relates to cultivation methods (number of tractor passages) and livestock management (stocking density, overgrazing).

It is assumed that with no-tillage, the number of tractor passages decreases significantly; which is not always true under reduced tillage.

There are few available data on the impact of simplified cultivation techniques on soil lift, i.e. the capacity of the soil to bear a certain weight without suffering damages, and its resistance to compaction, but the vertical orientation of the pores and better aggregate stability improve soil resistance to severe soil packing. Moreover, other data show that under no-tillage, the resistance to penetration can increase.

The effect of tillage practices (conventional or not) on soil compaction depends mainly on:

- soil humidity during tractor passages,
- the initial state of the soil,
- crop rotation.

Soil contamination/water quality

Surface water contamination by pesticides is directly linked to the amount of water flowing as run-off. By reducing water run-off (see above), simplified tillage and soil cover can improve the surface water quality and reduce the lateral losses of pesticides compared to conventional tillage (CT), on equal amounts of pesticides used (Tebrügge and Düring, 1999; ITADA, 2005; Labreuche *et al.*, 2007a). The reduction of pesticide flow ranges from 29 % to 100 % (ITADA, 2005), depending on the type of pesticide (solubility, absorption coefficient) and the type of simplified tillage systems applied (the simpler the tillage system, the more efficient the reduction of pesticide transfer).

Moreover, the increase of soil organic matter and biological activity can increase the amount of pesticides fixed (adsorption) or their breakdown in the topsoil layer, and reduce pesticide transfers by run-off (Labreuche *et al.*, 2007a; ITADA, 2005).

Several processes are involved in pesticide leaching, but the effects of adopting simplified tillage techniques are highly variable (Tebrügge and Düring, 1999; Holland, 2004; Labreuche *et al.*, 2007a; ITADA, 2005). On the one hand, under simplified cultivation methods (and especially no-tillage), the increase of soil macro-pores (and the better vertical orientation and connectivity of these biopores) facilitates a more rapid movement of water and of the pesticides within (preferential vertical transport). On the other hand, the macro-pores created by earthworms (biopores) are covered with organic matter and retain agrochemicals, preventing the preferential vertical transport. Absorption and breakdown of pesticides are higher under no-tillage or reduced tillage (associated with soil cover) because of the increase of soil organic matter and biological activity in the surface soil.

Regarding the parameters listed above, the most important factor for reducing groundwater pollution is the management of the period of pesticide use in the field. If a high draining period (significant rainfall) takes place just after the pesticide is used in the field, the quantity of pesticides transferred to groundwater could be higher under no-tillage or reduced tillage (preferential vertical transport). On the contrary, if no draining period occurs after the pesticide is used, biological breakdown could play a significant role and prevent water contamination.

Water quality is also very much affected by nitrogen (N) and phosphorus (P), typically contained in fertilisers. Nitrates are soluble nutrients, loosely linked to soil particles. Thus, nitrate losses are directly linked to soil water flows, in particular more with leaching than run-off (Le Souder *et al.*, 2007).

Findings concerning the effect of tillage systems on nitrate leaching are sometimes contradictory (Holland, 2004; ITADA, 2005; Le Souder *et al.*, 2007). However, it is generally recognised that, under simplified cultivation techniques, the greater density of macro-pores may contribute to nitrate leaching because of a higher total volume of water moving through the soil. On the contrary, several authors report that soil cover shows a significant effect in reducing nitrate losses, whatever the tillage system used (ITADA, 2005; Le Souder *et al.*, 2007).

Regarding phosphorus (P), the literature reports that, although total phosphorus losses are reduced under no-tillage or reduced tillage, soluble phosphorus losses and the risk of eutrophication are higher compared to CT. This is due to the double nature of P (soluble and particulate, the latter accumulating on soil organic matter) and, once again, to the increase of soil macro-pores (and the better vertical orientation and connectivity of the biopores), which facilitate a more rapid movement of water and enhance a preferential flow of the water surplus. Therefore, fertiliser techniques and application rates under conservation agriculture should be adjusted (Holland, 2004). For example, careful control of mineral fertiliser application rates or local input of phosphorus close to the seed can be good solutions for preventing run-off losses (Castillon *et al.*, 2007).

Greenhouse gas (GHG) emissions

Soil tillage contributes to greenhouse gas (GHG) emissions (CO_2, N_2O, CH_4) through a number of processes:

- direct GHG emissions: at the farm scale, emissions from energy consumption (fuel, gas, electricity);
- indirect GHG emissions: emissions due to input manufactures (fertilisers, seeds, pesticides, machines);
- emissions/storage from soil processes and vegetative covers: carbon balance, N_2O soil emissions, N_2O consumption by soil organisms (transformed into neutral atmospheric nitrogen N_2), CH_4 emissions from crops, CH_4 consumption by soil organisms (transformed into CO_2).

Simplified cultivation techniques are found to allow significant fuel savings (see below), leading to a reduction in CO_2 emissions ranging from 27 to 162 kg CO_2/ha/yr (Labreuche *et al.*, 2007b). CO_2 emissions are also reduced because of the non-breaking of soil aggregates (reduced mineralisation) with respect to conventional ploughing.

Under simplified techniques, various rates of increase in N_2O emissions can occur compared to conventional plough-based tillage. This seems to be due to changes in gas flows within the topsoil, and to the production of anoxic conditions (increase of soil bulk density and reduction of soil porosity). However, long-term experiments over 10 years show that N_2O emissions from a no-tillage managed soil are comparable to those from soils where conventional tillage was applied. Moreover, the introduction of a cover crop such as green manure can reduce the use of mineral nitrogen on the subsequent crop, especially when the cover crop used is a legume (or a mix of several plants, including a legume). This could significantly reduce the N_2O emissions caused by the production and use of mineral fertilisers.

Little or no difference between conventional, reduced and no-tillage systems in the soil oxidation ability of CH_4 into CO_2 by micro-organisms is reported in the literature. However, the amount of CH_4 transformed biologically into CO_2 in conventional crops is very low (less than 10 kg CH_4/ha/yr). Thus, the amount of CH_4 released seems to be small in relation to the GHG balance and soil tillage.

In conclusion, implementation of simplified tillage techniques (and soil cover) improves the GHG balance.

Other than GHGs, NH_3 (ammonia) and NOx (nitrogen oxides) are also major air pollutants. However, few data are available across Europe on this topic.

Simplified tillage techniques may have diverse effects on ammonia volatilisation from the soil. On the one hand, crop residues on surface soil increase the soil-atmosphere exchange surface, and thereby may increase ammonia volatilisation. On the other hand, the presence of crop residues on surface soil reduces water losses by evapotranspiration, soil temperature and soil pH. All these processes involve a decrease in ammonia volatilisation.
The reduced soil aeration, under simplified cultivation techniques, seems to increase nitrogen oxide emissions with respect to conventional tillage.

Biodiversity

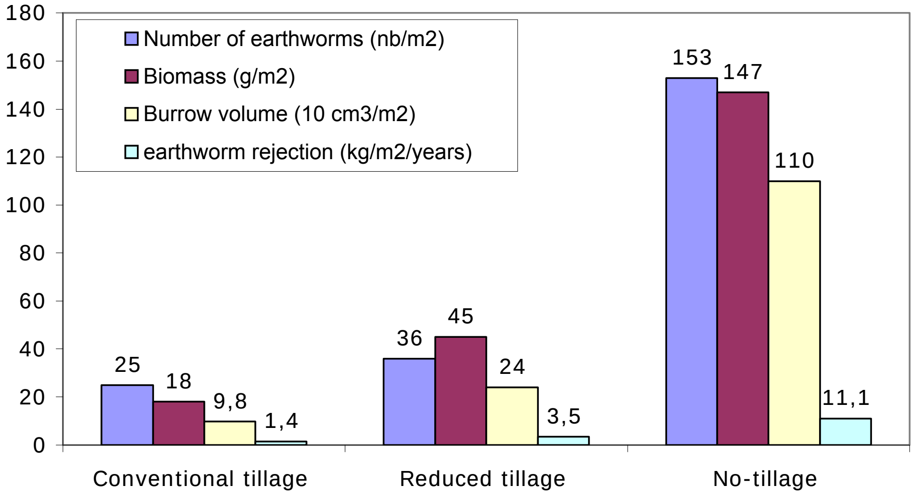
Reduced tillage or no-tillage methods increase the amount of biological activity and change its composition and distribution compared to conventional tillage (Javürek *et al.*, 2006, Holland, 2004). Soil structure, and the amount and distribution of soil organic matter, are the main factors influencing soil biodiversity (Holland, 2004).

Evidence in the literature shows positive trends as regards the abundance and activity of the micro-organisms (+30 to +100 % microbial biomass in topsoil, according to De Tourdonnet *et al.* (2007a) and meso- or macro-fauna feeding on soil organic matter.

Soil microorganisms have a variety of functions, particularly that of recycling of nutrients. Furthermore, meso- and macrofauna have an important role in creating soil porosity.

However, many other factors influence soil biodiversity as well, including fertility, time of cultivation, use of pesticides, crop residues management, crop rotation, and use of mineral fertiliser. The impact of the simplified tillage system on earthworm populations feeding on organic matter is well documented, and its effects are clearly positive (see Figure 3.6)

Figure 3.6: Link between soil tillage methods, earthworm populations and their activity



Source: Tebrügge and Düring, 1999

Few data are available on the impact of conservation agriculture on biodiversity outside the soil domain. However, the intensification of agriculture is considered to be the cause of decline in many bird species (Holland, 2004). In Europe, the supply of adequate seeds over the winter, and of invertebrate food for chicks, are considered to be two of the factors driving bird population dynamics. Ploughed fields are universally avoided, probably because they provide little seed or invertebrate food, with birds preferring fields where stubble remains. The soil surface is less disturbed under simplified tillage techniques and, therefore, seed availability should be higher than under conventional tillage. Moreover, the crop residues left when simplified tillage techniques are used provide a habitat for arthropods, attracting more frequent visits by birds and a greater diversity. The presence of crop residues is considered the most important factor influencing the choice of nesting sites of ground nesting birds.

Simplified cultivation techniques may also favour undesired forms of biodiversity like weeds and pests (diseases), related to the non-deep burial of seeds (ITADA, 2005; Labreuche *et al.*, 2007a). The vertical distribution of seeds is modified by the use of direct-drilling (more than 90 % of seeds remain in the first 10 cm of soil). Therefore, contrary to conventional ploughing, most of the stock of weed seeds is concentrated in the top layer (Aibar, 2006).

Moreover, the crop residues left by no-tillage increase soil humidity and decrease soil temperature. This creates favourable conditions for germination and emergence, and induces a change in the number and type of weeds: perennials and annual grass are promoted, while dicotyledonous are disadvantaged.

It is reported that the amount of herbicides used does not systematically increase under simplified cultivation techniques, but rather non-selective herbicides are preferred (there are risks of resistant weed species coming up). The effect of the quality of weeding and of the agricultural system (rotation, sowing density, period of sowing, variety choice) remains dominant for weed management (ITADA, 2005; Labreuche *et al.*, 2007a).

The presence of crop residues in the topsoil layer, and the moisture increase, can have an effect on pests and crop diseases (Labreuche *et al.*, 2007a; Real *et al.*, 2007). Diseases or pests, especially those attenuated by soil inversion, are clearly favoured by reduced tillage or no-tillage methods. This is the case for various *fusarium* species, ergot, take-all (fungal diseases of cereals) and slugs (especially in no-tillage or with the sowing of a cover crop). However, a wide range of diseases is not affected by soil tillage. In some other cases, such as that of cereal eyespot, reduced tillage or no-tillage decrease the level of infestation.

The literature reports that the overall amount of insecticides or fungicides is not significantly affected by the use of simplified cultivation techniques. However, the use of molluscicides (against slugs) might increase (Labreuche *et al.*, 2007a).

Crop rotation:

Compared to the previous conservation agriculture practices, much less literature is available on crop rotations and, in particular, on their impact on the environment and their economic performance. This is mainly due to the vast amount of possible crop combinations and local soil and climate conditions that could be encountered.

Nevertheless, the following general guidelines can be given.

Suitable and well adapted crop rotations can effectively contribute to soil conservation by:

- decreasing weed, pest and disease pressures, leading to a reduction in herbicide and pesticide use, and prevention of water contamination;
- improving soil quality and soil fertility;
- decreasing soil erosion thanks to a better soil cover;
- recycling mineral elements (mainly nitrate, phosphorus and potassium), leading to a reduction in fertiliser use and prevention of water contamination;
- reducing energy dependence (less mineral nitrogen is needed if leguminous plants are introduced in the rotation);
- increasing crop and farmland biodiversity, with a long rotation composed of many varieties (landscape diversity), supplying food and habitat for numerous animals (Arrue *et al.*, 2007a; Barz *et al.*, 2007).

Various features of crop rotations can be responsible for these beneficial effects. First, the incorporation of legumes in cereal rotations provides the nitrogen necessary for the development of arable crops by means of N_2-fixation (Arrue *et al.*, 2007b; Magid and Nielsen, 2007). Indirectly, the resulting lower application of chemical fertilisers allows saving energy and reduced N_2O emissions. It is important, when including legumes in a rotation, to take into account the period when nitrate leaching is most likely to occur (Barz *et al.*, 2007).

Second, inclusion of grass and legumes in a rotation can also increase the yield of the main crop, especially during the first year of row-crop cultivation. This is due to the improvement in the organic status and fertility of the soil (Morgan, 2005; Arrue *et al.*, 2007b; Labreuche *et al.*, 2007a; Magid and Nielsen, 2007).

Third, the control of weeds, pests and diseases by a suitable crop rotation significantly reduces the need for pesticides (Viaux, 1999) and decreases the risk of pollution. However, to minimise the risks of weed, pest and disease- infestations, the longest possible rotation (at least five to ten years) is necessary (Viaux, 1999; ITADA, 2005). The sequence should be composed of many varieties of crops adapted to the local pedo-climatic conditions. Species should be genetically distant to reduce the number of common parasites. It follows that monocultures and short rotations, being more sensitive to pests and diseases, should be avoided (Barz *et al.*, 2007; Arrue *et al.*, 2007a).

B) Economic performance

This section is divided into five topics to show the separate economic consequences of simplified tillage techniques at farm level and analyse their effectiveness on:

- crop yields
- labour time
- fuel use
- machinery costs
- profitability (gross and net margins, cost effectiveness).

These effects often differ according to soil type and climate, with marked differences between northern and southern Europe.

Crop yields

No-tillage ensures more homogeneous yields in the long run. It can produce crop yields in the first years at least comparable to those of conventional tillage. With time, yields can be significantly higher, especially during drought periods (Baker, 2007; Lahmar and Arrue, 2007).

Pedo-climatic conditions have an important influence on no-tillage yields. Indeed, under a semi-arid climate such as that in the Mediterranean area, rainfall is low, variable and erratic, with high intensity storms (precipitation is distributed within two periods: autumn/early winter, and spring – the latter occurring only in western areas). Under these conditions, soils are dry and subject to wind and water erosion, and no-tillage is particularly appropriate (increase of soil water content, erosion reduction); for example, Lahmar and Arrue (2007) reported an increase in yields from 10 to 15 % in Mediterranean Basin conditions. An increase in yields from 10 to 15 % was observed (Lahmar and Arrue, 2007) in the Mediterranean Basin conditions. In northern Europe temperate climates, precipitations are more abundant and better distributed throughout the year. These weather conditions allow the use of simplified tillage techniques, but losses in yields are observed. However, only 5 % of European fields under simplified tillage techniques are affected by a loss of yield greater than 10 % (Holland, 2004).

As for crop rotations, in addition to erosion control, the inclusion of grass and legumes in a rotation can increase the yield of the main crop, especially during the first year of row-crop cultivation. This is due to the improvement of the organic status and fertility of the soil (Morgan, 2005). In Spain, it was found that yields are significantly lower in the cereal/cereal rotation than in the cereal/fallow and cereal/legume rotations (Arrue *et al.*, 2007b). Likewise, the introduction of pea in a rotation induces a rise of wheat yields, which is greater under direct sowing than under conventional tillage (Labreuche *et al.*, 2007a).

Labour time

All the literature reviewed agrees that, whatever the geographical area concerned, simplified cultivation techniques lead to a decrease in labour time per hectare for arable crops (for soil tillage, mechanical or chemical weed control before sowing and sowing). This is mainly due to the reduced volume of displaced soil and to the less frequent machine passages (Rieu, 2004; De Tourdonnet *et al.*, 2007b).

Results of studies for northern Europe (see Table 3.5) show a reduction of labour time of 60-70 % when switching from conventional to no-tillage methods; and of 30-40 % from conventional to reduced tillage methods (Tebrügge and Böhrnsen, 1997; ITADA, 2005; Longueval, 2007).

In the semi-arid areas of southern Europe (see Table 3.5), where NT is more suitable for the pedo-climatic conditions, labour time is reduced by a factor of 4 (Pérez de Ciriza *et al.*, 2006). Thus, using NT systems, farmers can handle an area four times larger than that using CT (Sánchez-Girón *et al.*, 2004). In Italy, labour time is reduced by a factor 2 (Bonari *et al.*, 1995).

Table 3.5: Labour time (h/ha and % relative to CT) in Europe, as affected by tillage systems

	Northern Europe					**Southern Europe**		
	Midi-Pyrénées, France			**France**	**Germany**	**Castilla-León, Spain**	**Navarra, Spain**	**Toscana, Italy**
Crops	**Cereal straw**	**Sunflower**	**Maize**		**Cereals**			**Rape**
CT	**3h45**	**4h**	**4h**	**7h**	**3h**		**4h**	
RT-d		**3h20**	**3h**	**6h30**	**2h**		**2h30**	
RT-s	**2h30**	**2h**		**6h**			**1h45**	
NT	**1h10**			**4h**	**0h30**		**1h**	
RT-d/ CT (%)		-20 %	-25 %	-10 %	-33 %	-22 %	-38 %	
RT-s/ CT (%)	-33 %	-50 %		-14 %				-55 %
NT/CT (%)	-68 %			-57 %	-83 %	-45 %	-75 %	

CT= conventional tillage; RT-d = deep reduced tillage; RT-s = surface reduced tillage; NT= no-tillage
Source: Bonari *et al.*, 1995; Pérez de Ciriza *et al.*, 2006; Tebrügge *et al.*, 1997; Rieu, 2004; Longueval, 2007

Fuel saving

Due to lower labour time requirements and limited machine passages, reduced tillage and no-tillage allow systematic savings on fuel (Bonari *et al.*, 1995; Pérez de Ciriza *et al.*, 2006; Arrue *et al.*, 2007; Kavvadias, 2007; Lahmar and Arrue, 2007; Lahmar and de Tourdonnet, 2007) (see Table 3.6). However, the size of the fuel saving is very variable, and can depend on the type of cultivation technique used: reduced or no-tillage, and the type of soil (in particular its clay content) (Labreuche *et al.*, 2007a).

Reduced tillage allows savings ranging from 10 to 50 l/ha, while most of the available data show savings ranging from 10 to 20 l/ha. The most important benefits (35 to 50 l/ha) concern heavy soils with high clay content.

No-tillage allows savings ranging from 15 to 60 l/ha (up to 80 l/ha for olive tree plantations). Most of the available data show savings ranging from 25 to 35 l/ha. Again, the greatest savings (45 to 60 l/ha) concern heavy soils with high clay content.

Table 3.6: Fuel savings in northern and southern Europe (l/ha) as affected by tillage systems

Northern Europe					
	Midi-Pyrénées, France			France	Germany
Crops	DW-S	S	M		W
RT/CT	11.5	23	45	20-40	15.6
NT/CT					36.7

Southern Europe											
	Seville, Spain		Navarre, Spain	Spain	Greece						
Crops	S	W	M	Op	W	M	S	SB	C	A	T
RT/CT	9.2	9.6	26-38	60 - 80 l/year							
NT/CT	28.7	21.8	48		13-30	24-36	10-16	21-31	15-22	17-25	14-21

DW=Durum Wheat; S = Sunflower; M = Maize; SG = Small grain; W=Wheat;
Op = Olive tree plantations; SB = Sugar beet; C = Cotton; A = Alfalfa; T=Tomatoes (legumes).
CT= conventional tillage; RT-d = deep reduced tillage; RT-s = superficial reduced tillage; NT= no-tillage
Source: Tsatsarelis, 1994; Pérez de Ciriza *et al.*, 2006; Tebrügge and Böhrnsen, 1997; AEAC.SV, 2006; Longueval, 2007; García-Torres *et al.*, 2002

Machinery costs

Compared to CT, NT systems overall do not increase agricultural machinery costs, but farmers have initially to invest in relatively expensive specific machines for sowing (direct drill) (Baker, 2007; Lahmar and Arrue, 2007). Therefore, a large-size farm, or alternatively, the support of farmer associations, could help pay for these investments more easily (Rieu, 2004; ITADA, 2005; Lahmar and Arrue, 2007).

In spite of the initial expenses, fewer machines are needed and they are used less, significantly contributing to reducing machine expenses (less wear). Over a long period, NT lower machinery operating costs translate into profits:

- In France, EUR 26 /ha savings in the first years, and up to EUR 81 /ha in the following years, are possible (Rieu, 2004).
- In England, under the same agricultural conditions, NT was cheaper than CT by EUR 76 /ha, and RT less expensive than CT by EUR 38 /ha (Baker, 2007).
- In Germany, the purchase costs are 40 % lower under NT than CT (Tebrügge and Böhrnsen, 1997) (Table 3.7).
- In Greece, 79 % of holdings are under 5 ha. Therefore, the purchase of new machinery presents financial difficulties. A solution for these farmers would probably be to hire a contractor (Tsatsarelis, 1994).

Table 3.7: Purchase costs (EUR) of different machinery equipment: example for a 150 ha farm in Germany

Tillage system	**NT**	**RT**	**CT**
Tractor	(52 kW) EUR 30 500	(100kW) EUR 55 000	(100 kW) EUR 55 000
Stubble cultivation		Disc harrow (4 m) EUR 15 500	Disc harrow (4 m) EUR 15 500
Plant protection	Sprayer (12 m, 1000 l) (EUR 5 500)	Sprayer (12 m, 1000 l) (EUR 5 500)	Sprayer (12 m, 1000 l) (EUR 5 500)
Soil tillage		Wing share cultivator + rotary harrow	4-furrow plough (1.70 m) EUR 10 500 + land packer EUR 1 600 vertical rotary harrow
Grain drill	No-tillage drill (3 m) EUR 26 000	+ seed drill (2.5 m) EUR 22 500	+ seed drill (3 m) EUR 16 000
	Sugar beet, 6 rows		
Spacing drill	EUR 7 600	EUR 7 600	EUR 6 000
TOTAL	**EUR 64 100**	**EUR 100 600**	**EUR 104 600**

Source: Tebrügge and Böhrnsen, 1997

Profitability

Conservation agriculture produces yields comparable to CT but, unlike organic farming, does not justify selling products at a better price (there is no specific market or labelling system). Therefore, the economic profitability of conservation agriculture largely depends on reducing costs (Lahmar and de Tourdonnet, 2007; Tebrügge and Böhrnsen, 1997; Holland, 2004), including costs of labour, machinery, purchased inputs and water.

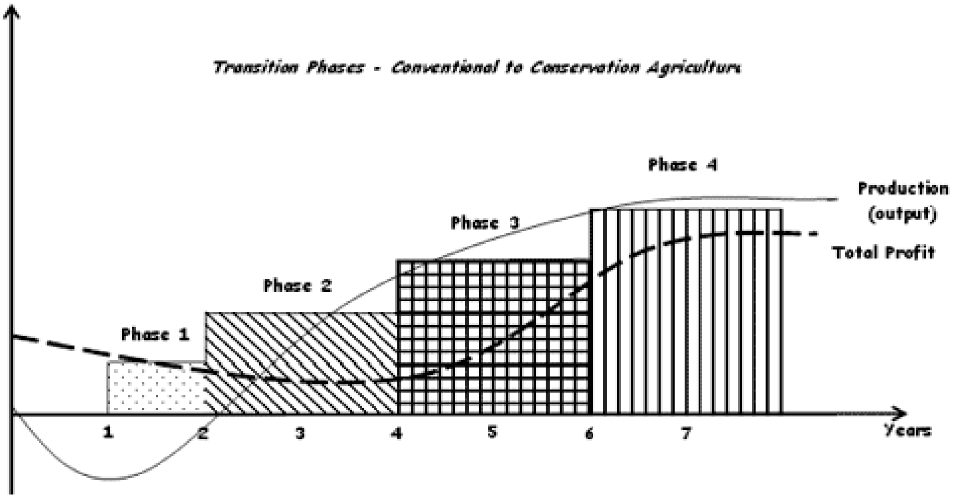
These costs vary greatly from case to case, and closely depend on the farmer's skills (Arrue *et al.*, 2007a), on the geographical and climate conditions and on the type of soil (Holland, 2004). In northern Europe, results of simplified tillage techniques appear slightly less favourable (Kächele *et al.*, 2001; ITADA, 2005; Javürek *et al.*, 2007).

In general, CA is a more complex agriculture than CT, requiring a period of training and local adaptation before favourable economic results can be obtained.

The transition period (see Figure 3.7) is variable and risky: yield losses can occur. In this case, economic profitability is reduced. The possibility of receiving subsidies, especially during the transition period, appears to be a major factor for economic viability (Lahmar and de Tourdonnet, 2007).

In several European countries (France, Germany, UK), there is evidence that margins increase with time (Tebrügge and Böhrnsen, 1997; Kächele *et al.*, 2001; Meyer-Aurich *et al.*, 2001; Holland, 2004; ITADA, 2005; Barz *et al.*, 2007; Vandeputte, 2007). Farm size is an important factor for economic viability: CA appears more economically interesting for large farms, where labour time is limited (De Tourdonnet *et al.*, 2007b).

Figure 3.7: The transition phase of conservation agriculture adoption



First phase: improvement of tillage techniques; second phase: improvement of soil conditions and fertility; third phase: diversification of cropping pattern; fourth phase: the integrated farming system is functioning smoothly
Source: FAO, 2004

A summary table of the economic performance of simplified cultivation techniques at farm level is given in Annex 3.3.

3.1.2 Organic farming

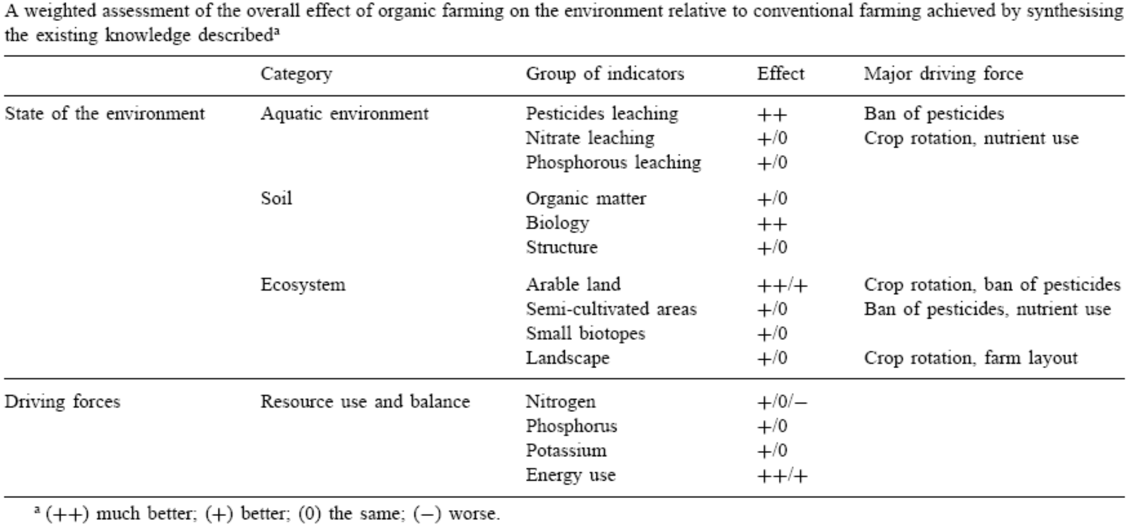
Organic production is an integrated system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes (FAO, 2008). The organic production method thus plays a dual societal role, where, on the one hand, it supplies a specific market responding to a consumer demand for organic products, and, on the other hand, delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development (Council Regulation (EC) No 834/2007). Organic farming (OF), therefore, emphasises the use of management practices in preference to the use of purchased inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system.

Soil and environmental impact, and economic performance

In 2005, the area devoted to organic farming (including area within fully organic systems and area under conversion), certified under regulation (EEC) 2092/91, covered 5.3 million ha in the EU-15 (6.1 million ha in the EU-25), while in 1998 it covered only 2.3 million ha (Eurostat, 2007b). This represents an increase of 130 % over the period 1998-2005. The organic farming area reached 3.7 % of the total Utilised Agricultural Area (UAA) of the EU-25 in 2003 and 4 % in 2005. However, there is considerable variation amongst Member States: in 2005, one fifth of the EU-25 organic farming area was located in Italy.

Using the driving force-state-response (DSR) framework for the identification of a series of qualitative indicators, Hansen *et al.* (2001) assessed the impact of organic farming on the environment. Qualitative results, summarised in Table 3.8, confirm the findings of other authors.

Table 3.8: A weighted assessment of the overall effect of organic farming on the environment relative to conventional farming



A weighted assessment of the overall effect of organic farming on the environment relative to conventional farming achieved by synthesising the existing knowledge described[a]

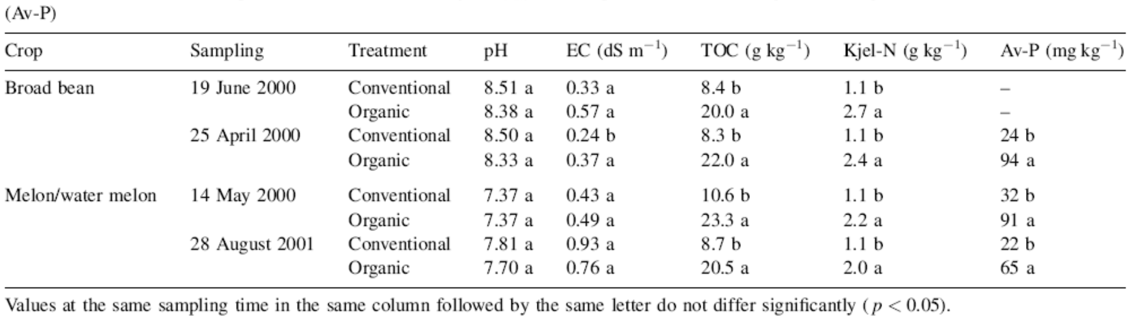
	Category	Group of indicators	Effect	Major driving force
State of the environment	Aquatic environment	Pesticides leaching	++	Ban of pesticides
		Nitrate leaching	+/0	Crop rotation, nutrient use
		Phosphorous leaching	+/0	
	Soil	Organic matter	+/0	
		Biology	++	
		Structure	+/0	
	Ecosystem	Arable land	++/+	Crop rotation, ban of pesticides
		Semi-cultivated areas	+/0	Ban of pesticides, nutrient use
		Small biotopes	+/0	
		Landscape	+/0	Crop rotation, farm layout
Driving forces	Resource use and balance	Nitrogen	+/0/−	
		Phosphorus	+/0	
		Potassium	+/0	
		Energy use	++/+	

[a] (++) much better; (+) better; (0) the same; (−) worse.

Source: Hansen *et al.*, 2001

Conventional farming is known to sometimes to lead to a reduction in soil fertility as a result of soil organic matter depletion. To understand whether organic farming could be a solution to soil fertility loss, Melero *et al.* (2006) carried out field experiments and assessed the different impact of inorganic and organic fertilisers in a crop rotation system. Table 3.9 displays the results. Soil pH and soil salinity were not found to be different between conventional and organic management. Indeed, neither inorganic nor organic fertilisation appeared to cause soil salinisation. However, organic fertilisation increased total organic carbon (TOC) content, more than conventional fertilisation and positively affected soil organic matter content, thus improving soil quality.

Table 3.9: Mean values of soil characteristics by farming system



Mean values of soil (0–15 cm) pH and electrical conductivity ($EC_{1:2.5}$); total organic carbon (TOC); Kjeldahl-N (Kjel-N); C/N ratio; and available-P (Av-P)

Crop	Sampling	Treatment	pH	EC (dS m^{-1})	TOC (g kg^{-1})	Kjel-N (g kg^{-1})	Av-P (mg kg^{-1})
Broad bean	19 June 2000	Conventional	8.51 a	0.33 a	8.4 b	1.1 b	–
		Organic	8.38 a	0.57 a	20.0 a	2.7 a	–
	25 April 2000	Conventional	8.50 a	0.24 b	8.3 b	1.1 b	24 b
		Organic	8.33 a	0.37 a	22.0 a	2.4 a	94 a
Melon/water melon	14 May 2000	Conventional	7.37 a	0.43 a	10.6 b	1.1 b	32 b
		Organic	7.37 a	0.49 a	23.3 a	2.2 a	91 a
	28 August 2001	Conventional	7.81 a	0.93 a	8.7 b	1.1 b	22 b
		Organic	7.70 a	0.76 a	20.5 a	2.0 a	65 a

Values at the same sampling time in the same column followed by the same letter do not differ significantly ($p < 0.05$).

Source: Melero *et al.*, 2006

Contrary to the above thesis, some other authors (Gosling and Shepherd, 2005; Monokrousos *et al.*, 2008) have argued that the long-term application of OF does not give rise to significant differences in total soil organic matter, total nitrogen or C:N ratio, compared to conventionally managed soils. Instead, concentrations of extractable potassium and phosphorus are reported to be significantly lower in soils managed organically, thereby, contributing to a decline in soil fertility.

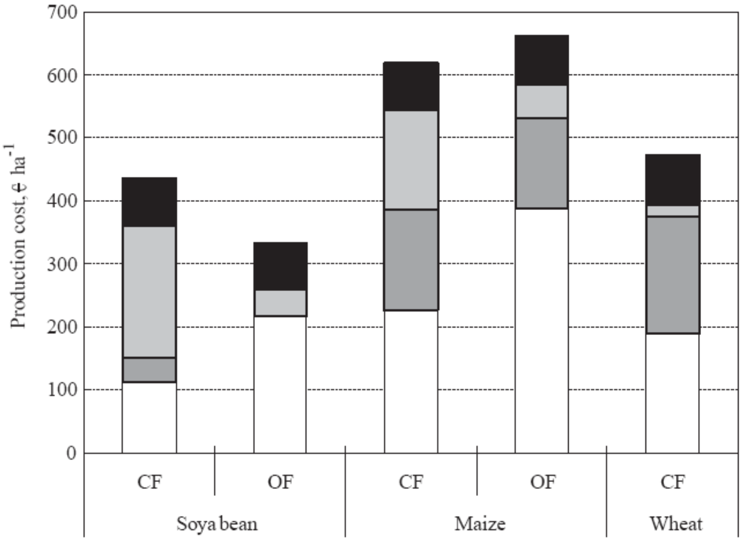
Transformation of organic fertilisers into soil organic matter and nutrients is operated by soil microorganisms and enzymes based on physical and chemical conditions, in particular temperature and water content. Microbial biomass, which acts itself as a reservoir of plant nutrients such as N and P, was found to be significantly higher under organic than conventional management (Melero *et al.*, 2006; Truu *et al.*, 2008).

Hole *et al.* (2005) carried out a complete review of the effects of organic farming on biodiversity in the UK. The majority of the studies considered clearly demonstrated that organic farming tends to increase species abundance and/or richness across a wide range of taxa compared to conventional farms, especially for those species known to have experienced declines in range and/or abundance as a consequence of past agricultural intensification.

As far as the economic impact is concerned, Sartori *et al.* (2005) studied the production costs of a 3-year soya bean, maize and wheat rotation in Italy under both conservation farming (reduced tillage) and organic farming (OF). Results are presented in Figure 3.8 and Table 3.10.

In general, conservation farming costs are heavily affected by the need to purchase fertilisers, insecticides and herbicides, whereas OF is more affected by the cost of mechanical operations.

Figure 3.8: Average production cost by farming practice

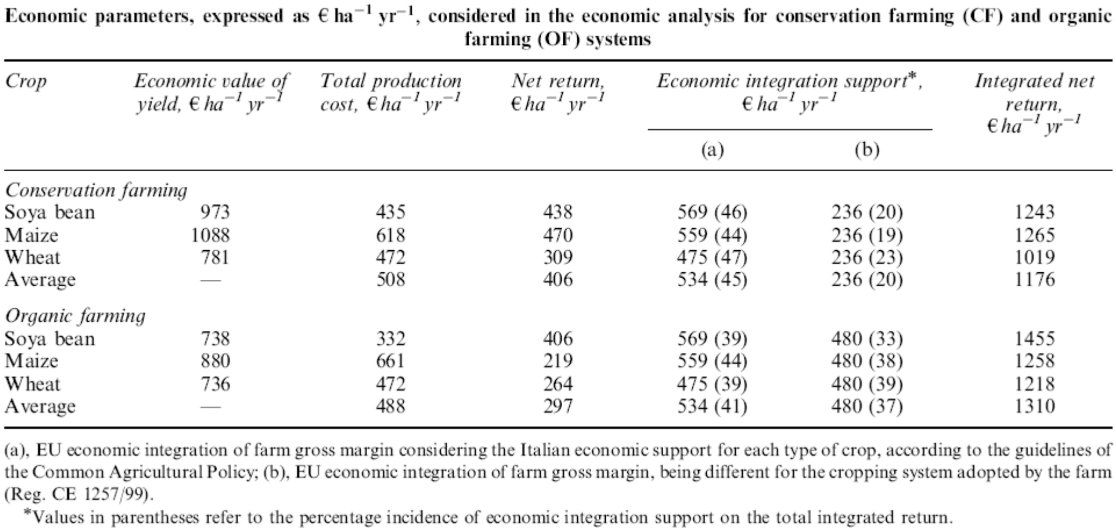


Average production cost of agronomic practices for each crop and for both conservation farming (CF) and organic farming (OF) systems: □, tillage; ▨, fertilisation; ▩, crop protection; ■, harvest

Source: Sartori *et al.* (2005)

The net return clearly depends also on the yields (higher in conservation farming), with some variation according to the crop. Overall, the results showed that, in the area studied, and despite the higher production costs for conservation farming, its higher yields generated a better net return (excluding subsidies) than that of OF. However, once EU subsidies were also considered, the opposite was true and organic farming scored higher net economic benefits, primarily because of greater policy support for organic production systems.

Table 3.10: Economic parameters by farming system in EUR/yr/ha



Economic parameters, expressed as € ha^{-1} yr^{-1}, considered in the economic analysis for conservation farming (CF) and organic farming (OF) systems

Crop	*Economic value of yield, € ha^{-1} yr^{-1}*	*Total production cost, € ha^{-1} yr^{-1}*	*Net return, € ha^{-1} yr^{-1}*	*Economic integration support*, € ha^{-1} yr^{-1}*		*Integrated net return, € ha^{-1} yr^{-1}*
				(a)	(b)	
Conservation farming						
Soya bean	973	435	438	569 (46)	236 (20)	1243
Maize	1088	618	470	559 (44)	236 (19)	1265
Wheat	781	472	309	475 (47)	236 (23)	1019
Average	—	508	406	534 (45)	236 (20)	1176
Organic farming						
Soya bean	738	332	406	569 (39)	480 (33)	1455
Maize	880	661	219	559 (44)	480 (38)	1258
Wheat	736	472	264	475 (39)	480 (39)	1218
Average	—	488	297	534 (41)	480 (37)	1310

(a), EU economic integration of farm gross margin considering the Italian economic support for each type of crop, according to the guidelines of the Common Agricultural Policy; (b), EU economic integration of farm gross margin, being different for the cropping system adopted by the farm (Reg. CE 1257/99).

*Values in parentheses refer to the percentage incidence of economic integration support on the total integrated return.

Source: Sartori *et al.* (2005)

Pažek and Rozman (2007) developed a technological and economic computer model (acronym: KARSIM; Figure 3.9) for simulating different business alternatives before and after investment in farm product processing. The simulation model calculates organic enterprise budgets for individual farms, but also other results that are useful as input parameters for cost-benefit analyses, such as Net Present Value and Internal Rate of Return[7]. On the assumption that expected prices and yields are achieved and that products successfully marketed, after 10 years of constant cash flow and 8 % discount rate, the study showed that investments into farm food processing on the two sampled organic farms[8] are financially feasible, with a generated maximal Net Present Value of EUR 7 705.26 on the organic farm 2.

Figure 3.9: The structure of the deterministic simulation model (DSM) for cost calculations and planning on organic farms KARSIM 1.0

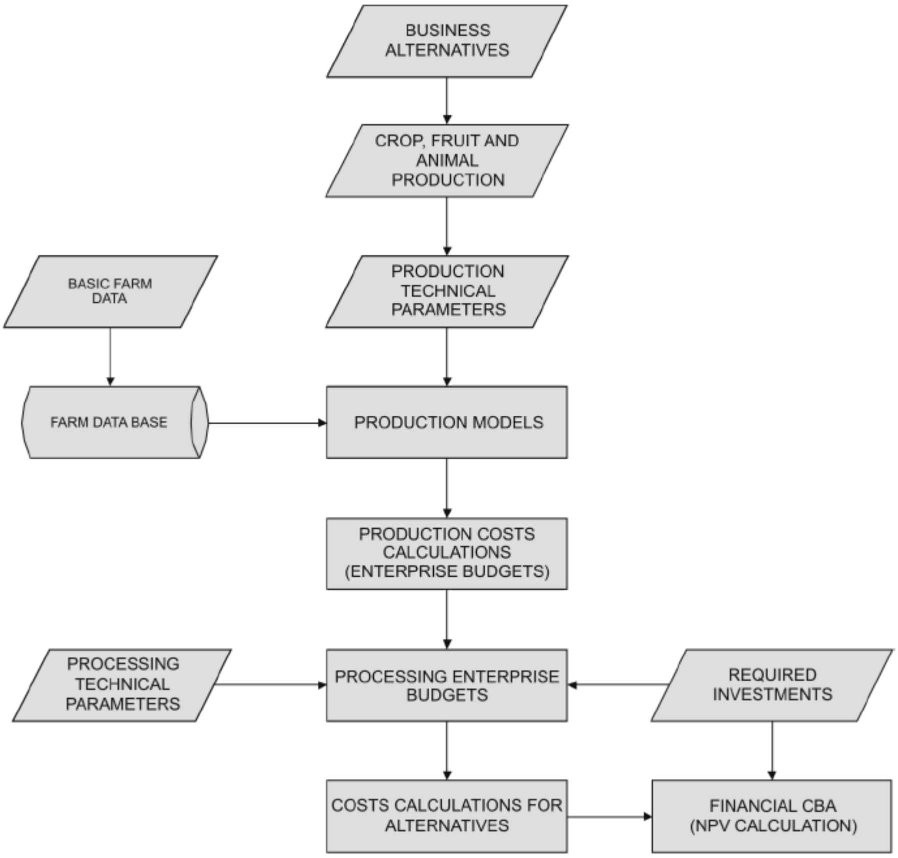


Figure 1: The structure of deterministic simulation model (DSM) for cost calculations and planning on organic farms KARSIM 1.0

Acs (2006) analysed the consequences of conversion from a conventional to organic farming system over time by developing and running a Dynamic Linear Programming model for a typical arable farm in the central clay region of the Netherlands. The results of the analysis of the basic scenario, based on average local empirical data, seem to confirm the above results.

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[7] IRR: The internal rate of return (IRR) is an indicator of the efficiency of an investment (whether it should be done or not), as opposed to net present value (NPV), which indicates value or magnitude. For NPV, see also the Agroforestry paragraph for an explanation.

[8] *Organic farm 1*: production of apples and plums (69 % and 31 % of area, respectively) in a grassland orchard and their processing into apple cider (50 %), apple vinegar (50 %) and plum brandy (100 %) (where % is the share of output produced). Further, milking sheep, with 100 % of milk processed into soft sheep cheese. *Organic farm 2*: production of apples and plums (80 % and 20 % of area, respectively) and their processing into apple cider (87 %), apple vinegar (7 %), apple juice (6 %) and plum brandy (100 %). Transformation of spelt wheat into spelt flour and husked spelt grain in equal share.

With a 10-year planning horizon, conversion to organic farming appears more profitable than maintaining conventional production. Yet farmers have to 'survive' the economically difficult conversion period of at least two years, when yields are lower but they receive only conventional product prices, in order to get this higher income. This is also confirmed by other authors (Kerselaers *et al*., 2007).

However, conversion to organic farming may not always be economically optimal if additional difficulties arise. Indeed, extra depreciation costs lower the labour income during the conversion period and, if these extra costs are higher than 25 %,, conversion becomes less profitable than conventional farming. Also a slight drop in prices makes conversion less profitable than conventional farming. It is suggested that a stepwise conversion is best to overcome the economic difficulties of the conversion period. In this situation, governmental incentives (e.g., taxes on chemical use, subsidies to organic production, investment subsidies for machinery and buildings, tax benefits or income support during the conversion period) might be helpful to motivate farmers to convert.

According to Abildtrup *et al.* (2006), the empirical evidence does not indicate that conversion to organic farming will enhance economic growth and employment despite the clear environmental benefits of organic farming due primarily to the absence of pesticides.

Argilés and Duch Brown (2008) performed a panel regression with a sample of farms in Catalonia, Spain, to test the influence of organic farming on farm output, costs and incomes. The cost structures of both types of farming and comments on their social and environmental performance were also assessed. Results indicate that organic agriculture has a significant influence on raising financial returns, yet no significant influence was found on farm costs or bottom line profits when calculating them with registered financial costs and also including the opportunity costs of the work effort supplied by the farm family.

In addition, detailed information on costs showed that organic farming generates more employment and consumes less energy, insecticides, fungicides, chemical-based fertilisers and crop protectors, as well as less purchased feedstuff and medicines for livestock, thus contributing to alleviate the environmental impact of agriculture.

Pacini *et al*. (2004) argued that a rigorous financial and environmental sustainability analysis requires an integrated ecological-economic modelling approach that is implemented at a spatial scale detailed enough to allow pedo-climatic characteristics, spatial aspects, impacts of alternative production practices and their economic performances to be addressed. Indeed, the authors maintain that the assessment of environmental impacts associated with agricultural production, including organic farming, are location-specific and are intrinsically connected with production decisions.

Pacini *et al.* (2003) evaluated the financial and environmental aspects of sustainability of organic, integrated and conventional farming systems at farm level. They applied an integrated economic-environmental accounting framework to three case study farms in Tuscany, Italy, covering different farming systems and different spatial scales. Although the environmental response of each system was found to depend closely on pedo-climatic factors, both at regional and site scale, results evidenced that OF has the potential to improve the efficiency of many environmental indicators as well as being remunerative.

3.1.3 Ridge tillage

Ridge tillage is the system of cultivating crops on pre-formed ridges, alternated with furrows protected by crop residues. Ridges may be narrow or wide and furrows can be parallel to the contour lines or constructed with a slight slope, depending on whether the objective is to conserve moisture or to drain excess moisture. Ridges can be semi-permanent or be constructed each year, which will govern the amount of residue material remaining on the surface.

Soil and environmental impact, and economic performance

Ridge tillage is the second most common non-inversion tillage system in the cornbelt of the USA after no-tillage. It is used in various parts of the world (Henriksen *et al.*, 2006), but is has only been studied in experiments in most parts of Europe (Gyuricza *et al.*, 1999).

Ridge tillage has repeatedly proven to maintain or even increase yield and profitability, allowing a reduction in the use of fertilisers and pesticides. For instance, it has potential to increase N use efficiency by plants (Schlinker *et al.*, 2007; Henriksen *et al.*, 2006) because, given the conformation of ridges, precipitation runs off the side of the ridge, thereby reducing leaching of inorganic N placed deep in the middle. In northern Europe, where N leaching is a major concern in agriculture, the implementation of ridge tilling in autumn and winter could greatly ease this problem. Moreover, the shape of ridges has also an important effect on soil moisture, radiation absorption and decomposition of organic matter (increased mineralisation). Soil microbial biomass has been found to be two to three times higher in fields with ridges, which may affect N-turnover (Henriksen *et al.*, 2006).

Other studies on the impact of ridge tillage regarding specific crops, pests, chemical products and soil response generally confirm the positive effect of this cultivation system. Stathakos *et al.* (2006) reported higher yields compared to conventional tillage for cotton cultivation (with early sowing), and demonstrated that ridge tillage cultivation methods allow more than 20 % machinery savings (reduced energy requirements and costs).

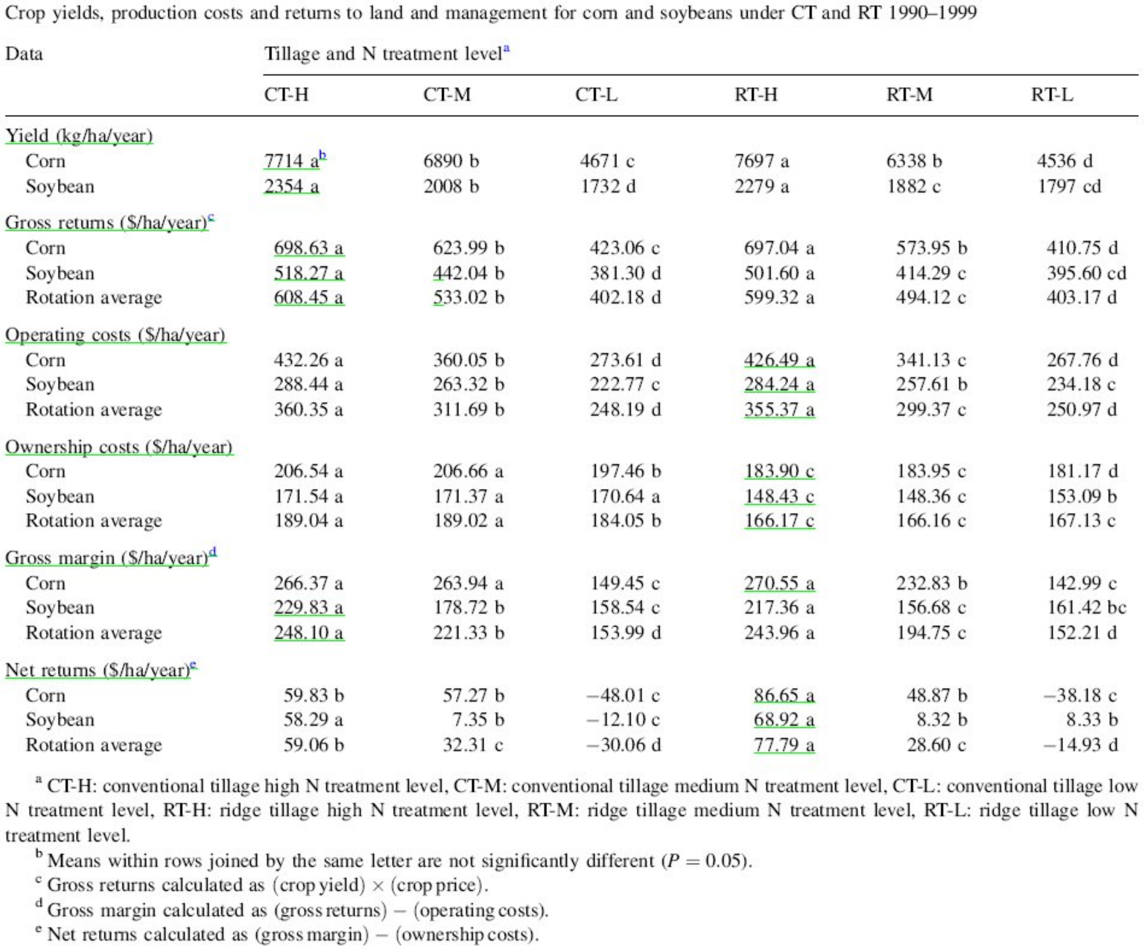
For maize cultivation under direct drilling and ridge tillage, the soil moisture content of the 0-10 cm layer in the inter-rows was 3.5-5.6 % higher than in the ploughed field or elsewhere on the ridge (sides and top of the ridge) (Gyuricza *et al.*, 1999; Birkás *et al.*, 1998). An opposite trend was found for the temperature.

Birkás *et al.* (1998) reported that the maize yields achieved with ridge tillage in an experiment carried out on a 3 % slope, were 10 % higher over a three-year average than in the traditional tillage treatment, while the effect of erosion on the area used for ridge tillage was 85 % less than on traditionally tilled areas. Neither of the tillage systems proved to be disadvantageous as regards weed cover.

On the contrary, ridge tillage has no significant or low effect on the dynamics of herbicides (half-life) (Otto *et al.*, 1997), on cotton pests (*Aphis gossypii* Glov. and *Thrips tabaci* Lind) (Gencsoylu and Yalcın, 2004), on microbial counts in the soil under potato fields and on potato yield compared to conventional tillage, in combination with mechanical and mechanical-chemical weed control (Klikocka *et al.*, 2003).

Archer *et al.* (2002) performed a cost-benefit analysis of ridge tillage in a corn (*Zea mays* L.) and soybean (*Glycine max* (L.) *Merr.*) rotation with high, medium and low nitrogen treatments on a Chernozem soil in the northern Corn Belt of the USA. Comparison of 10 years of experimental data on the economic returns, risk and input use for ridge tillage with those for conventional tillage produced the following results (Table 3.11).

Table 3.11: Crop yields, production costs and returns to land and management for corn and soybeans under conventional and ridge tillage



Crop yields, production costs and returns to land and management for corn and soybeans under CT and RT 1990–1999

Data	Tillage and N treatment level[a]					
	CT-H	CT-M	CT-L	RT-H	RT-M	RT-L
Yield (kg/ha/year)						
Corn	7714 a[b]	6890 b	4671 c	7697 a	6338 b	4536 d
Soybean	2354 a	2008 b	1732 d	2279 a	1882 c	1797 cd
Gross returns ($/ha/year)[c]						
Corn	698.63 a	623.99 b	423.06 c	697.04 a	573.95 b	410.75 d
Soybean	518.27 a	442.04 b	381.30 d	501.60 a	414.29 c	395.60 cd
Rotation average	608.45 a	533.02 b	402.18 d	599.32 a	494.12 c	403.17 d
Operating costs ($/ha/year)						
Corn	432.26 a	360.05 b	273.61 d	426.49 a	341.13 c	267.76 d
Soybean	288.44 a	263.32 b	222.77 c	284.24 a	257.61 b	234.18 c
Rotation average	360.35 a	311.69 b	248.19 d	355.37 a	299.37 c	250.97 d
Ownership costs ($/ha/year)						
Corn	206.54 a	206.66 a	197.46 b	183.90 c	183.95 c	181.17 d
Soybean	171.54 a	171.37 a	170.64 a	148.43 c	148.36 c	153.09 b
Rotation average	189.04 a	189.02 a	184.05 b	166.17 c	166.16 c	167.13 c
Gross margin ($/ha/year)[d]						
Corn	266.37 a	263.94 a	149.45 c	270.55 a	232.83 b	142.99 c
Soybean	229.83 a	178.72 b	158.54 c	217.36 a	156.68 c	161.42 bc
Rotation average	248.10 a	221.33 b	153.99 d	243.96 a	194.75 c	152.21 d
Net returns ($/ha/year)[e]						
Corn	59.83 b	57.27 b	−48.01 c	86.65 a	48.87 b	−38.18 c
Soybean	58.29 a	7.35 b	−12.10 c	68.92 a	8.32 b	8.33 b
Rotation average	59.06 b	32.31 c	−30.06 d	77.79 a	28.60 c	−14.93 d

[a] CT-H: conventional tillage high N treatment level, CT-M: conventional tillage medium N treatment level, CT-L: conventional tillage low N treatment level, RT-H: ridge tillage high N treatment level, RT-M: ridge tillage medium N treatment level, RT-L: ridge tillage low N treatment level.

[b] Means within rows joined by the same letter are not significantly different ($P = 0.05$).

[c] Gross returns calculated as (crop yield) × (crop price).

[d] Gross margin calculated as (gross returns) − (operating costs).

[e] Net returns calculated as (gross margin) − (ownership costs).

Source: Archer *et al*., 2002

The analysis above confirmed that ridge tillage can be an economically viable alternative to conventional tillage with higher net returns and lower economic risk (at high N treatment levels). Yields, operating costs and fertiliser use were not significantly different between tillage systems. Conversely, ridge tillage was reported to need significantly higher amounts of pesticides, whereas fuel and labour use were significantly lower.

3.1.4 Contour farming

Contour farming involves field activities such as ploughing, furrowing and planting to be carried out along contours (at right angles to the normal flow of run-off), and not up and down the slope (IIRR, 2008).

Soil and environmental impact, and economic performance

Contour farming aims to create detention storage within the soil surface horizon and slow down the rate of run-off, thus giving water the time to infiltrate the soil. It is successful on slopes with a gradient of less than 10 % (IIRR, 2008). On steeper slopes, 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 soil, climate, slope aspect and land use of the individual fields.

Tillage erosion can be considered as the major degradation and desertification process in cultivated hilly areas (DISME, 2004). The morphology (slope gradient, curvature) and characteristics of tillage operations (tillage implement, and the direction, speed and depth of tillage) appear to be the main factors controlling soil redistribution over a slope.

In Denmark, Heckrath *et al.* (2006) conducted mouldboard ploughing experiments to systematically investigate the effect of different tillage directions on soil redistribution, on hill slopes. Tillage in the direction of the maximum slope was found to be almost twice as erosive as slantwise contour tillage. However, the study highlighted that actually up- and downslope tillage at 45º to the direction of the maximum slope, turning soil upslope, is the least erosive of possible directions. Moreover, Van Muysen *et al.* (2002) clearly showed with experimental data that the average soil displacement distance is not only a function of slope gradient, but also strongly affected by tillage speed and tillage depth: the higher the speed and the deeper the tillage depth, the more erosion. Tillage in the direction of the slope was demonstrated to be about 22 % more erosive than contour tillage carried out at a similar tillage depth and speed.

However, De Alba *et al.* (2006) argued, based on model simulations, that the rate of displacement of a soil particle on a 15 % slope was almost at its maximum with contour ploughing (at 30 cm depth) compared to other tillage directions. Indeed, contour tillage with lateral overturning in a downward direction (i.e. a 90º direction) caused a soil down-slope displacement that was 2.2 times higher than that of down-slope tillage carried out along the steepest slope.

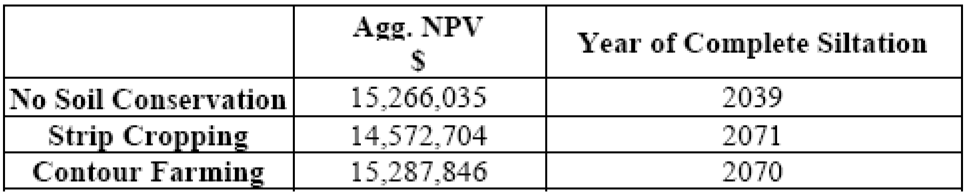
Regarding water run-off, a three-year experiment was carried out between 1997 and 2000 in central Greece (Terzoudi *et al.*, 2007) to assess this phenomenon on sloping cultivated fields, combining tillage (conventional tillage, reduced tillage using a heavy cultivator and a disk-harrow), tillage and planting directions (parallel or perpendicular to the contours) and presence/absence of winter cover crops. The study reports that reduced tillage and winter cover crops had a positive effect on the time to incipient ponding, reducing run-off and erosion. Other studies have confirmed these results (Quinton and Catt, 2004).

De Alba and Barbero (2007) suggested, however, that there may be a threshold value of rainfall intensity, beyond which contour tillage could not be an effective practice for reducing water erosion. Beyond this threshold, this practice could significantly increase soil losses.

Literature on other effects of contour tillage on soil conditions, apart from erosion, is very scarce for Europe. Some authors include beneficial effects on the carbon content and soil organic matter but only when coupled with appropriate conservation agriculture techniques, such as reduced or no-tillage, implying the use of crop residues on the soil surface.

Based on a literature review and the use of a model, Kapadia *et al.* (2002) carried out a cost-benefit analysis of some soil conservation measures, including contour farming and strip cropping in a watershed basin with downslope reservoir and dam in Northwest Connecticut (US), relative to a non-conservation scenario. They demonstrated that, apart from being more beneficial than strip cropping for soil conservation (reservoir life increased by 30 years), contour farming is also economically more viable, unless discount rate and soil erosion rate parameters are at relatively high values (>6 % and >3.6 t/ac/yr respectively) (see Table 3.12). On the whole, erosion is controlled more effectively with strip cropping, but economic analysis favours the adoption of contour farming.

Table 3.12: Comparison of the effects of no soil conservation, strip cropping and contour farming scenarios



	Agg. NPV $	Year of Complete Siltation
No Soil Conservation	15,266,035	2039
Strip Cropping	14,572,704	2071
Contour Farming	15,287,846	2070

NPV=Net Present Value (see the Agroforestry paragraph); figures calculated based on dam's year of construction 1961; interest rate=6 %; soil erosion rate=3.4 t/ac/yr; years of model run 1958 - 2000, watershed surface 12.7 km^2.
Source: Kapadia *et al*., 2002

Interestingly, it has been calculated that if a total of 1.3 million m^3 of sediment had been excavated in the year of major storms in the simulation (1994), a 30-year extension in the reservoir life would have been achieved at a discounted cost of USD 26 099. This is the amount that could have been saved by the public authorities if conservation had been practiced in upstream cropland.

3.1.5 Subsoiling

Subsoiling involves loosening deep hardpans in soils, thereby improving the soil's infiltration rate and root penetration. The operation reaches below the ploughing depth to break up a compacted layer beyond the reach of the normal tillage equipment. The working depth of the subsoiler should be decided according to the compaction identified and the soil moisture content at this depth (FAO, 2000).

Soil and environmental impact, and economic performance

Agriculture worldwide is witnessing a steady increase in the use of larger and heavier equipment for field operations, which can cause or contribute to enhancing the risk of soil compaction. 'Traditional' mouldboard tillage leads after a while, in most soils, to the formation of a harder soil layer just below the cultivation depth. This is the result of machinery pressure, the plodding of draught animals' hooves and tractor wheels running in the open furrow during ploughing operations (Spoor *et al.*, 2003). These surface crusts are often accompanied by a worsening of soil structure and a decrease in porosity, causing water retention to deteriorate (Piovanelli *et al.*, 2006). But the usual remedies (deep mechanical operations) are often applied wrongly and fail to prevent further soil loading stresses (soil rearrangement, loss of bearing capacity). In addition to a given loading stress, compaction damage depends largely on soil particles and the stability of aggregates, as well as upon soil moisture status and the protection received by the subsoil from the topsoil at the time of loading. The degree of protection depends upon the firmness of the soil above and on the presence or absence of any stronger soil layers. Soil hardpan should be simply fissured or cracked to restore rooting and drainage, but with minimum disturbance to the remaining bulk of the soil profile.

Crop yield reductions, caused by soil compaction, can vary depending upon crop sensitivity and the position of the pan within the soil profile (Birkás *et al.*, 2004).

Field studies by Pagliai *et al.* (2004) showed that the use of ripper subsoiling and minimum tillage on a loam soil increased soil macro- and micro-porosity and the homogeneity of the soil profile compared to conventional tillage systems. Moreover, Piovanelli *et al.* (2006) concluded that this tillage combination on a loamy-sandy soil can be regarded as an excellent conservation system, as it permits a better sequestration of carbon, reducing CO_2 emissions into the atmosphere.

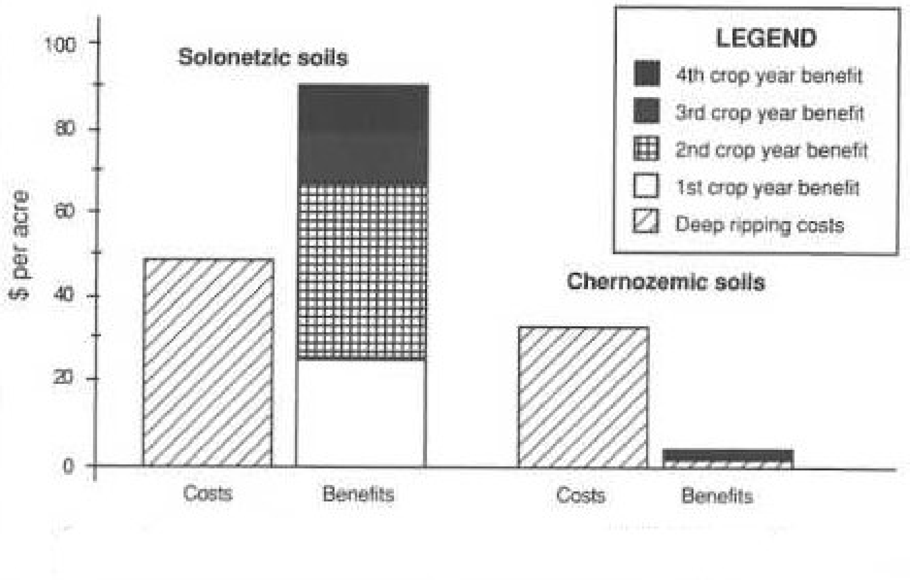
The effects of subsoiling are influenced by many other parameters such as a combination of practices, type of crop and soil, (micro-)climate, period of soil cultivation, etc. In their study on inter-row subsoiling applied for potato crops in the growing season, Henriksen *et al.* (2007) reported that effects of subsoiling may be influenced by the soil water status in the growing season, precipitation immediately before and after the subsoiling operations, and the crop growth stage at the time of subsoiling. Henriksen *et al.* (2005) showed that under the Kemink system (based on subsoiling, ridges and controlled traffic), only pre-planting subsoiling gave positive results on sugar beet yields (but with no consequences on barley). Olesen and Munkholm (2007), after analysing subsoiling in organic farming on loamy sand and sandy loam soils in Denmark, concluded that under cool and generally moist climates and for the crops studied (winter wheat, lupin, barley), subsoil loosening was not always to be recommended for counter-acting subsoil compaction. By contrast, in arid and semi-arid regions of Spain, and on loamy sand soils under crop rotation with grey pea and barley, improvements on the physical and chemical conditions of the soil were recorded in the months following subsoiling. However, they diminished rapidly with time and only some residual effects on total N and available P and K content in the top-layer were still evident after two years following the experiment (Lopez-Fando *et al.*, 2007).

Experiments to identify the effects of subsoiling on long-term no-tilled corn fields in Kentucky (US) have demonstrated that subsoiling is likely to be profitable only on fields where significant compaction is found to exist (Murdock, 1999). In the test area, where less than 30 % surface area was moderately compacted, plant stands were only about 5 % higher on average when subsoiling was used, compared to no-till, no-subsoiled ones. A small rise in corn yield (82 kg/ha) was registered in favour of the subsoiling treatment but this was not statistically significant, and was not sufficient to cover the cost (USD 40 /ha) of the subsoiling operation. Furthermore, because even after 10 to 15 years of no-tillage the test fields had only a small amount of compaction as indicated by soil penetrometer measurements, long-term no-tillage of fields was not found to be sufficient grounds on which to base a subsoiling decision.

In Saskatchewan (Canada), the Soil and Crop Management Subcouncil has investigated the financial consequences of subsoiling (deep ripping) in two areas characterised by Solonetzic (very dense, high in clay and sodium) and Chernozemic (better quality prairie) soils (SSCMS, 2005). The economic returns to deep ripping of Solonetzic soils in the test areas suggest that the revenues generated by the first two crops are sufficient to pay for the cost of the operation (Figure 3.10). This study used average market crop prices of the 1980s and an annual discount rate of 5 % for interest and inflation. The impact of subsequent crop revenues becomes smaller as the yield increases diminish and the discount accumulates. The study also clearly shows that deep ripping Chernozemic soil zones is economically impractical, as the costs are much greater than the benefits.

Other authors oppose the idea that subsoiling can indeed favour crop growth, and question whether it might ever bring any yield advantage (Arbieri *et al.*, 1997). No information is available in the European literature on the financial aspect of subsoiling.

Figure 3.10: Recovery of the cost of deep ripping in two Solonetzic and Chernocemic areas in Canada. Units: CAD ($)/ac



Source: SSCMS, 2005

3.1.6 Intercropping

Intercropping is defined as the growth of two or more crops in proximity, in the same field during a growing season, to promote interaction.

Each crop species has its own characteristic needs for light, water and nutrients according to its own ecological niche. In monocropping systems, all plants belong to the same species and compete for exactly the same resources. It follows that the simultaneous growing of different crops (with sufficiently different niches) on the same piece of land could bring more efficient exploitation of these resources (Hauggaard-Nielsen *et al.*, 2001).

In intercropping, as in any bio-diverse ecosystem, the competition/complementarity between plants enhances the overall stability of the system, including a significant resilience against pests, diseases and weeds.

A common example of intercropping is legumes and cereals. Legumes are well known to help maintain soil fertility via symbiotic di-nitrogen (N_2) soil fixation, which could be exploited by cereals for a complementary and more efficient use of N sources without compromising cereal N use, yield level and stability (Intercrop, 2008).

At the same time, some authors also warn that combinations of crops in intercrop systems must be carefully chosen and, that under certain conditions (if intercropping leads to excessive competition for resources), intercrops might show reduced yields with respect to stand-alone crops (Thorsted *et al.*, 2006a; Thorsted *et al.*, 2006b; Santalla *et al.*, 2001).

Soil and environmental impact, and economic performance
Intercropping pea and barley showed that productivity increased by 25 to 36 % compared to sole crops. This is explained by the intake of N by barley, generated by pea (while N generated by peas as a sole crop, is mainly available for weeds) (Hauggaard-Nielsen *et al.*, 2001).

Intercropping legume and cereal crops may be favourable against pests. In Spain, where the weedy root parasite *Orobanche crenata* causes huge damage to legume crops and where standard agronomic practices (use of herbicides) do not sufficiently respond to the problem, intercropping of faba bean and pea reduces *O. crenata* infestation significantly. This was also confirmed under intercrop culture of faba bean and cereals. It was suggested that inhibition of the weed's seed germination might be due to allelochemicals released by cereal roots (Fenández-Aparicio *et al.*, 2007).

Intercropping may be also useful for reducing nutrient pollution from farming while maintaining yields. Whitmore and Schroder (2007) reported positive effects (reduced leaching) on soil nitrogen dynamics under competing intercrops. Under-sowing grass, between the rows of an established maize crop, appears to reduce nitrate concentrations in water draining from soils during winter by 15 mg/l compared with a conventional catch crop and by more than 20 mg/l compared with a fallow soil.

In terms of soil biodiversity, Schmidt *et al.* (2003) reported that temperate wheat–clover intercropping systems have been shown to support much larger earthworm (*Lumbricidae*) populations than conventional wheat monocropping systems in Ireland and Britain. In particular, earthworm populations seem to greatly benefit from the input of organic matter from the mixed winter wheat–white clover crop, given its quantity, nutritional quality and also continuity throughout the year. Earthworms are responsible for the creation and maintenance of the soil macro-porosity, as discussed for other practices.

An economic analysis based on prices and costs, including labour, revealed that the economic returns from field maize intercropped with some dry bean varieties were similar to the average income value of the bean sole cropping. Yet, the highest economic returns of the bean–sweet maize intercropping systems were superior to the average income value of single-cropped beans (Santalla *et al.*, 2001).

Martin *et al.* (1987) studied the consequences of intercropping corn and soybean in Canada, confirming that intercropped corn is generally more cost-effective than mono-cropped corn. Fertiliser cost of treatments was lower, generating an economic advantage of USD 130-260 /ha as shown in Table 3.13. Quality or percent of crude protein of the intercrop silage was also significantly higher than silage from mono-cropped corn.

Table 3.13: Effects of intercropping on yield, LER, protein content and cost effectiveness

Treatments		Dry weight yield (kg/ha)	LER	Protein (%)	Cost effectiveness compared to control (C)
C	Monocropped corn	13 946	-	9.38	same
	120 kg N/ha	(10 398)	-	(8.16)	same
I-1	100 % corn-50 % bean				
	60 kg N/ha	15 186	1.21	9.10	USD 261
	alternate rows	-	-	-	-
I-2	100 % corn – 100 % bean				
	60 kg N/ha	14 691	1.23	9.63	USD 217
	alternate rows	-	-	-	-
I-3	67 % corn-67 % bean				
	60 kg N/ha	12 807	1.14	10.09	USD 150
	within rows	-	-	-	-
I-4	67 % corn-67 % bean				
	60 kg N/ha	13 213	1.13	10.04	USD 132
	alternate rows	(10 353)	(1.23)	(8.75)	(USD 135)
I-5	67 % corn-67 % bean				
	120 kg N/ha	12 997	1.13	10.76	USD 76
	alternate rows	(9 958)	(1.20)	(9.95)	(USD 44)

LER=Land Equivalent Ratio (e.g. LER=1.21 indicates that the amount of land needed to produce a certain yield from pure stands is 21 % higher than the amount of land needed to grow the same yield under intercrops with the same species

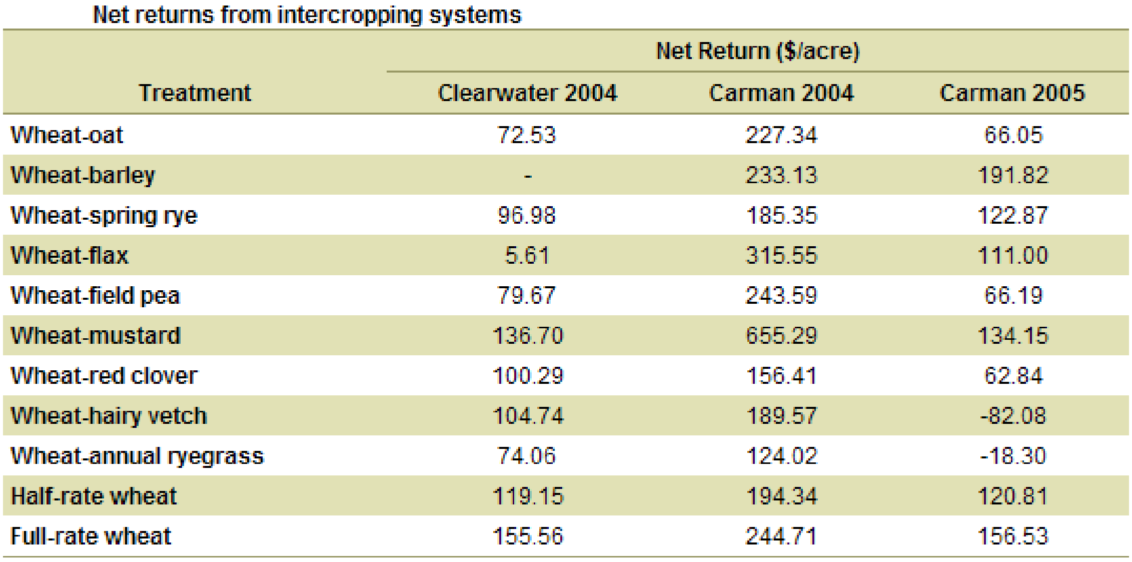
Source: Martin *et al.*, 1987.

Prins and de Wit (2006) argued that the commonly used Land Equivalent Ratio (LER) (see Table 3.13) is a poor measure for measuring cropping advantage of intercrops over sole cropping. Instead, net returns, weed suppression abilities and yield reliability of the different crops should be compared. Indeed, single-cropped grain legumes are highly susceptible to weeds and have low yield reliability. Other authors have supported this approach, stating that the feasibility of intercropping depends heavily on the profitability of the system in addition to increased yields (University of Manitoba, 2006).

Table 3.14 highlights the variability in net returns for a number of intercrops tested by the University of Manitoba in experiments in the US, ranging from USD 655 /ac to a loss of USD 82 /ac (University of Manitoba, 2006). Full-rate wheat was among the most consistently profitable treatments, and even half-rate wheat was more profitable than many of the intercrop combinations. Wheat-barley and wheat-spring rye were the more profitable cereal intercrop combinations. The wheat-mustard intercrop proved to be among the most profitable, while wheat-flax and wheat-field pea gave inconsistent but potentially promising results.

The cover crop treatments tended to have lower returns because the cover crops did not provide a marketable product, nor did they generally have significant positive effects on wheat yield. In fact, the cover crops resulted in negative returns in two cases (see Table 3.14). However, not included in this analysis are the benefits that cover crops can provide to the subsequently grown crops. Legume cover crops, in particular, can provide significant nitrogen contributions to the soil, which are especially important in organic cropping systems.

Table 3.14: Net returns from intercropping systems



Net returns from intercropping systems

Treatment	Net Return ($/acre)		
	Clearwater 2004	Carman 2004	Carman 2005
Wheat-oat	72.53	227.34	66.05
Wheat-barley	-	233.13	191.82
Wheat-spring rye	96.98	185.35	122.87
Wheat-flax	5.61	315.55	111.00
Wheat-field pea	79.67	243.59	66.19
Wheat-mustard	136.70	655.29	134.15
Wheat-red clover	100.29	156.41	62.84
Wheat-hairy vetch	104.74	189.57	-82.08
Wheat-annual ryegrass	74.06	124.02	-18.30
Half-rate wheat	119.15	194.34	120.81
Full-rate wheat	155.56	244.71	156.53

Source: University of Manitoba, 2006: Clearwater and Carman are the two test sites.

3.1.7 Grasslands

Definition/types

Grasslands are areas on which the vegetation is dominated by grass and grass-like plants. The latter are plants that resemble grasses but have stems that are solid in cross-section, including rushes and sedges (IFAD, 2008).

There are many types of grasslands (temperate, flooded, mountain), but this project will distinguish only between temporary and permanent grasslands.

The European Commission defines permanent grassland (pasture) as 'land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or longer' (Commission Regulation No 796/2004). Therefore, temporary grasslands are those of less than five years of age, included in a crop rotation; they might also be considered as a form of cover crop. In the Mediterranean area the term ‘temporary’ grassland is not in use but replaced by ‘artificial’ grassland containing wheat/barley or some grasses to be grazed during one or two seasons respectively (EGF, 2007). In some Member States, Good Agricultural and Environmental Condition (GAEC) include measures for the protection of grasslands. The cross compliance conditions attached to the CAP's direct income support contain the requirement for Member States to ensure that land which was under permanent pasture in 2003 is maintained under permanent pasture (Council Regulation (EC) 1782/2003**).**

Environmental and economic performance

In Europe, permanent and temporary grasslands occupy about 20 % of the continental landmass, but have undergone a gradual decline over the past 25 years having been turned over to crops, abandoned or returned to fallow land or forest (INRA, 2005). More specifically, permanent grasslands cover 32 % of the EU's UAA but with important differences between the Member States: France, UK and Spain have over seven million of hectares of permanent grassland; in the UK, Ireland and Slovenia permanent grassland covers at least 60 % of the UAA. Eurostat and many national statistic collections allocate temporary grassland (<5 years) to arable land. There is no overview of the temporary grassland area available in Eurostat (EGF, 2007).

Many analysts and observers have suggested that the CAP might be partially responsible for having stimulated the market intensification of agriculture, even after the introduction of the agri-environment measures in 1992, which proved insufficient to reduce agronomic pressures to plough up grassland (Souchère *et al.*, 2003).

Gardi *et al.* (2002) found that the quality of soils was higher in permanent grasslands with respect to arable lands, as evidenced by the standard soil quality indicators (organic carbon, aggregate stability), and demonstrated the importance of permanent grasslands as biodiversity ‘hot spots’ within the intensive agro-ecosystems.

On the biological side, Plantureux *et al.* (2005) reported that profitable intensive grass production (fertilisation, grazing and mowing management) from semi-natural grasslands is incompatible with maintaining a high level of biodiversity.

Plassart *et al.* (2008) confirmed this view. They studied the influence of ageing grassland on microbial community structure in different long-term grassland regimes and compared them to tillage in neighbouring fields in order to evaluate whether grassland restoration can be considered to be a specific type of management for soil conservation in northern France. The authors found much richer fungal and bacterial populations in permanent grassland than in croplands, and a strong relationship between fungal genetic diversity and the ageing grassland. An increase in microbial activities (percent of mineralisation) was also observed according to the age of the meadow confirming that grassland restoration may have a positive impact on maintaining the soil status.

Other authors have recognised that permanent pastures with a good botanical composition can effectively cover the soil, with positive effects on production, carbon storage, capturing minerals and nitrates, and erosion prevention (EGF, 2007). Finally, Souchère *et al.* (2003) used mathematical modelling to show that ploughing of 17 % of permanent grassland leads to a sharp rise both in run-off volume (>75 %) and soil loss (>85 %) within a catchment basin.

Nevens and Reheul (2003) made a 31-year comparison, from the production point of view, of permanent grassland with 3-year leys alternating with three years of arable forage crops, and found no significant differences in net grassland feed energy yield. The permanent grassland was grazed by heifers after a silage cut in spring. Both the grasslands were regularly fertilised (200-350 kg N/ha/yr). The authors explained this high performance of the permanent grassland in terms of (a) an optimal (or even supra-optimal) N fertilisation and (b) the preservation of a fairly good botanical composition.

Furthermore, regular renovation of grasslands and establishment of temporary grasslands would allow for the introduction of the newest developed varieties of good and well adapted grass species on the farm. Breeding always creates new varieties with specific characteristics for higher yield and/or quality, improved resistance against diseases, and biotic and abiotic stress (caused by frost, draught, etc.) (EGF, 2007).

In ley-arable farming, the grassland is temporary and apart from the forage production an important function is to improve soil fertility for future arable crops. Organic farming depends heavily on a ley-arable farming system and the area of short-term grass-white clover (*Trifolium repens* L.) swards is expected to grow in parallel with the rise of organic farming.

Hoving (2005) affirmed that grassland renovation is a relatively expensive activity, where the benefits largely involve the temporary increase in net grass production. Although an appropriate cost-benefit analysis is hard to perform since financial benefits are difficult to determine,a computer program named 'Grassland Renovation Guide' for simulating a cost-benefit analysis and a nitrogen balance is available from the Animal Science Group Institute at Wageningen University (the Netherlands).

The Lithuanian Agricultural Advisory Service (2001) agreed that cost-benefit analysis is not easy to perform for grassland improvement. The latter would only be justified if the costs involved were compensated by higher yields, better forage quality and easier working. In the Netherlands, conditions for renovation of grassland are reported to include:

- grass sward containing less than 50 % good quality grasses and less than 35 % perennial ryegrass;
- sward containing more than 15 % couch grass or more than 25 % annual meadow grass;
- land being very uneven and proper working, e.g. mowing, no more feasible;
- grass sward being seriously damaged by frost or heavy machinery;
- insufficient or inefficient drainage.

Grasslands of medium botanical quality (50-75 % good grasses and < 25 % couch grass) can be improved through proper fertilisation, intensive mowing or grazing provided that the lower quality grass species are evenly distributed over the area. However, this implies embarking farmers in a 2-year, expensive process (Lithuanian Agricultural Advisory Service, 2001).

From the conservation point of view, Hodgson *et al.* (2005) found that, over a wide range of productivity scenarios, an induced increase of grassland soil fertility causes a large, apparently exponential, increase in livestock-carrying capacity and in marginal returns. However, high levels of biodiversity are usually confined to less productive conditions, with an inherently low carrying capacity for livestock and low marginal returns. Thus, management of grasslands to maintain high biodiversity is generally incompatible with management for maximum economic profit.

According to Kumm (2004), an increasing proportion of the remaining semi-natural pastures in the Swedish forest-dominated regions are losing their grazing (along with their biodiversity). This is caused by the high costs of grazing small pastures with cattle from generally small herds, and by the cessation of income support per head of cattle from the CAP.

The author suggested, based on calculations of economies of scale in beef production and opportunity cost of forest and arable land, that recreating extensive pasture-forest mosaics consisting of existing semi-natural pastures and adjacent arable fields and forests can secure economically sustainable grazing. This solution would also reduce the risk of local extinction of grassland species due to habitat isolation, usually occurring in small and isolated grasslands.

3.1.8 Agroforestry

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs) are deliberately used on the same land management unit as agricultural crops, either in some form of spatial arrangement or temporal sequence (ICRAF, 1993).

The denomination 'silvo-arable agroforestry' (SAF) comprises agricultural systems where trees and crops are cultivated on the same land area.

Soil and environmental impact and economic performance

As far as soil degradation processes are concerned, many authors suggest that agroforestry has positive effects on soil fertility maintenance, erosion control (Torquebiau, 2000), water-holding capacity, carbon sequestration and nitrate leaching in intensively managed agricultural landscapes, through the potential for tree roots to recover nitrogen from below the crop rooting zone (Reisner *et al.*, 2007). However, the effects of agroforestry on the environment are highly variable, depending on biophysical conditions, management, choice of crops and tree species (Palma *et al.*, 2007b).

Torquebiau (2000) also reported that agroforestry contributes to a vast series of additional services, such as microclimate improvement, biodiversity enhancement, watershed protection, and provides multiple products, including food, wood, fodder, mulch, fibres, medicines, but also warned about potential competition between trees and crops for water, light and nutrients.

Palma *et al.* (2007a), using Yield-SAFE ('Yield Estimator for Long term Design of Silvoarable AgroForestry, SAF, in Europe') and other relevant models, assessed the environmental performance of agroforestry systems by measuring variations of four different indicators (soil erosion, nitrogen leaching, carbon sequestration and landscape biodiversity) at 19 randomly stratified landscape test sites in the Mediterranean and Atlantic regions of Europe. At each site, the effect of introducing agroforestry was examined at plot level to simulate the growth of one of five tree species (hybrid walnut *Juglans spp.*, wild cherry *Prunus avium* L., poplar *Populus spp.*, holm oak *Quercus ilex* L. *subsp. ilex* and stone pine *Pinus pinea* L.) at two tree densities (50 and 113 trees/ha) in combination with up to five crops (wheat *Triticum spp.*, sunflower *Helianthus annuus* L., oilseed rape *Brassica napus* L., grain maize and silage maize *Zea mays* L.). At landscape level, the effect of introducing agroforestry on 10 or 50 % of the agricultural area, on either the best or worst quality land, was examined.

Across the 19 landscape test sites, the computer simulations showed that SAF could significantly reduce erosion by up to 65 % when combined with contouring practices at medium (>0.5 and <3 t/ha/yr) and high (>3 t/ha/yr) erosion sites. Nitrogen leaching could be reduced by up to 28 % in areas where leaching is currently estimated to be high (>100 kg N/ha/yr), but this was dependent on tree density. Predicted mean carbon sequestration through immobilisation in trees over a 60-year period ranged from 0.1 to 3.0 t C/ha/yr (5-179 t C/ha) depending on tree species and location. Landscape biodiversity was increased by introducing SAF by an average factor of 2.6.

The long-term economic profitability of SAF systems was also assessed by Palma *et al.* (2007b) for the above test sites.

The criteria used in the evaluation (soil erosion, nitrogen leaching, carbon sequestration, landscape biodiversity), and infinite net present value[9] were assessed at each landscape test site and under six alternative levels of government financial support. Assuming equal weighting between environmental and economic performance, the analysis showed that SAF systems were preferable to conventional arable farming for the French site. Here, the best results were observed when agroforestry was implemented on 50 % of the farm's highest quality land on the farm; the effect of tree density (50-113 trees/ha) was small. By contrast, in Spain and the Netherlands, the consistently greater profitability of conventional arable agriculture relative to the agroforestry alternatives made overall performance of agroforestry systems dependent on the proportion of the farm planted, and the tree density and land quality used (Palma *et al.*, 2007b).

Reisner *et al.* (2007) reported that, in temperate and Mediterranean climatic zones, agroforestry can contribute to enabling farmers to cultivate poor soils as arable land and to protect large areas through the soil-improving effects of trees (e.g. enhancing soil organic matter, improving water-holding capacity and increasing nutrient inputs through nitrogen fixation). This can make marginal areas economically more attractive and can help preserve attractive landscapes for recreation. However, modern agroforestry systems are hardly adopted by farmers. One reason for this could be that agroforestry is not supported by subsidies, whereas agriculture and forestry receive government support separately in all countries.

The development and introduction of new agroforestry techniques could help to reduce of environmental risks on a considerable amount of the European arable land area. Results indicate that silvoarable agroforestry systems deserve public support to, at least, the same extent as conventional agricultural and forestry production (Reisner *et al.*, 2007).

3.1.9 (Conservation) Buffers

Conservation buffers, or buffer zones, are areas or strips of land maintained in permanent vegetation (NRCS, 2008).

Many different types of buffers are in use worldwide (filter strips, field borders, windbreaks, grassed waterways, riparian buffers and so on) aimed at preventing soil erosion from wind and water, reducing leaching of nutrients and drift of pesticides from arable fields into water bodies, roads or other areas, enhancing biodiversity and diversifying output.

Soil and environmental impact, and economic performance

Most studies report that buffer strips next to arable land can significantly reduce the volume of suspended solids, nitrates and phosphates transported by agricultural run-off to water bodies. They can abate 70 - 80 % of suspended solids, 70 - 98 % of phosphorus and 70 - 95 % of nitrogen (Bradbury and Kirby, 2006) but their effectiveness remains linked to the mechanisms by which these pollutants are transported (Muscutt *et al.*, 1993). Probst *et al.* (2005) demonstrated also that the width of the buffer strips and the degree of plant interception are two of the most significant parameters determining their effectiveness.

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[9] See Glossary for net present value (NPV). The infinite NPV (iNPV) is today's NPV of a system of infinite duration, in which each replication has a rotation of n years.

Furthermore, Maa *et al.* (2002) found that widening as opposed to lengthening the buffers might also have a positive effect on flora species concentration.

Despite numerous studies on the environmental efficiency of buffer strips, their cost effectiveness and their economic consequences for farmers and society are not appropriately documented.

In general, establishing buffer areas necessarily reduces the amount of land area available for other uses including agriculture, and costs money for soil preparation and seeding or planting. Certain national agri-environmental measures include compensation to farmers for these costs. In addition, for buffers consisting of grassed strips, constant maintenance is required to keep the buffer filter efficiency at a high level (Tschantz *et al.*, 2003), generating additional costs. Regarding benefits, evidence based on 12 and 24 m wide grass strips has shown that the filter effect of buffers allows a significant reduction of pollution in water bodies and soil, with clear beneficial consequences for public expenditure on pollution remedy programmes, biodiversity conservation and enhancement strategies, and health protection plans (Morschel *et al.*, 2004). Buffers might also become a source of additional products (wood, fruits, etc.) and income.

A study of the financial aspects of setting up grass buffer strips alongside cropland to avoid sediment deposition on adjacent roadways (Morschel *et al.*, 2004) showed that, by concentrating the intervention on high risk zones, savings from reduced road clean-ups can already cover compensation costs to farmers for planting and maintaining grass strips. The same study also highlighted that erosion control programmes often have little effect due to poor awareness among farmers and to insufficient subsidies to motivate them (compared to other subsidies for other land use types).

Furthermore, a case study in Denmark on the effectiveness and cost of using buffer zones to protect nitrogen-poor nature areas vulnerable to ammonia eutrophication (ammonia emissions from livestock) (Schou *et al*., 2006) found that the average cost of establishing buffer zones was from five to thirteen times less than other measures, such as extensive farming on eutrophicated areas. Thus, depending on local conditions, establishing buffer zones can indeed bring an economic advantage if they replace or reduce the need for other nature restoration activities. Management of field margins, buffer strips along waterways and woodland patches are already included in the Finish agri-environmental programme.

Helmers *et al*. (2006) reviewed some studies on the cost-benefit aspects of buffer zones in the US. According to Qiu (2003, in Helmers *et al*., 2006), installing buffers on two small watersheds in Missouri and considering a 10-year evaluation horizon, private costs linked to land use opportunity and buffer installation costs, resulted in an annualised cost of USD 62.4 and in an annualised benefit of USD 73.30 /ac, that includes Conservation Reserve Program land rental rate and 50 % cost share for the creation of the buffer from government subsidies. However, the value of the production lost by taking land out of production should be balanced against the value of 'green' payments received, which may offset the loss.

The US National Conservation Buffer Initiative’s goal of establishing two million miles of buffers on private land by 2002 was analysed by Santhi *et al.* (2001, in Helmers *et al.*, 2006). The study considered the economic and environmental benefits of the present goal and of a hypothetical doubled goal. Estimated reductions in losses of sediment, total nitrogen and total phosphorus, as well as the total net cost of the buffers (including the US consumers' loss from reduced supply, program payments to landowners, federal technical assistance cost, and the US producers' net gain from higher prices due to the reduced supply) were calculated. The net cost was then compared to the value of water quality improvements based on studies cited in Ribaudo *et al.* (1999, in Helmers *et al.*, 2006). Results indicated that the two million mile buffer goal cost was USD 793 million and the value of water quality improvements was USD 3 288 million, yielding a benefit-cost ratio of 4:1. With a doubling of the goal to four million miles, the cost increased to USD 1 302 million, the return from water quality improvements was estimated to be USD 5 650 million, with a benefit-cost ratio of 4:3. The analyses thus showed the buffer programs to be cost-effective.

Nakao and Sohngen (2000, in DEFRA, 2008) found that the cost of a ton of soil erosion reduction varies across site characteristics in a watershed depending on a range of factors including field shape, tillage methods and field size, plus the effectiveness of the buffers and soil type. Therefore, given a certain objective of erosion reduction, the cost of a buffer and its cost-benefit ratio might vary significantly.

3.1.10 Terracing

Bench terraces consist of a series of levelled or nearly levelled platforms built along contour lines, at suitable intervals and generally sustained by stone walls (FFTC, 2007).

Soil and environmental impact, and economic performance

Terracing is one of the oldest means of cultivating slopes while saving soil and water. Terraces are created to stop or reduce the degrading effect of soil erosion by intercepting surface run-off, facilitating its infiltration, evaporation or channelling it at a controlled velocity to avoid soil erosion (Dorren and Rey, 2004). This is a type of technique very much used in the past and seen as an important cultural heritage in some areas.

Most of the available literature on terracing focuses on the effects on soil erosion. Little is known on other soil conservation problems.

A review by Dorren and Rey (2004) of the effect of terracing on erosion found that the efficacy of terraces against surface run-off and soil erosion depends on local conditions and dimensions, form and stability of the terraces. Efficiency greatly benefits from the application of additional conservation practices such as contour ploughing, strip cropping and permanent soil cover. They also cited numerous studies according to which terracing reduces run-off and soil loss due to water erosion to varying degrees, but does not prevent wind erosion.

Numerous other authors have also reported adverse effects of terracing, mainly linked to lack of maintenance or abandonment. Indeed, the high maintenance required, coupled with the high cost of labour and significant changes that have occurred in the socio-economic structure of the agricultural population in recent decades, generally induce farmers to abandon terraces (Dorren and Rey, 2004). Díaz *et al.* (2007) observed that, in some areas of Spain already characterised as badlands, recently abandoned terraces have undergone severe piping (or tunnel erosion). Klimek and Latocha (2007) reported that in hilly areas of central Europe, agricultural terraces were built in ancient times to allow cultivation and prevent surface wash. Terraces acted as ‘sediment traps’, storing the washed-off material within the slope. However, after abandonment, part of the washed material was transferred to valleys, often becoming overbank deposits, covering older gravel and boulder alluvium.

However, Cots-Folch *et al.* (2006) highlight that the EU policy for vineyard restructuring[10] subsidises up to 50 % of the construction cost of terraces, which in turn account for 34 % of the total cost of starting a new terraced vineyard. Ramos *et al.* (2007) observed that in Spain, for instance, terraces have been adapted for mechanisation by levelling, usually in disregard for traditional soil and water conservation measures. New terraces are also constructed almost exclusively on the basis of their trafficability (suitable width for machinery movement), and thus in a totally different manner from the local tradition. These new terraces, very costly to build and maintain, have proved unsustainable due to their dimensions, with major mass and soil movements and damages to vineyard soon after construction.

Cots-Folch *et al.* (2006) also noted that huge amounts of earth materials are displaced to build these terraces, which results in a deep transformation of the landscape. The figures given are in the range of those typical of catastrophic natural mass movements, confirming terracing as a major anthrophic geomorphic process causing the detachment and displacement of huge amounts of soil particles, parent materials and rocks resulting in the loss of the original soil profiles.

Literature on the economics of terraces is very scarce. No information on European cases was found.

A study on Peruvian slow formation terraces[11] (Antle *et al.*, 2004) noted that location, discount rates, access to credit, physical features like soil characteristics and slope of their fields, wealth, and other characteristics may influence terrace investment decisions. Using an integrated modelling approach, the authors found that, with no subsidy and low productivity, only about 8 % of terraced fields with low slopes, and about 14 % of steeply sloped terraced fields, were profitable in the area. On steeply sloped fields, a 90 % subsidy on construction and maintenance costs turned terraces profitable on 95-100 % of these fields, but a 100 % subsidy achieved less than 65 % adoption on fields with low slopes. With medium terrace productivity and high slopes, terrace adoption approached 100 % with an 80 % subsidy on construction and maintenance. Finally, assuming higher interest rates with medium productivity, even on steeply sloped fields with a 100 % subsidy, adoption reached about 60 % only, showing again the sensitivity of the analysis to interest rates.

Having investigated the economics of terraces in the Peruvian Andes, Valdivia (2002) argued that a simple cost-benefit analysis of terracing is often not sufficient to establish its profitability and confirmed that many factors can affect it. Discount rates, investment and maintenance costs, time needed to achieve full maturity of terraces, erosion and terracing effects on productivity are some of the key parameters influencing profitability. Erosion, in turn, is affected by farmers' land management decisions based on economic, social and institutional factors. Therefore, more complex models should be used, especially in geomorphologically heterogeneous territories like the one studied.

For northern Peru, Valdivia (2002) applied such a model, concluding that terrace investments may be profitable for farmers in a significant number of areas. However, the actual probability of implementation increases with factors linked to erosion (e.g., slope, and related

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[10] EC Council Regulation No. 1227/2000.

[11] A slow-formation terrace is a terrace formed after erection of a barrier by accumulation of soil behind it as soil movement occurs on the field.

soil and climatic conditions), making terrace adoption most likely to occur on steeply sloped fields.

Peru was also the study area for Posthumus and De Graaff (2004), who carried out a cost-benefit analysis for eleven cases of bench terraces based on both measurement of physical parameters and farmers' interviews. The study revealed that profitability of bench terraces was lower than farmers believed. The financial attractiveness of terracing to farmers was shown to depend on their personal opportunity cost of labour. Because farmers' labour in bench terracing is only a temporary off-farm activity, an opportunity cost of their labour below the market wage could be appropriate, which would make terracing worthwhile in most cases.

3.2 Other practices affecting soil

This section reports on soil conservation practices that have not yet been addressed in the previous sections. Practices are analysed according the soil degradation processes which they refer to. This distinction is introduced for ease of reading, yet it is clearly artificial since soil has to be considered as a complex structure and soil degradation processes are always interlinked with one another.

3.2.1 Practices linked to soil contamination

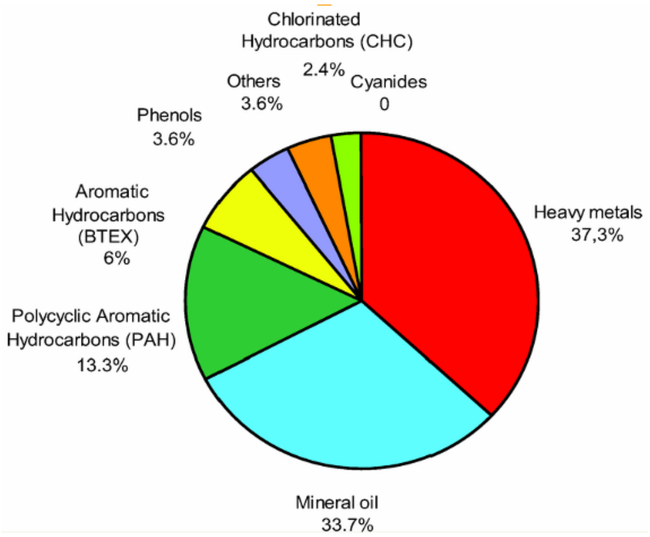
Soil contamination is the occurrence of pollutants in soil above a certain level, causing a deterioration or loss of one or more soil functions. Contamination may occur locally as a consequence of the deliberate or accidental release of man-made chemicals into the soil, typically arising from the application of pesticides or fertilisers, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills, discharge of industrial wastes or rupture of underground storage tanks (JRC, 2008a).

Contamination may also be diffuse as a result of pollutants being transported through the air or water by distant sources. Examples of these include rain run-off from roofs, roads and other structures that may introduce heavy metals such as lead or mercury into the soil (McGill University, 2002). Atmospheric deposition is also possible due to emissions from industry, traffic and agriculture. Deposition of airborne pollutants releases into soils acidifying contaminants (e.g. SO2, NOx), heavy metals (e.g. cadmium, lead arsenic, mercury), and several organic compounds (e.g. dioxins, PCBs, PAHs). Acidification can also occur over time as a result of calcium and magnesium leaching out, because hydrogen is added to soils by decomposition of plant residues and organic matter, or because nitrification of ammonium occurs when fertilisers (UAN solutions, urea, ammonium nitrate, ammonium sulfate, anhydrous ammonia), manure, or plant residues are added to the soil (NCCES, 2005). Acidifying contaminants gradually decrease the buffering capacity of soils, in some instances leading them to surpass their critical load, resulting in a sudden massive release of aluminium and other toxic metals into aquatic systems. In addition, acidification favours the leaching out of nutrients with subsequent loss of soil fertility and possible eutrophication problems in water and excess nitrates in drinking water. Moreover, it may damage beneficial soil microorganisms, slowing down biological activity. Ammonia and other nitrogen deposition (from agriculture, traffic and industry emissions) cause the unwanted enrichment of soils and subsequent decline of biodiversity of forests and of high nature value pastures. In some

European forests, nitrogen input reaches extreme values of up to 60 kg N/ha/yr. Pre-industrial deposition was below 5 kg (Montanarella, 2003).

The most common chemicals involved in contamination are heavy metals, petroleum hydrocarbons, solvents and pesticides. The occurrence of this phenomenon is correlated with the degree of industrialisation and intensity of chemical usage (JRC, 2008a). The European Environment Agency (EEA) reports the following pollutants and their percentages at continental scale (not limited to agriculture).

Figure 3.11: Pollutants and their percentages at continental scale (not limited to agriculture)



Source: EEA, 2007

In agriculture, contamination occurs mostly when, in a certain production system, the balance between farm inputs and outputs is not achieved in relation to the local conditions.

Excess fertilisation can cause nutrient imbalances in soil, which frequently result in the contamination of ground- and surface water. Pesticides can accumulate in the soil, leach into the groundwater and evaporate into the air from which further deposition onto soil can take place. They may also affect soil biodiversity and enter the food chain.

The extent of nitrate problems in Europe underlines the seriousness of this imbalance. An additional problem relates to heavy metals (e.g. cadmium, copper) in fertilisers and animal feed. Their effects on soil and soil organisms are not clear, although studies have shown the possible uptake of cadmium in the food chain. The effects on soil of antibiotics contained in animal feed are unknown.

Pesticides are toxic compounds deliberately released onto the crops to fight plant pests and diseases. The current authorisation process of pesticides assesses inter alia the environmental risks of individual pesticides in the soil. By this authorisation process, pesticides with unacceptable risks are being eliminated. However, information on the combined effects remains limited. The volume of active pesticide ingredients sold across the EU-15 reached 321 386 t in 1998. While the use of pesticides is regulated, and they should be only applied in accordance with good farming practices, pesticides have been found to leach through the soil into groundwater and to be eroded with soil into surface water. Accumulation in the soil occurs, in particular, with those active components now prohibited in the EU.

Waste and sewage sludge discharged on agricultural soil are also of real concern in some parts of Europe. A whole range of pollutants, such as heavy metals and poorly biodegradable trace organic compounds, potentially contaminate soils which can result in an increase of concentrations. Some compounds can be broken down to harmless molecules by soil microorganisms, whereas others are persistent, including heavy metals, which may accumulate in the soil with the subsequent risk of soil microorganisms, plants, fauna and human beings. Potentially pathogenic organisms like viruses and bacteria are also present. However, sewage sludge contains organic matter and nutrients such as nitrogen, phosphorus and potassium, that are of value to the soil, and the options for its use include application on agricultural land. Provided contamination is ascertained at source and prevented, the careful, monitored use of sewage sludge on soil should not cause a problem. On the contrary, it could be beneficial and contribute to an increase of soil organic matter content. Every year, 6.5 million tons of sludge (dry matter) are produced in the EU. Release of sewage sludge is regulated in Europe by the Council Directive 86/278/EEC, which is one of the statutory management requirements included under the CAP Pillar 1 cross compliance mechanism.

A more serious concern for human health arises from the large number of highly contaminated sites in Europe. According to recent estimates, soil contamination requiring clean up is present at approximately 250 000 sites in Europe (EU Member States plus Iceland, Liechtenstein, Norway, Switzerland and Turkey) (EEA, 2007).

The clean-up of contaminated soils is usually a difficult and costly operation (Montanarella, 2003) that can be carried out off-site (soil is removed from the field, treated and returned) or on-site (contaminants are removed without any soil movements), depending on the type, severity and extent of contamination. No information is available on large-scale clean-up operations carried out in agricultural soils in Europe. Mitchell (2001) and McGill University (2002), the latter with a focus on urban agriculture, proposed the following techniques:

- liming: this is a technique for reducing soil acidity. Limestone (calcite), primarily calcium carbonate ($CaCO_3$), is discharged to neutralise acid waters and soils.;
- soil washing: soil is physically removed from the contaminated parcel, followed by treatment at a plant on or off-site;
- soil vapour extraction: soil contaminants are extracted through a system of wells and pipes, which is usually an effective technique but very expensive;
- excavation: soil is physically excavated, moved to a landfill and replaced using heavy machinery by new soil, at a relatively high cost. If necessary, the new soil layer can be isolated from deeper non-excavated layers by applying geotextiles (synthetic blanket-like materials) that work as an impermeable barrier against contaminants. Geotextiles are themselves relatively low-cost, but liable to tear;
- microbial/fungal remediation: selected microbes or fungi are used to transform contaminants into a less toxic form. Microbes can be very effective in the treatment of hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs). Cost is generally relatively low, and the timeframe is short. However, increased toxicity from certain metals can appear;
- phyto-remediation: selected plants are used to extract contaminants or to degrade them in the soil. Cost is low but the time frame can extend up to several years and contaminated plants must then be eliminated.

3.2.2 Practices linked to soil compaction

Soil compaction in conventional farming is caused by a number of factors, namely excessive weight of machinery, high number of passes, long-term use of mouldboard ploughing operations and cattle trampling. When soil compaction occurs, solutions do not always exist (see subsoiling) or may not be easy to apply.

Cropping techniques that are alternatives to soil-compacting tillage systems have already been discussed (see no-tillage and reduced tillage). Whatever the tillage applied, however, the problem of machinery impact on soil remains. Several authors (Alakukku *et al.*, 2003; Vermeulen and Klooster, 1992) recommended the use of lighter machinery or adjusted tyres. Keller and Arvidsson (2004) demonstrated that risk of subsoil compaction can be reduced by the use of reduced wheel load, e.g. by the use of dual or tandem wheels that, despite the larger area trafficked, would also allow tyre inflation pressure to be reduced. Indeed, tyre pressure affects the soil-tyre surface of contact and, in turn, has significant repercussions on stress exerted on topsoil and upper subsoil. These authors also found that soil stress and soil compaction are not a function of axle or total vehicle load.

Other authors have advised that widespread compaction can be prevented by careful design of permanent tramlines or traffic lanes limiting damage to small, dedicated strips of land (Lamers *et al.*, 1986).

This, however, does not solve the problem of deep plough pans caused by conventional ploughing. Munkholm *et al.* (2005) successfully experienced cultivation of grass-clover ley as a contributing solution to compaction.

Soil compaction can also be caused by excessive cattle trampling. In this case, reduction of the stocking density, areal grazing restrictions (rotational grazing) and pasture improvement (sod seeding) should be applied.

3.2.3 Practices mainly linked to salinisation

Secondary soil salinisation is related to and affected by irrigation. Irrigation serves the purpose of feeding plants when rainfall is not sufficient, but water needs to be extracted cautiously from rivers and aquifers to avoid their depletion. Furthermore, excessive irrigation can degrade waterbodies, soils and wildlife habitats by dissolving and transporting chemicals (Bellows, 2004).

The use of non-polluted water, and in the right amount, is essential for avoiding the removal of nutrients (especially N) and soil structural modifications.

In arid and semi-arid environments, on soils rich in salt, insufficient irrigation or irrigation with saline water, combined with a high degree of evapo-transpiration might result in the uptake of soil salts and in the formation of salt crusts on the soil surface (FAO, 2005). Several different irrigation methods (micro- or drip irrigation, spray or sprinkler irrigation, flood irrigation, etc.) might also influence soil in different ways. Common agricultural formulae can be used to determine the exact water requirements for each crop so as to avoid the above soil problems.

3.2.4 Practices mainly linked to erosion

Beyond 'conventional' ploughing, other traditional agricultural practices such as stubble burning may greatly contribute to soil degradation. Stubble burning has traditionally been used in semi-arid land for pest and weed control, and to remove crop residues to facilitate planting (Virto *et al.*, 2007). However, a number of detrimental soil and atmospheric property modifications are attributed to the burning of crop residues (IRRI-CIMMYT, 2007), including:

- loss of soil cover leading to greater erosion;
- destruction of soil nutrients and organic matter, especially nitrogen (for wheat, 40 to 80 % of the nitrogen in crop residues is lost as ammonia);
- increase in soil urease activity due to after-burn ashes and further long-term N losses from soil and applied fertilisers;
- deterioration of the soil's physical properties such as soil structure and fertility and reduction of soil fauna;
- release of carbon dioxide, nitrous oxide, ammonia and particulate matter are released into the atmosphere.

As a consequence, permanent stubble burning has been banned or time-limited in many European countries as part of their respective Good Agriculture and Environmental Conditions for the entitlement to Common Agriculture Policy payments.

Water-related soil degradation can also be prevented by an appropriate drainage system intended to avoid excess water on the soil, limit and divert water run-off (and therefore soil erosion) or avoid water stagnation on flat surfaces (causing anaerobic soil conditions). Drainage can be superficial, such as in the case of ditches, or sub-superficial, with deep permeable drains. When crops are cultivated on the slopes, for example, hillside ditches can be excavated more or less along contour lines to convey the excess run-off water outside the crop. Furthermore, superficial drains can be structured with grass cover, small dams, rocks or irregular routes to avoid water erosion.

Field patterns and size, especially when accompanied by appropriate hedgerows, buffers, and drainage, can also have an influence on soil erosion. By controlling these parameters, in fact, the water run-off path at watershed level can be diversified or diverted, and erosion reduced or blocked, as Martin *et al.* (2004) showed for France.

In conclusion, it has to be stressed that some practices, or failure to use appropriate remedies, could have a very negative impact on soil degradation. Policy makers should take this into account.

3.3 Current extent of soil conservation practices in Europe

The lack of official statistical data at European level on the type and spatial distribution of the various soil-relevant agricultural practices makes it impossible to give a precise picture of the extent of soil conservation practices used in agriculture. However, several sources of information other than statistical have been investigated in order to understand the current general picture in Europe.

Initially, estimates at national level were retrieved from the European Conservation Agriculture Federation (ECAF) website regarding Conservation Agriculture (ECAF, 2008b); the Farm Structure Survey (FSS) of Eurostat (2007a) and the Farm Accountancy Data Network (FADN, 2008) were then analysed, but they contain very little regarding the actual farming practices.

Therefore, data were gleaned from various European research studies and projects, in particular IRENA (Indicator reporting on the integration of environmental concerns into agriculture policy, indicator 14), which proved useful in permitting practices to be mapped at NUTS 2 or 3 level (Nomenclature des Units Territoriales Statistiques) for EU-15 (IRENA, 2005).

The IRENA operation was initiated following a specific request by the European Council to the Commission to report on the integration of environmental concerns into Community sectoral policies. As a contribution to meeting this requirement for the agricultural sector, the Commission developed agri-environmental indicators (AEI) to monitor such integration, including indicators 14.1 (soil cover on arable land) and 14.2 (tillage systems). However, IRENA provides a snapshot of the situation in 2004, and relied on *ad hoc* research and other EU projects like PAIS (Proposal for Agri-Environmental Indicators) and LUCAS (Land Use/Cover Area frame statistical Survey) as sources of data.

A survey was then e-mailed to selected agriculture research institutes, national mapping agencies, farmers' associations involved with conservation agriculture and experts to try and get more updated and complete results in each of the 27 Member States. The response rate was not particularly high, and all the replies received confirmed the present lack of any precise or statistically structured data, except for a few countries, notably France and Ireland.

A relevant ongoing project, contracted by the European Environment Agency (EEA, 2008) to the University of Eberswalde (Germany), to provide 'support for agri-environmental analysis at the EEA', was later found. One of the project tasks was to 'report on available farm management data and their potential use in updating Agro Environmental Indicators (IRENA) fact sheets 14.1 and 14.2'. This study, which reiterates the need for a systematic collection of data on farming practices, analysed the current availability of information through existing projects such as MOCA, MARS, KUL, LUCAS, GEOSYS, PAIS and KASSA. The update of the IRENA 14.2 figures was kindly provided by EEA to JRC, but once again, these figures only concern estimates at national level.

The situation may improve in the future with a new survey (Survey on Agriculture Production Methods (SAPM)) that Eurostat intends to launch. This new initiative should start in 2011 and will be an additional module of the FSS. Hopefully, tillage methods will be part of the questionnaires.

Of all the practices taken into account in this chapter, only organic farming is well documented in European agriculture surveys. Indeed, detailed statistics (mainly at NUTS 2 level) are available from the FSS 2005 (Eurostat, 2007), which have allowed the creation of a specific map. These data and the map on the current application of conservation agriculture techniques in Europe, based on all available data, are contained in Annex 3.4.

4 Regulatory environment and policy instruments

4.1 Analytical framework

This chapter analyses EU policies, including their national and regional implementation, with respect to their relevance for protecting, conserving and/or improving soil quality within an agricultural context. The intervention logic approach has been chosen as the most appropriate concept for this analysis, since it allows all the above-mentioned aspects to be addressed from the policy perspective required by the scope of the project. It also allows the framing of policies and linkages in a consistent way without having to pass through general theoretical assumptions from both an economic and political point of view.

Policy design starts with identifying the expressed needs of society, and transforms this into appropriate policy responses. In our context, society demands the public good soil quality and the arrest of soil degradation. The policy response is a catalogue of measures within the Common Agricultural Policy (CAP) and environmental legislation. In the context of soil and agricultural land use, private property rights to land and the public good (soil quality through addressing soil degradation) have to be reconciled and integrated.

4.1.1 Public goods and property rights

Most environmental quality attributes (assets or services), including those related to soil (such as soil biodiversity, soil organic matter, soil health and so on) are associated with incomplete markets. An incomplete market refers to the inability of institutions to establish well-defined property rights[12].

A common cause of market failure concerning the property rights of environmental quality is the non-excludability of its consumption (that is, no one can be effectively excluded from using the good). Since in addition, there is non-rivalry in consumption (the quantity of supply does not decrease with consumption), environmental quality has public good characteristics. As a result, environmental quality will not be provided without public intervention (Hanley *et al.*, 1997).

Market failure also expresses itself as (negative) externality, in our case soil degradation. An externality exists, if the consumption or production activities of an economic agent affect (positively or negatively) the utility or profit of another agent. Off-site effects of water or wind erosions are such examples. The market is incomplete because no exchange institution exists where agents can buy and sell external benefits or costs. A special case are externalities 'over time' like the gradual but slow loss of organic matter, which affects soil fertility in the future. In this case, the consequences are borne by the next generation.

Hence, both public goods and externalities justify public intervention in order to satisfy society’s demand for environmental quality (i.e. soil protection and conservation).

Following Ortiz-Miranda and Estruch-Guitart (2004), the first step of public intervention is to define and allocate property rights over the environment (assets, products), which until this is done, are freely obtained from the public domain (Barzel, 1997). This might result in either

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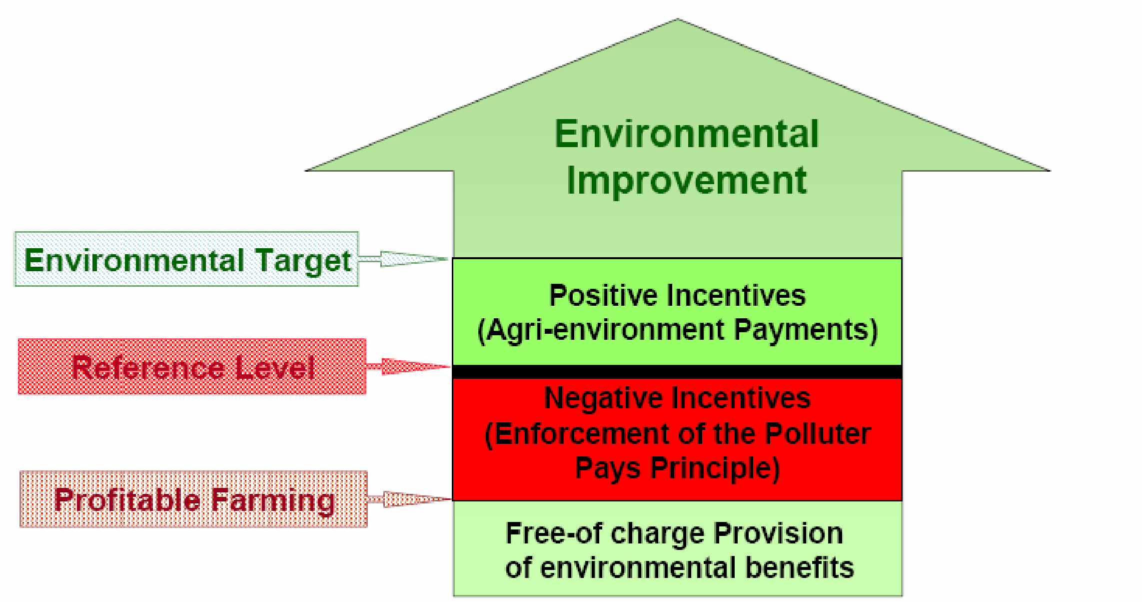
[12] Proprty rights of land are generally well defined; however, those relating to water and air usually lack definition, and hence these resources are not 'owned' (see, for example, Barzel, 1997).

the withdrawal or confirmation of (all or parts of) the rights enjoyed by farmers and other agents in the past (Bromley and Hodge, 1990; Ortiz-Miranda and Estruch-Guitart, 2004). The second step is to define the reference level (Scheele, 2008), i.e. what level of environmental protection must be respected by all according to current legal requirements, as opposed to those improvements that go beyond these expectations and that may therefore be supported or rewarded by additional incentive-based policies.

Once the reference level has been defined, public intervention represents in terms of property rights i) the *enforcement of property rights* i.e. respecting the given environmental standard as laid down by environmental (and agricultural) legislation (e.g. Nitrates Directive), and ii) *bargaining additional property rights* e.g. a provision of agricultural soil conservation practices that improve the environment beyond the reference level (environmental target of Figure 4.1).

The first of these two aspects of public intervention refers to the application of the polluter pays principle, while the second can be understood as purchasing public goods provided by the private sector.

Figure 4.1: Provision of environmental benefits versus avoiding harmful effects



Source: Scheele (2008)

The Common Agricultural Policy recognises both these aspects in its instruments through introducing cross compliance conditions to improve the enforcement of environmental legislation (SMRs) and to require additional agricultural and environmental standards (GAEC). Incentives for environmental improvements that go beyond the minimum standards are provided by compensation payments under rural development policy.

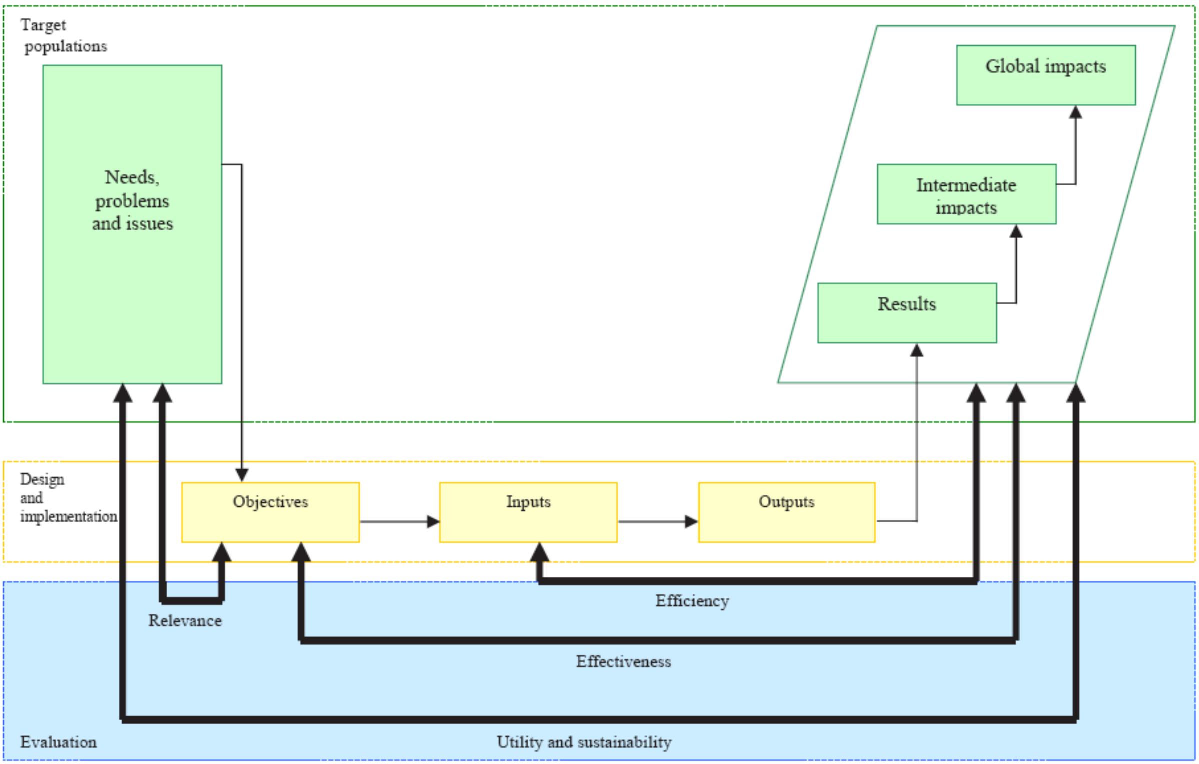
It is not always possible to establish environmental standards, including measurable reference levels (threshold values), at farm or field level; instead these standards are often expressed in the form of direct requirements on farmers' behaviour (farming practices), while threshold values are established for regions (nitrate vulnerable zones, river basins, etc.).

4.1.2 The Intervention logic approach

The intervention logic approach breaks a policy down into different steps, from societal needs to policy formulation, implementation and impacts. This allows a clear and detailed understanding of all the mechanisms involved and their effects. This procedure leads eventually to the identification of gaps or malfunctions and permits improvements to be recognised at each stage of the policy cycle.

In a first step, the analysis of the relevance of a policy by comparing the formulated policy objectives with soil protection needs is performed *ex ante*, in order to evaluate to what extent the policy matches the needs. The second analytical step is the *ex post* analysis of the effectiveness of the policy with regard to soil protection. Figure 4.2 illustrates the intervention logic approach, while Figure 4.3 sets out the analytical sequence.

Figure 4.2: Analysis of the intervention logic approach



Source: EC (2004)[13]

The analysis through the intervention logic approach starts with defining the *needs* that are to be addressed by the policy. These needs are translated into policy objectives that can be framed in a directive or regulation. We distinguish here between three categories of objectives: general, specific and operational objectives.

General objectives represent those referred to in the legislation (such as maintaining permanent pasture), while the *specific objectives* are those leading to the achievement of the general objectives (for example, compliance with the requirement to keep land in good agricultural and environmental condition (GAEC)). Finally, the *operational objectives* represent targets regarding implementation, enforcement and monitoring mechanisms (such as rates of payment reduction imposed on non-compliant farmers).

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[13] Evaluating EU Activities. A Practical Guide for the Commission Services, DG BUDG July 2004, p. 72

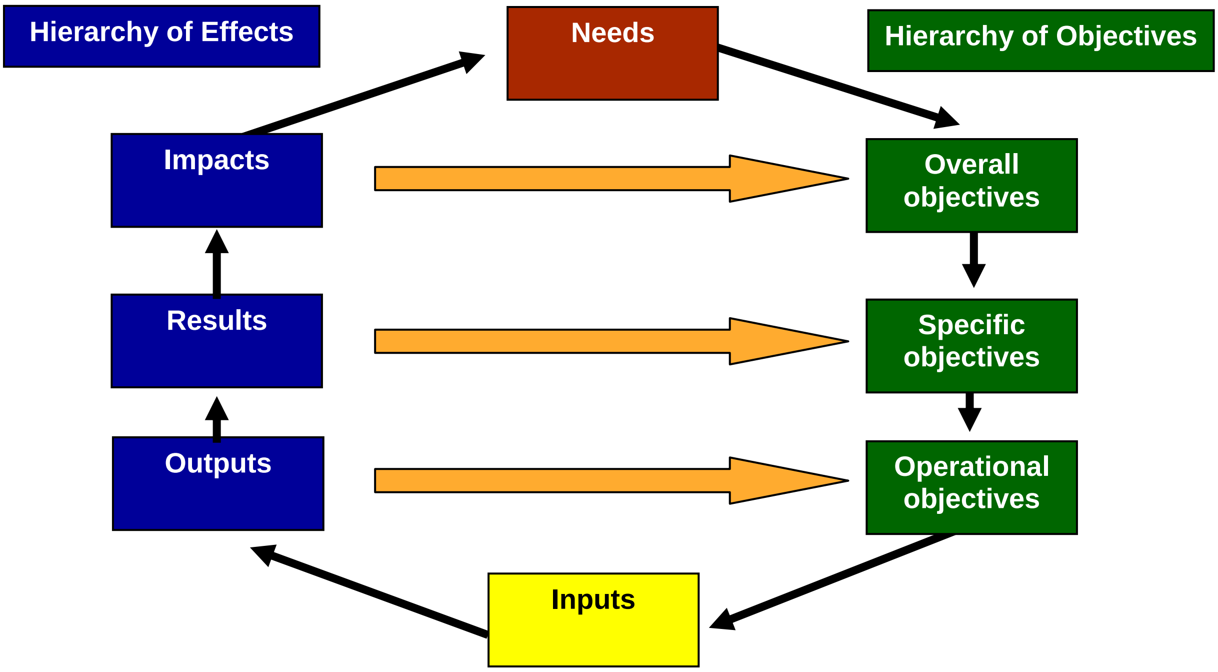
The next step in the policy cycle is the transformation of the different objectives into appropriate *inputs*. These inputs are concrete measures directed to achieving the objective, consisting of mechanisms like control systems, inspection regimes and the details of policy implementation. These inputs produce measurable *outputs*, like uptake rates, monitoring frequency, and extent of achievement regarding the operational objectives. Beyond these outputs are the *results,* which relate to the specific objectives, for example, the rate of compliance with certain requirements.

In order to asses how far the policy meets its general objectives, it is necessary to evaluate the type of *impact* these results produce. The impact assessment allows us to measure the extent to which the societal need (for example, the maintenance of permanent pasture) has been met.

The final step, which closes the sequence, is a verification of the utility and sustainability of the policy in relation to the needs the policy should address. Utility here refers to the occurrence of other effects (either positive or negative) than those effects that correspond with the stated objectives of an intervention. Evaluating sustainability involves assessing to what extent any positive changes resulting from a policy intervention can be expected to last beyond the actual period of policy implementation.

The orange arrows in Figure 4.3 represent the different levels of evaluation from bottom to top; for example from farm level (bottom arrow) to European Union level (two upper arrows).

Figure 4.3: Simplified presentation of the intervention logic approach



Source: Canenbley (s.a)

Description and analysis of the different components of the intervention logic requires the use of indicators that reflect measurable results. These have to be developed appropriately for each policy.

4.1.3 EU-wide survey

The EU-wide survey of policies addressing soil degradation processes through soil-friendly farming practices included national and/or regional implementation of CAP instruments (i.e. cross compliance and rural development policy) and relevant national and environmental policies[14]. In order to complement the literature review with a policy inventory, the questionnaire was designed to gather, to the best extent possible, the following information:

i) Main policy objective,

ii) Soil conservation objectives within the policy (where applicable),

iii) Geographical coverage of the policy,

iv) Level of implementation (EU, national, regional),

v) Technical measures required,

vi) Uptake or compliance rate,

vii) Implementation parameters (contract length, monitoring, control and sanctioning, mechanisms etc.), and

viii) Expert views on appropriateness of specifications and success and problems of its implementation.

The policy inventory was based on a voluntary online survey directed towards relevant officers and experts in national ministries and administrative bodies.

Adapting a common classification of environmental policies according to their influence on farmers' behaviour (Baumol and Oates, 1979), the policies have been grouped into three categories: 'mandatory measures' (like environmental directives, cross compliance), 'voluntary incentive-based measures' (such as measures within Rural Development Plans, national and regional efforts) and 'awareness-increasing measures and private initiatives' (like environmental farm plans, sustainable agriculture initiatives, codes of good agricultural practice). Some complementary questions on interviewees' perception of the performance of agricultural soil conservation via national and EU policy instruments, as well as their perception of the survey were briefly addressed. Since many experts on policy and regulatory environment concerning soil conservation were consulted by the review, this opportunity was used to gather some additional information on the feasibility of online questionnaires as a research tool at the supranational (EU) level.

Data were received from 53 institutions from 24 Member States, providing more than 400 data entries, each describing one policy measure or a group of measures relevant for soil conservation. With the exception of the Czech Republic, Lithuania and Spain, all Member States contributed to the survey. For countries with a federal structure (Austria, Belgium, Germany, Italy and the United Kingdom), data were also obtained at regional level.

Given the voluntary nature of the survey, information per country did not necessarily contain the complete list of policy measures relevant for soil conservation. Some participating experts did not have easy access to the relevant information. Besides, experts did not always describe single measures (like planting of hedges, reduced tillage, or restricted use of pesticides), but

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[14] Survey carried out by Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V. in spring 2008.

often entire programmes containing a variety of measures of which only a part related to soil protection (e.g. Rural Development Programme, ÖPUL, MEKA etc.). Consequently, the inventory should not be treated as a complete list of measures, but rather as an overview of soil conservation policy measures existing in the EU-27 Member States.

As illustrated in Table 4.1, only three of the administrations approached (the Lithuanian Ministry of Agriculture, the Federal Ministry for Food, Agriculture and Consumer Protection (BMELV), Germany, and the Federal State Ministry of Agriculture of Thüringen) formally refused to participate, while eight others did not participate but did not formally decline.

Table 4.1: Overview of invited and participating institutions

Country Name	Region/level	Institution	Data delivered	Participation refused
Austria	*national*	Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft	X	
	Burgenland	Land Burgenland		(no participation)
	Lower Austria	Land Niederösterreich	X	
	Upper Austria	Direktion für Landesplanung, wirtschaftliche und ländliche Entwicklung	X	
	Salzburg	Amt der Salzburger Landesregierung	X	
	Steiermark	Land Steiermark		(no participation)
	Tyrol	Land Tirol	X	
Belgium	Wallonia	Ministere De La Region Wallonne	X	
	Flanders	Ministry of the Flemish Community	X	
Bulgaria	*national*	Ministry of Agriculture	X	
Cyprus	*national*	Ministry of Agriculture	X	
Czech Republic	*national*	Ministry of Agriculture		(no participation)
	University	Czech Technical University in Prague		(no participation)
Denmark	*national*	Ministry of Food, Agriculture and Fisheries	X	
Estland	*national*	Ministry of Agriculture	X	
Finland	*national*	Ministry of Agriculture and Forestry	X	
France	*national*	Ministry of Agriculture	X	
Germany	*national*	Federal Ministry for Food Agriculture and Consumer Protection (BMELV)		x
	national	German Society for conservation Agriculture	X	
	Baden-Württemberg	Ministerium für Ernährung und ländlichen Raum Baden Württemberg	X	
	Bavaria	Bayerisches Staatsministerium für Landwirtschaft und Forsten	X	
	Brandenburg	Ministerium für Ländliche Entwicklung	X	
	Hesse	Hessisches Ministerium für Umwelt, ländlichen Raum und Verbraucherschutz	X	
	Mecklenburg Western Pomerania	Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg-Vorpommern	X	
	North Rhine Westfalia	Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the State North Rhine-Westphalia	X	

Country Name	Region/level	Institution	Data delivered	Participation refused
	Lower Saxony	Niedersächsisches Ministerium für Ernährung, Landwirtschaft, Verbraucherschutz und Landesentwicklung	X	
		Landwirtschaftskammer Niedersachsen	X	
	Rhineland-Palatinate	Ministerium Für Wirtschaft, Verkehr, Landwirtschaft und Weinbau	X	
	Saarland	Saarländisches Ministerium für Umwelt	X	
	Sachsen-Anhalt	Ministerium für Landwirtschaft und Umwelt Sachsen-Anhalt		(no participation)
	Saxonia	Sächsisches Staatsministerium für Umwelt und Landwirtschaft	X	
	Schleswig-Holstein	Ministerium für Landwirtschaft, Umwelt, und ländliche Räume des Landes Schleswig-Holstein		(no participation)
	Thüringen	Federal State Ministry of Agriculture		x
Greece	*national*	Ministry of agriculture	X	
Hungary	*national*	Ministry of Agriculture	X	
	Research Institute	Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences	X	
Italy	*national*	APAT - Servizio Geologico d'Italia	X	
	national	Ministero delle Politiche Agricole Alimentari e Forestali	X	
	Piemonte, Campania, Liguria, Lazio, Marche, Bolzano, Sardegna	Regions were involved by the Ministero delle Politiche Agricole Alimentari e Forestali	X	
Ireland	*national*	Ministry of Agriculture	X	
Latvia	*national*	Ministry of Agriculture	X	
Lithuania	*national*	Ministry of Agriculture		x
	Research Institute	Lithuanian Institute of Agrarian Economics		(no participation)
Luxembourg	*national*	Ministry of Agriculture,	X	
Malta	*national*	Ministry for Rural Affairs and the Environment	X	
Netherlands	*national*	Ministry of Agriculture	X	
Poland	*national*	Joint venture of ministries of agriculture and environment and civil experts	X	
Portugal	*national*	Ministry of Agriculture	X	
Romania	*national*	Ministry of Agriculture and Rural Development	X	
Slovak Republic	*national*	Soil Science and Conservation Research Institute	X	
Slovenia	*national*	Ministry for Agriculture and scientific consortium	X	
Spain	*national*	Ministerio de Medio Ambiente y Medio Rural y Marino		(no participation)
Sweden	*national*	Ministry of Agriculture	X	
United Kingdom	UK (England)	DEFRA-Department of the Environment Food and rural affairs	X	
	Scotland	Soil Policy Coordination Team,ERAD/ACE	X	

Country Name	Region/level	Institution	Data delivered	Participation refused
	Wales	Welsh Assembly Government	X	
	Northern Ireland	UK Environmental Policy Branch of the Department of Agriculture and Rural Development, Northern Ireland	X	

More than 400 soil protection measures were identified by the selected experts, while several measures were additionally added by Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V. (Table 4.3). Most measures were inserted in the category ‘mandatory measures’ (MM) followed by the category ‘voluntary incentive-based measures’ (VIBM). Only a limited number of ‘awareness-increasing measures and private initiatives’ (AIM+PI) were contributed to the survey (Table 4.2). Details (Member State, region, policy measure category, year of introduction and description) of all measures are given in Annex 4.2 (Country fiches).

Table 4.2: Soil protection policies by categories (number of measures per category)

Member State	Code	Mandatory measures (MM)	Voluntary incentive-based measures (VIBM)	Awareness-increasing measures and private initiatives (AIM+PI)	Total number of measures
Austria*	AT	33	7	8	48
Belgium*	BE	8	1	-	9
Bulgaria	BG	6	5	-	11
Cyprus	CY	1	1	1	3
+Czech Republic	CZ	4	2	-	6
Denmark	DK	1	9	1	11
Estonia	EE	8	6	-	14
Finland	FI	7	5	1	13
France	FR	5	11	-	16
Germany*	DE	10	25	8	43
Greece	GR	8	3	-	11
Hungary	HU	3	2	-	5
Ireland	IE	2	1	-	3
Italy*	IT	46	22	5	73
Latvia	LV	3	1	-	4
+Lithuania	LT	2	2	-	4
Luxembourg	LU	2	6	1	9
Malta	MT	5	13	-	18
Netherlands	NL	1	1	-	2
Poland	PL	1	2	1	4
Portugal	PT	6	2	-	8
Romania	RO	1	7	-	8
Slovakia	SK	11	11	-	22
Slovenia	SI	9	5	-	14
+Spain	ES	6	1	2	9
Sweden	SE	2	5	1	8
United Kingdom*	UK	37	10	6	53
Total	**-**	**228**	**166**	**35**	**429**

*Member States with regional responsibilities regarding soil conservation.
+ Data added by ZALF.

Where a country was not covered by at least two data entries from national experts, an additional literature review was necessary. Measures were thus inserted for the Czech

Republic, Lithuania and Spain, and the data inserted by ZALF were labelled as additional data. The added information is less precise than the questionnaire replies, and could not be used to provide specific examples in Chapter 5.4 due to lack of detail. Overall 19 measures were added to the online forms, while 57 measures received major editing (i.e. translation, renaming, adding of references, and removal of non-functioning links) or other major corrections (Table 4.3). Concerning the policy attributes, no editing was done. The following sources have been utilised in this process:

- Rubio, J.L., Imeson, A.C., Bielek, P., Fullen, M.A., Pascual, J.A., Andreu, V. and Recatalá, L.A.C. (2006): Directory of European Organisations and Persons Working on Soil Protection. Bratislava, Slovakia.
- Eggers, J., Mettepenningen, E., Beckmann, V., Kunz, A. and Hagedorn, K. (2005): Analysing Institutional Arrangements of Agri-Environmental Schemes in Europe. Final Report.
- Hartmann, E., Schekahn, A., Luick, R. and Thomas, F. (2006): Kurzfassung der Agrarumwelt- und Naturschutzprogramme, Bundesamt für Naturschutz, Bonn, Germany.
- EEA (European Environment Agency) (2006): Integration of environment into EU agriculture policy-the IRENA indicator based assessment report, Copenhagen, Denmark.
- Prokop, G. (2005): The state of EU soil policy and soil related research. *Reviews in Environmental Science and Bio/Technology* 4, pp. 81-86.
- JRC (Joint Research Centre of the European Commission) (2008b): Institute for the Environment and Sustainability, Land Management and Natural Hazards Unit Links to soil related bodies.
- European Commission (2008b): Standing Committee on Agricultural Research Portal.
- European Commission, Agriculture and Rural Development (2008): Beneficiaries of CAP payments.

Table 4.3: Measures added or edited by ZALF (numbers)

Member State	Measures added	Measures edited
Austria*		11
Czech Republic	6	
Denmark		3
Finland		8
France		16
Germany		12
Hungary	3	
Lithuania	2	
Portugal		6
Romania		1
Spain	8	
Sum	**19**	**57**

*Member States with regional responsibilities regarding soil conservation.

In those Member States having federal structures, the number of reported policy measures was generally much higher than for other countries. The following countries are represented by more than one institution:

Austria*: Federal Ministry of Agriculture, Forestry, Environment and Water Management (National level) and the regions of: Lower Austria, Upper Austria, Salzburg, and Tyrol.
missing: Burgenland, Steiermark, Kärnten, Vorarlberg
Belgium*: Regions of Flanders and Wallonia
Germany*: Baden-Württemberg, Bayern, Brandenburg, Hessen, Mecklenburg-Vorpommern, Niedersachsen, Nordrhein-Westfalen, Rheinland-Pfalz, Saarland, Sachsen.
missing: Federal Ministry for Food, Agriculture and Consumer Protection, Thüringen, Schleswig-Holstein, Sachsen-Anhalt; (City-states Berlin, Bremen and Hamburg were not involved in the survey).
Italy*: APAT (National Level) and the regions of: Piemonte, Campania, Liguria, Lazio, Marche, Bolzano, Sardinia.
missing: Valle d’Aosta, Lombardia, Provincia Autonoma Trento, Veneto, Friuli-Venezia Giulia, Emilia-Romagna, Toscana, Umbria, Abruzzo, Molise, Puglia, Calabria, Sicilia.
United Kingdom*: England, Scotland, Northern Ireland and Wales.

When single measures like hedge-planting, reduced tillage or restricted pesticide use were listed as single policies, more data entries were received than when programmes containing a variety of measures (e.g. rural development programmes) were entered as a single soil conservation policy. Listing all sub-measures relevant to agricultural soil conservation in the EU-27 on the level of their design and implementation (National, Regional or local) would have resulted in several thousand entries.

Finally, it has to be kept in mind that the differences among the MS reflect: i) the diversity of soil conditions and problems, ii) the attention the MS pay to soil protection, iii) the levels of policy design below the national level and the commitment of respondents within the EU-wide survey.

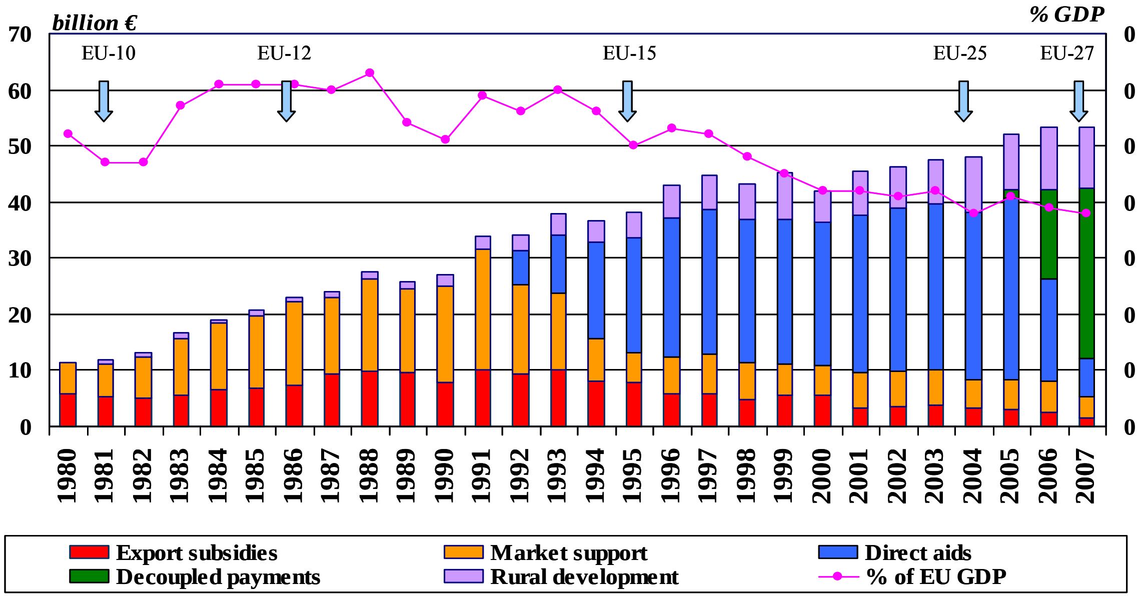
Analysis of the above records has enabled cause-effect links to be identified between EU level policies and farm-level action through their national/regional implementation (chapter 4.4).

4.2 Common Agricultural Policy

The agricultural and rural development policy of the European Union (EU) – the Common Agricultural Policy (CAP) – has always been concerned with ensuring that Europe has sufficient food at reasonable and stable prices. The goal of food security is as important as ever. However, societal expectations in Europe are evolving. The CAP is increasingly designed to meet a wide range of needs, including the maintenance of farm incomes and environment-friendly farming practices, enhancing food quality and promoting animal welfare. In particular, the desired relationship between agriculture and the environment is captured by the term 'sustainable agriculture'. This calls for natural resources to be managed in a way that ensures that their benefits are also available for the future.

The CAP comprises two principal headings of budgetary expenditure: Pillar 1, which comprises direct income support to farmers mainly under the Single Payment Scheme (Single Area Payment Scheme in the New Member States), together with some internal and external market support measures, and Pillar 2, which consists of a range of selective incentive payments targeting rural development. Notwithstanding recent reforms, Pillar 1 remains the dominant part of the CAP in terms of the EU budget dedicated to it and the area of farmland benefiting from it. Direct payments to farmers are important instruments of the CAP in terms of income support and, although they are now for the most part decoupled from production decisions, the cross compliance conditions attached to them affect the agriculture-soil link either directly (via requirements that directly target soil use) or indirectly (by influencing other resource management decisions that have implications for soil use).

Figure 4.4: Changing composition of CAP expenditure (1980-2007)



Source: European Commission, Directorate-General for Agriculture and Rural Development (2008)

The 2003 reform of the CAP shifted the basis for support from production (coupled support) to agricultural area regardless of its use (decoupled support), with stronger, sanctions-backed requirements for farmers to adhere to environmental standards, public, animal and plant health safeguards, and animal welfare requirements (compulsory cross compliance). Our report will focus on cross compliance (see section 4.2.1). Other aspects of Pillar 1 policies may have an impact on soils albeit of a more indirect nature. Rural development policies (Pillar 2) will be dealt with in section 4.2.2.

Compulsory modulation (shifting budgetary funds from Pillar 1 to Pillar 2) and national envelopes increased the levels of funding available for environmental measures. This gives Member States the possibility of using an additional instrument to strengthen environmental objectives: 'The additional payment shall be granted for specific types of farming which are important for the protection or enhancement of the environment or for improving the quality and marketing of agricultural products under conditions to be defined by the Commission in accordance with the procedure referred to in Article 144(2).' (Article 69 of Regulation 1782/2003). Among the eight Member States using this instrument, only Finland explicitly targets improvement of the soil structure to prevent erosion, while the other seven refer to general environmental objectives only.

Finally, it is worth mentioning that compulsory set-aside, which had for some years been an integral part of the direct payment scheme (with considerable effects on land use and soil status), and was maintained by the 2003 reform of the CAP, was finally discontinued in the Health Check revision of the CAP in 2008.[15]

4.2.1 Cross compliance

Cross compliance, a horizontal tool for both pillars and compulsory since 2005 (Council Regulation (EC) 1782/2003), plays an important role in the protection, conservation and/or improvement of soils. Under cross compliance rules, a farmer's receipt of the single farm payment and payments for eight rural development measures under axis 2 are conditional on his compliance with a set of standards.

Direct aids to farmers are made mainly via one ‘Single Farm Payment’ (SFP) per year. After the 2003 CAP reform, various Member States chose (subject to certain rules) to maintain some production-linked support. However, with the 2008 Health Check CAP changes, all remaining production-linked support was removed except for suckler cow, goat and sheep premia. The shift in the emphasis of CAP support towards direct aids to farmers, and away from price support, has been accompanied by clearer obligations on farmers to manage their farms in sustainable ways. ‘Cross compliance’ makes direct payments to farmers conditional on their respecting environmental and other requirements defined at EU and national levels. The Health Check simplified cross compliance requirements by withdrawing standards that are unrelated to farmer responsibility, and will add new requirements intended to retain the environmental benefits of set-aside and improve water management.[16].

The primary purpose of cross compliance is to promote more sustainable agriculture. As summarised by IEEP (2006), the preamble to Regulation 1782/2003 set out three objectives. The first is to integrate basic standards for the environment, food safety, animal health and welfare and good agricultural and environmental practice into the common market organisations by linking direct aid to rules relating to agricultural land and agricultural production activity. The use of the word ‘basic’ is noteworthy. It is apparent that cross compliance is a means of enforcing compliance with pre-existing legislation in the agricultural sector and is therefore a tool to help meet the objectives of this body of legislation. This objective has been summarised by Farmer *et al.* (2007) as: 'More broadly, cross-compliance can also be considered to be a tool to speed up Member State implementation of the various regulations and directives that constitute the statutory management requirements (SMRs) listed in Annex III of Regulation 1782/2003. It also seeks to complement a control system founded on criminal prosecution with a more efficient sanctioning system linked to the Single Payment. Moreover, cross-compliance is one approach to ‘greening the CAP’, the general aim of which is to increase the broader acceptability of making direct payments to farmers in the opinion of both the WTO, in the

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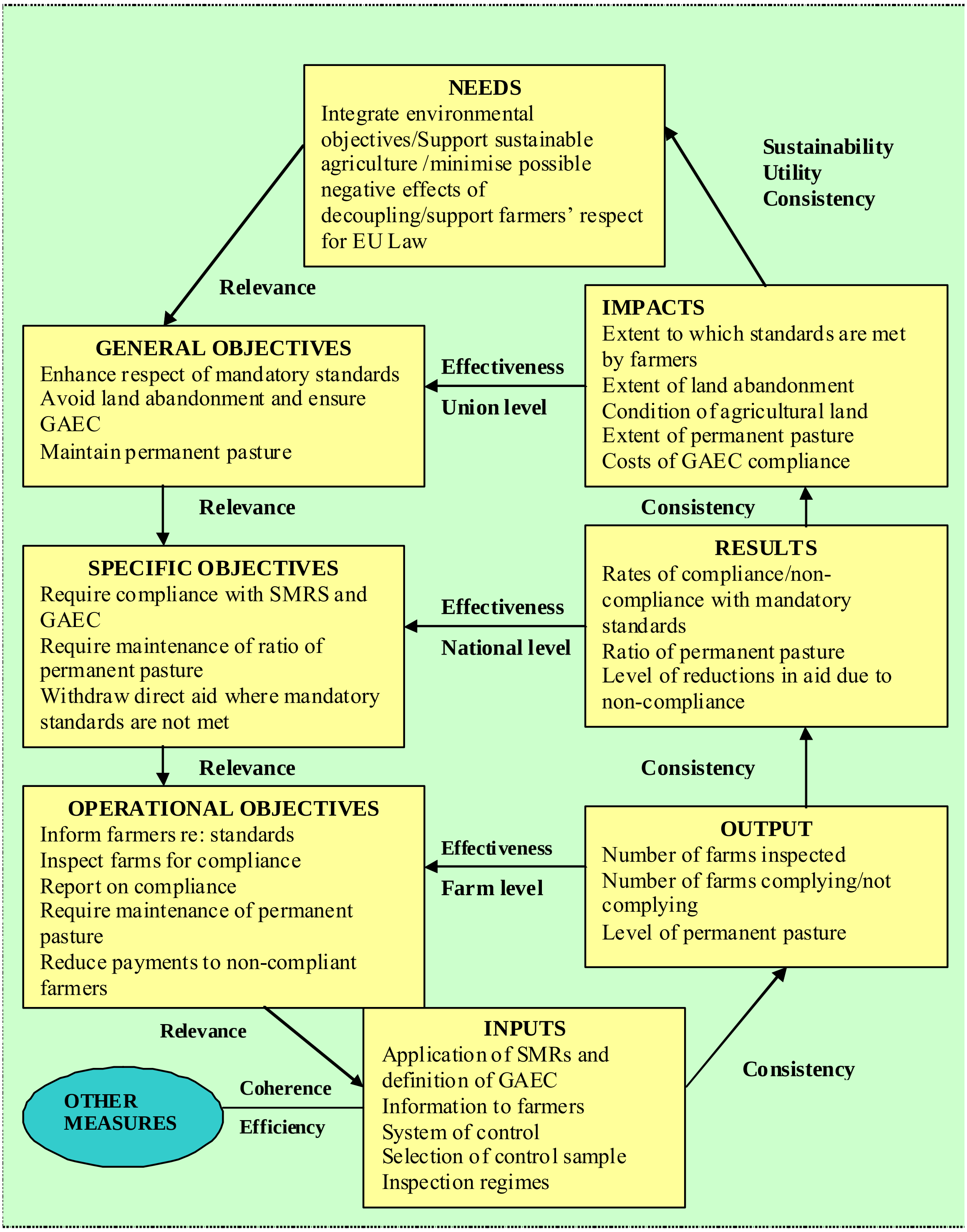
[15] For more details on the Health Check revision of the CAP please refer to: http://ec.europa.eu/agriculture/healthcheck/index_en.htm.

[16] COM(2008) 306 final, p. 5: 'In particular, the proposals aim at withdrawing certain Statutory Mandatory Requirements that are considered not relevant or linked to farmer responsibility, and to introduce into Good Agricultural Environmental Condition requirements that retain the environmental benefits from set-aside and address issues of water management.'

context of the multi-lateral trading system, and the general public, who hold concerns about the environmental damage caused by intensive agriculture' (Farmer *et al.*, 2007, p.8).

An assessment of the effectiveness of cross compliance must focus on the extent to which these three general, EU level objectives are being met (see the list of measurable impacts in Figure 4.5).

Figure 4.5: The objective and outcomes of cross compliance



Source: Alliance Environment (2007), part II, p. 5

Farmers must, in any case, comply with all legislation affecting their businesses. The significance of cross compliance is that farmers must comply in order to receive direct aids. Cross compliance is not a new concept but it was previously only voluntary for Member States and applied only to environmental standards. Cross compliance became compulsory with the implementation of the CAP reform 2003 (Regulation 1782/2003). All farmers receiving direct payments (even when they were/are not yet part of the SPS) have been subject to cross compliance since 2005. A farmer's failure to respect cross compliance conditions can result in deductions from, or complete cancellation of, his direct payments, even when they are not yet part of the SPS (i.e. the few remaining coupled payments). Amounts of direct payments resulting from such penalties revert to the EU (though Member States may retain up to 25 % of the amounts deducted).

Statutory Management Requirements (SMRs)

All direct payments are subject to 19 statutory management requirements[17] (SMRs) in the field of environment, public, animal and plant health, and animal welfare (Table 4.4). These SMRs have all been part of EU legislation for some time. However, their link with farmers' direct payments via the cross compliance requirement gradually became applicable between January 2005 and January 2007. The new Member States applying the Single Area Payment Schemes (SAPS) have been granted a transitional derogation from the application of these requirements and all (except Malta and Slovenia) have made use of this derogation.

Table 4.4: Environmental statutory management requirements (SMRs) within cross compliance

Birds Directive	Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds (OJ EC L 103, 25 April 1979, Page 1) Art. 3, 4(1), (2), (4), 5, 7, and 8;
Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ EC L 206, 22 July 1992, Page 7) Art. 6, 13, 15, and 22(b);
Nitrates Directive	Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ EC L 375, 31 December 1991, Page 1) Art. 4 and 5;
Sewage Sludge Directive	Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (OJ EC L 181, 4 July 1986, Page 6) Art. 3;
Groundwater Directive	Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances (OJ EC L 20, 26 January 1980, Page 43) Art. 4 and 5.

The monitoring of statutory management requirements (SMRs) is a central element of the cross compliance instrument. Standards need to be verifiable in order to implement proper monitoring and enforcement measures. In principle, two basic monitoring approaches can be distinguished: direct, on-the-ground checking of whether or not particular requirements are satisfied, and the use of indicators reflecting outputs or results. The relative merits of these approaches partly depend on the particular SMR concerned, and which of its aspects is being evaluated. 'On the spot measurements and control is the most efficient way to control standards in the public, animal and plant health area; the identification and registration of animals and the rules on animal welfare differ from most of the standards relating to the environment. Due to the complexity of agricultural ecosystems and the interrelations involved

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[17] Regulation 1782/2003, Annex III.

there is often no direct, easily measurable link between agricultural practices and environmental qualities. In particular when it comes to diffuse pollution issues, cumulative effects or effects that can only be measured on a landscape level rather than on a farm level are difficult to measure directly. […]The success of any kind of control or auditing system is directly related to how practical the selected indicators are.' (Jongeneel *et al.*, 2007, p. 67). The latter statement not only holds true for the environmental SMRs but also to a large extent to the issues and standards set by GAEC. In addition, the selection of indicators depends on the availability of reference information.

The extent of compliance with environmental SMRs covered by cross-compliance in selected European countries, based on 2005 information, is reported by Jongeneel *et al.* (2007). On average, the degree of compliance with the Birds and Habitats Directives, the protection of groundwater and compliance with the Sewage Sludge Directive was found to be high, with some minor exceptions. In contrast, the rate of compliance with the Nitrates Directive was not satisfactory in some of the Member States analysed. These results have to be interpreted cautiously, as they depend on expert judgement and selective observation and are not based on a complete evaluation.

The effectiveness of SMR enforcement with respect to soil protection depends on two main factors. The first is the degree to which a specific SMR is aimed at reducing soil degradation processes. This will be discussed in section 4.3. Second, it depends on how the obligation set out in the SMR is translated into specific farm-level requirments, and how well these are understood by farmers. Although linking compliance with the SMRs to the receipt of SPS is a powerful tool, the effectiveness of this tool depends strongly on these operational characteristics. Member States have some discretion when translating some elements of the SMR standards into farm-level restrictions or guidelines so as to take their own environmental specificites into account. They are also required to set up a farm advisory system (FAS) in order to support cross compliance practices at farm level. A review of existing farm advisory systems for cross compliance environmental SMRs, carried out in 13 Member States[18] in the context of the CIFAS project[19], found that the situation differs greatly between Member States. Differences depend partly on budget limitations and lack of experience and capacity in some Member States. The report highlights the particular challenge in the provision of farm advice to small farmers for countries with a large number of small farms.

Despite these variations and difficulties, early signs regarding the overall effectiveness of cross compliance are positive. 'Evidence for both the known and expected outcomes of cross-compliance indicates it is making, or likely to make, a significant contribution to ensuring compliance with obligations. The initial costs of these achievements (arising only from obligations newly introduced by cross-compliance and administrative costs), both for farmers and the authorities, have been substantial in some cases although some of these costs may be considered as start-up costs which will reduce once the system is fully up and running' (Alliance Environment, 2007, p. 142).

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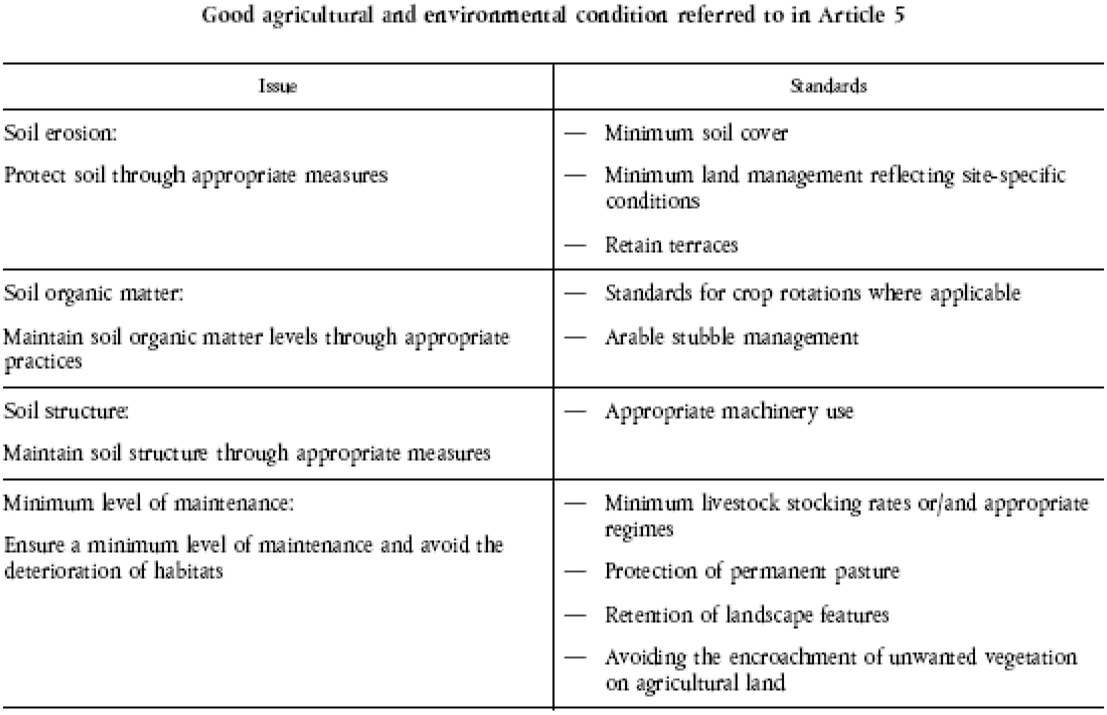
[18] Czech Republic, Germany, Denmark, Estonia, Spain, France, Greece, Hungary, Italy, Poland, Sweden, Slovenia, and the United Kingdom.

[19] Cross compliance Indicators in the context of the Farm Advisory System (CIFAS). European Environmental Agency: http://cifas.ew.eea.europa.eu/

Maintaining land in good agricultural and environmental condition (GAEC)

Another requirement under the common rules for direct payments is maintaining agricultural land, as already briefly mentioned, in Good Agricultural and Environmental Condition (GAEC). It is up to the Member States to define the minimum requirements in accordance with the framework set out in Annex IV of the Regulation 1782/2003. GAEC directly addresses soil protection and relates soil problems to farming practices, both in terms of machinery use as well as land management (see Table 4.5).

Table 4.5: Standards for keeping land in good agricultural and environmental condition (GAEC)



Good agricultural and environmental condition referred to in Article 5

Issue	Standards
Soil erosion: Protect soil through appropriate measures	— Minimum soil cover — Minimum land management reflecting site-specific conditions — Retain terraces
Soil organic matter: Maintain soil organic matter levels through appropriate practices	— Standards for crop rotations where applicable — Arable stubble management
Soil structure: Maintain soil structure through appropriate measures	— Appropriate machinery use
Minimum level of maintenance: Ensure a minimum level of maintenance and avoid the deterioration of habitats	— Minimum livestock stocking rates or/and appropriate regimes — Protection of permanent pasture — Retention of landscape features — Avoiding the encroachment of unwanted vegetation on agricultural land

Note: The issues and standards were updated in the Health Check revision of the CAP.
Source: Council Regulation (EC) No 1782/2003, Annex IV.

GAEC constitutes a common policy (framework) toward certain aspects of agricultural soil protection, and land and landscape maintenance. The Regulation (EC) 1782/2003, however, does not provide either common 'minimum' standards in the above respects or an indication of what the minimum should be. Hudec *et al.* (2007) emphasised that the intention to include GAEC standards in the cross compliance framework was based in part on the fear that large parts of formerly agricultural land would be abandoned after the decoupling of production from support. While the long-term implications of land abandonment for soil quality are rather variable, and in many locations positive, this motivation for the measure explains why Annex IV aims at rather short-term effects of land abandonment than at systematic long-term soil protection. Some Member States have used GAEC to compensate for gaps in their existing national legislation on soil protection, whereas other Member States already had a legislative basis in place, which they merely adopted for cross compliance (Hudec *et al.* 2007). This means that the extent and detail of the GAEC measures developed varies greatly across Member States. While the technical measures established in some countries might be insufficient and ineffective, they could well go beyond the scope and philosophy of Annex IV of Regulation (EC) 1782/2003 in other Member States (Dimopoulos *et al.*, 2006).

The degree to which cross compliance, and especially the GAEC requirement, is implemented will inevitably differ between the Member States for several reasons. The discretion available to Member States on the implementation of cross compliance is likely to result in different specific measures; the fact that Member States can implement cross compliance regionally increases the potential diversity. Political considerations, such as the extent to which Member States are willing to regulate the farming industry, appear to be a factor here (Gay and Osterburg, 2006). The summary of measures given in Table 4.6 is based on an inventory of measures throughout the EU made by Hudec *et al.* (2007). It shows that, taken together, Member States use almost the whole range of measures that appear frequently in the literature, but that individual Member States use them very selectively. The fact that GAEC is defined at national level enables Member States to address soil protection issues flexibly according to national priorities and local needs. However, Regulation (EC) 1782/2003 does not require there to be an assessment of needs, and therefore such an assessment is generally not provided by the Member States. In addition, some Member States have specific national standards and related measures.

Table 4.6: Summary of specific national measures within GAEC

GAEC Issue	Measure/Standard (Annex IV)	Specified technical measures	Applies to	Member State
	General	Farm soil erosion-reduction plan, soil protection review	Erosion vulnerable sites	NL, UK(EN,WA)
		Maintenance of landscape features	Agricultural land	NL, CZ, UK(SC)
		Re-establishment of grasslands	Recently converted grasslands	DK
Erosion	Minimum soil cover	Green (winter) cover	Utilised/ unutilised arable land/permanent crops	CY, DK, FR, LT, NL, PT, UK, DK, IT, NL, PT, ES
		Crop residue, Stubble cover, mulching	Utilised arable land	IE, FR, NL, UK
		No-tillage, reduced tillage	Utilised arable land	DE, ES
		Tillage (no cover)	Agricultural land	NL, ES. UK
	Minimum land management reflecting site-specific conditions	Green (winter) cover	Erosion vulnerable sites/ uncultivated field	BE(FL), NL, ES, HU, FI,PL
		Crop residue, Stubble cover, mulching		PL
		No-tillage, reduced tillage	Erosion vulnerable sites, (meadows - LU)	BE(FL), LU, ES
		Contour tillage (ploughing) and cultivation.	Erosion vulnerable sites	GR, MT, SK, ES, HU, SI, CY
		Restriction on growing row crops	Erosion vulnerable sites	BE(FL), CZ, NL, SK, HU
		Buffer strips	Erosion vulnerable sites	BE(FL), GR
		Preventing over grazing, stock density	Common-ages, natural, semi-natural vegetation,	IE, UK (EN, SC)
		Drainage furrows	Erosion vulnerable sites	IT
	Retain terraces	Ban on destruction		CZ, DE, GR, IT, ES, LU, MT, HU, CY, AT
	Standards for crop rotation	Crop rotation techniques	Arable land; 5 - 15% per crop (FR, DE), or minimum area on which rotation is required (SI)	FR, DE, MT, LU, HU, SI, IE, UK(SC)
		Humus balance calculation or soil organic matter analysis	Where crop rotation requirement is not met	DE, UK(SC)
Soil organic matter		Incorporation into the ground leguminous crops or organic materials	20% of holding area (GR), where deficit is persistent (EI)	GR, EI, UK(SC)
		Cover crop	Fallow land	SE
	Arable stubble management	The ban to burn straw, stubble or other crop plant remains	Arable land	BE, CZ, FR, DE, MT, ES, UK(EN,WA)
		Incorporation crop remains, green manure and stubble	Arable land, where stubble was burned (MT)	GR, LV, LT, MT, UK(SC)

GAEC Issue	Measure/Standard (Annex IV)	Specified technical measures	Applies to	Member State
		into the soil		
		Grazing crop remains and stubble	Arable land	GR
		Mulching crop remains and stubble	Arable land	GR
		Keeping stubble	Arable land	SE
Soil Structure	Appropriate machinery use	Ban of use of machinery	Water logged soils, pastures (IT)	AT, FI, GR, HU, MT, IE, IT, ES, UK
		Restrictions on the use of machinery - no track visible	Agricultural land	SI
Minimum level of maintenance	Minimum livestock stocking rates/and appropriate regimes	To avoid overgrazing; maximum stoking rate	Permanent pastures	IT, ES, UK (SC,WA), HU
		Ban to convert grasslands into arable land	Permanent pastures	IT
	Protection of permanent pasture	Restriction or ban on the conversion of grasslands into other use, re-establishment of grasslands	Permanent pastures	AT, BE, CZ, DE, DK, FR, IE, IT, LU, NL, PT, SE, UK(WA)
		Restriction or ban on ploughing grasslands	Permanent pastures	GR, ES, UK(SC)
		To avoid overgrazing; maximum stoking rate	Permanent pastures	ES, CY
	Retention of landscape features	Maintenance of landscape features like hedgerows, windbreaks, canals, ditches, drainage systems etc.	Agricultural land	CZ, ES (except Extramadura and Navarra), weakly linked: DE, GR, IE, UK

Source: Own summary of Hudec *et al.* (2007)

Table 4.6 highlights that Member States have made use of the flexibility provided within the establishment of GAEC. An evaluation of implementation at Member State level (Hudec *et al.,* 2007) has found both positive and negative examples, spanning all Member States, of how this flexibility has been used. The specific conditions of Member States and regions are considered in most cases, but the evaluation emphasises that an even sharper focus would have been possible. The implementation of the GAEC requirement is still in its early stages, and it can be expected that further adjustments will be introduced in the coming years as experience with this policy tool increases.

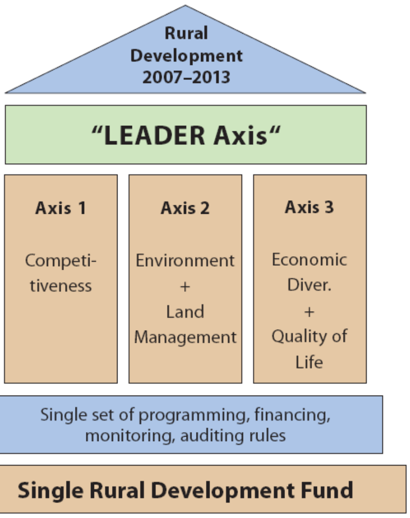
Cost estimates related to cross compliance with GAEC in selected EU Member States reported in Jongeneel *et al.* (2007) reflect the different requirements stemming from different applications of Annex IV. Data are scarce for all four groups of GAEC standards. The costs associated with soil erosion control are provided only for Italy, and amount to EUR 66 /ha for creating water gullies, EUR 20 /ha for extra ploughing costs, EUR 17 /ha for cleaning channels, and EUR 2 /ha for expenses related to shredding and planting. By contrast, the costs of reducing soil erosion by green manure cover crops, could reach EUR 500 /ha (Jongeneel *et al.,* 2007, p. 79). Based on information from farmers' associations, costs of mowing and removing stubble material in Germany were EUR 50-300 /ha. Costs associated with soil structure are also reported only for Italy, namely EUR 36 /ha for surface levelling and water drainage, and EUR 6 /ha for cleaning ditches. Data regarding minimum level of maintenance, again available only for Italy, vary in the range EUR 20-1 740 /ha. Average costs associated with maintenance of soil organic matter are EUR 222 /arable farm in France, and EUR 200 /arable farm in Spain (no information given in either case for animal farms); in the Netherlands, the operational costs of maintaining soil organic matter are low, with annual investment costs of EUR 0-100 /ha (median value of EUR 5 /ha) (Jongeneel *et al.*, 2007, p. 76). Other cost estimates provided for Italy are: yield loss from maintaining straw on the land (aimed at managing organic matter content of the soil): EUR 27 /ha; preventing deterioration of habitats on grassland: EUR 20 /ha; set-aside land management: about EUR 400 /ha; grove maintenance (including pruning, elimination of shoots and thorns): EUR 1 130 /ha; retention of landscape features for terraced surfaces: about EUR 1 750 /ha. Some cost estimates for the UK were given as: performing the soil protection review: up to EUR 3/ha; post-harvest management of combinable crop land: were estimated to be nil; introducing 2 m margins next to hedgerows and water courses: EUR 7-10 /ha.

4.2.2 Rural Development

The Rural Development Regulation (EC) 1698/2005 provides a policy framework with a set of measures that Member States can utilise to support the sustainable development of their rural areas. The regulation provides the principle objectives and the common rules for their applications. However, the selection of the measures most relevant to the local conditions, and the final specification of those measures, are chosen under the Rural Development Programme at national or regional levels (NUTS 0-2). The selection and specification of measures results from an assessment of the situation and the needs of the programming region but in accordance with the Community priorities for the programming period as outlined in the Strategic Guidelines (Decision 2006/144/EC). After consultation with the Commission and public discussion with the local stakeholders, the final draft of the Rural Development Programme of a given region is submitted to the Rural Development Committee for approval.

Member States and regions are obliged to spread their rural development funding over four axes and to allocate a minimum EAFRD share to each axis (Figure 4.6). Three axes are thematic (minimum spending of 10% for axes 1 and 3, and 25% for axis 2). The fourth axis, 'Leader', is horizontal (minimum spending of 5 %; 2.5 % in the new Member States), complementing the three thematic axes. All four axes contain measures or programmes that offer Member States the possibility to support actions for reducing soil degradation when such a need has been identified in their territories. Axis 2 is of particular relevance to soil protection, since both environmental improvement, and preservation of the countryside and landscape, encompass soil degradation processes. Regarding this axis, Member States are encouraged to focus on key actions of which some explicitly refer to soil, such as the delivery of environmental services (in particular, water and soil resources) or stress the role of soils in adapting to climate change.

Figure 4.6: Summary of the 2007-2013 Rural Development Policy



Source: DG for Agriculture and Rural Development (2006), p. 7.

Rural development policy offers options to the Member States or regions for encouraging farmers to go beyond the reference level of soil quality. Table 4.7 lists the measures included in the Rural Development Regulation (EC) 1698/2005 that can be regarded as potentially relevant to soil quality protection, conservation or improvement). Some of them, rather than directly targeting soil quality, address important determinants of soil quality.

Table 4.7: Rural development measures relating to soil conservation

Measure	*Reference number*	*Objective*
Vocational training and information actions (Art. 20 (a) (i))	111	to promote diffusion of knowledge in respect to technological innovation and sustainable management of natural resources
Use of advisory services (Art. 20 (a) (iv))	114	to help farmers meet costs arising from the use of advisory services for the improvement of the overall performance of their holding
Setting up of farm management, farm relief and farm advisory services (Art. 20 (a) (v))	115	to cover costs arising from the setting up of farm management, farm relief and farm advisory services
Modernisation of agricultural holdings (Art. 20 (b) (i))[20]	121	to improve the overall performance of the agricultural holding, while respecting the Community standards applicable to the investment concerned
Restoring agricultural production potential damaged by natural disasters and introducing appropriate prevention actions (Art. 20 (b) (vi))	126	
Natural handicap payments in mountain areas and payments in other areas with handicap (Art. 36 (a) (i-ii))[21]	211- 212	to support continued use of agricultural land (preventing abandonment of farming) and compensate for farmers' additional costs and income foregone related to the handicap for agricultural production in the area concerned

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[20] Alternatively called: Investment support

[21] Alternatively called: Less-Favoured Area (LFA) payments

Measure	*Reference number*	*Objective*
Natura 2000 payments and payments linked to Directive 2000/60/EC (Art. 36 (a) (iii))	213	to help farmers address specific problems resulting from implementation of the Birds, Habitats and Water Framework Directives in agricultural areas through compensation for costs incurred and income foregone
Agri-environment measures (Art. 36 (a) (iv))	214	to support provision of environmental services in agricultural areas
Support for non-productive investment (Art. 36 (a) (vi))	216	to support non-remunerative investments in order to achieve agri-environmental objectives (including those in the framework of agri-environment measures) or to enhance the amenity value of NATURA 2000 and high nature value areas.
Afforestation of agricultural land (Art. 36 (b) (i)) and First establishment of agroforestry stems on agricultural land (Art. 36 (b) (ii))	221, 222	to stimulate diversification from agriculture toward forestry which has high ecological (and good long-term economic) potential

Source: Regulations 1698/2005 and 1974/2006

Note: Measures related to forest areas (except for agroforestry and afforestation of agricultural land) were not taken into account as the SoCo study focuses on agricultural land use.

Through Leader, support is granted to local action groups (LAGs) to implement local development strategies with a view to achieving the objectives of one or more of the three other axes, as well as to implement cooperation projects involving the objectives selected, and to run and animate the local action group.It is impossible to conclude to which extent they address soil protection at the EU level, since the required level of detailed information, in particular the link to farming practices and specific soil degradation processes, can only be obtained at the programme level. The policies can, however, be potentially used as instruments to promote soil-friendly practices and knowledge and to help farmers in their investments.

Table 4.8, which is based on the analysis of eight Rural Development Programmes (from websites of the respective Ministries of Agriculture, accessed in February 2008) provides an overview of rural development measures with an explicit reference to soil degradation processes. Due to the limited number of Rural Development Programmes included, the information can only be considered as an indication:

- Vocational training, information actions and use of advisory services can promote major diffusion of knowledge among farmers, which is essential for changing practices toward those that are more environment-friendly and sustainable (Challen, 2001; Eggers *et al.*, 2007). However, from the eight Rural Development Programmes investigated, only the Irish one dedicates the vocational training and information action measure fully to environment-friendly farming and only the Czech programme explicitly mentions soil erosion as an area where education is needed.
- Under the investment support measure, soil protection is never mentioned as an objective in the eight cases studied. However, supporting innovations with respect to environmental and resource use efficiency may have potential for addressing soil quality issues.
- Maintaining the countryside and maintaining and promoting sustainable farming systems through continued use of agricultural land are the overarching objective of the Less-Favoured Areas (LFA) scheme as revised in 2005 (Regulation (EC) 1698/2005). With respect to LFA payments, none of the scanned Rural Development Programmes refer in particular to soil protection. Nevertheless, LFA measures are generally relevant to soil protection through their objective of preventing land abandonment. Farmland

abandonment has generally negative impacts on soil, such as increased erosion and reduction of soil organic matter quality (Pointereau *et al*., 2008). Targeting LFA aid to areas suffering from natural handicaps like poor soil texture or steep slopes, and to extensive farming systems important for land management, reduces the above risks. Maintaining agricultural land use in these areas thus delivers environmental and landscape benefits that would otherwise not be provided by the market alone. The LFA scheme compensates farmers who continue the agricultural activity for additional costs and income foregone resulting from the natural handicap in the area concerned. However, the payments do not compensate farmers for the costs incurred or income forgone resulting from complying with specific environmental requirements in terms of farm management practices.

- Non-productive investment was either not introduced (5 regions) or not specifically targeted to soil protection (3 regions).
- Only two out of eight examples mention soil protection as a particular objective of the afforestation of agricultural land measure. Both these cases aim at controlling or correcting effects of erosion.
- Three out of eight agri-environment schemes do not particularly refer to soil protection; among these three, however, the Czech and Andalusian cases refer to related environmental objectives (such as landscape) or mention soil-friendly farming practices (such as conservation agriculture).

In a study commissioned by DG AGRI, 63 Rural Development Programmes of six Member States (Austria, France, Germany, Ireland, Italy and the United Kingdom) were screened for measures[22] that have a potential effect on soil or biodiversity protection or on greenhouse gas (GHG) mitigation (European Commission, 2006b). Out of a total of more than 3 000 reviewed measures, 246 measures are expected to have a medium potential impact on soil protection and 113 measures a high potential impact. The results clearly show that the core environmental focus of Rural Development Programmes in the six Member States is on above-ground biodiversity protection (habitat, species and genetic diversity). However, in Italy, the focus is on soil protection, followed by biodiversity protection and GHG mitigation.

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[22] Considering the following seven measures of the Regulation 1257/1999: (1) Investment in agricultural holdings (Ch. I, Art. 4-7); (2) Less-favoured areas (Ch. V, Art. 13-21) and Areas with environmental restrictions (Ch. V, Art. 16); (3) Agri-environmental measures (Ch. VI, Art. 22-24); (4) Improving processing and marketing of agricultural products (Ch. VII, Art. 25-28); (5) Afforestation of agricultural land; (6) Other forestry measures (Ch. VIII, Art. 30-32); and (7) Land improvement.

Table 4.8: Summary of Rural Development measures related to soil

Country	Soil degradation described	Policy Measures with presence of a soil protection related objective							Technical measures in Agri-environment measures	
		Vocational training and information actions	Investment support	LFA payments	Natura 2000, WFD payments	Non-productive investment	Afforestation of agricultural land	Agri-environment measures	Individual	Organic farming
		111	121	211, 212	213	216	221, 222	214		
AT	**Soil erosion**	Explicit (but marginal) reference only to environmental protection knowledge	Innovations in respect to environmental and resource use efficiency	No explicit reference to soil protection	√	-	Only implicitly in the ecological concern of the afforestation and particular land	Erosion and surface water run-off	Under-sown crops by maize, grass cover or green mulch or straw cover, maintenance of terraces, green cover crop (winter), mulch and direct sowing.	√
CZ	**Soil erosion**, compaction, loss of organic matter, contamination	Explicit reference to the protection against erosion.	No explicit reference to environment protection	No explicit reference to soil protection	√	-	General improvement of environment, no reference to soil protection	Landscape management	Establishment of grasslands on arable land, intercrops, bio strips	√
DE (Saxony)	**Soil erosion**	-	Innovative environment improving technology (however no soil protection mentioned explicitly)	No explicit reference to soil protection	-	-	Protection against erosion	Reduction of erosion (effects): low input cultivation systems, environmentally friendly cultivation of arable land	Intercrops, under-sown crops, direct sowing, fallow areas (i.e. buffer strips), leaving stubble over winter.	√
ES (Andalusia)	**Soil erosion**	No explicit reference to environmental protection	No explicit reference to environment protection	No explicit reference to soil protection	√	No reference to soil protection	To correct effects of erosion	Conservation Agriculture, conservation of mixed agricultural, agroforestry and dehesa systems.	Conservation agriculture techniques	√

Country	Soil degradation described	Policy Measures - presence of a soil protection related objective							Technical measures in Agri-environment measures	
		Vocational training and information actions	Investment support	LFA payments	Natura 2000, WFD payments	Non-productive investment	Afforestation of agricultural land	Agri-environment measures	Individual	Organic farming
		111	121	211, 212	213	216	221, 222	214		
IE	Soil erosion, compaction, loss of organic matter, but **no widespread risk** of these, only local	Training supporting AEM and NATURA 2000	Marginal reference to environment protection	No explicit reference to soil protection	√	No reference to soil protection	-	Action 9: Produce tillage crops respecting environmental principles - biodiversity and soil protection	Green cover establishment, increased arable margins, minimum tillage crops	√
PL	**Soil erosion**, organic matter decline, compaction, soil **contamination, acidification**	No explicit reference to soil protection, only general environmental protection	No explicit reference to soil protection	No explicit reference to soil protection	√	-	No explicit reference to soil protection	Soil and water protection, biodiversity protection	Under-sown crops, intercrops, buffer strips	√
SE	**No serious soil degradation,** except high content of nitrates and phosphorus in top soils	No reference to soil protection	No reference to soil protection, but sustainable use of resources	No reference to soil protection, but sustainable use of resources	√	Only biodiversity and cultural heritage	-	No particular aim at soil protection		√
UK (England)	**Soil erosion, organic matter decline**, water absorption capacity of soils, biodiversity	No explicit reference to soil protection, while to water protection yes	No explicit reference to environment protection	No explicit reference to soil protection	-	No reference to soil protection, it might be introduced jointly with AEM within HLS	No explicit reference to soil protection	Reference at both levels: the Entry Level Scheme (ELS) and High Level Scheme (HLS): erosion, compaction, loss of organic matter	Not specified for ELS; for HLS: restrictions on grazing (to reduce soil compaction), seasonal removal of cattle in areas prone to water logging, compaction and poaching, reversion of eroded arable land to unfertilised permanent pasture	√ (OELS)

Source: Rural Development Programmes of Austria, Andalusia, England, Czech Republic, Poland, Saxony and Sweden, published on the respective websites of the Ministries of Agriculture, accessed in February 2008

Agri-environment Measures

Within axis 2 in particular, measures with the capacity to support specific farming practices and farming systems, such as agri-environment measures, have a high potential to target soil quality. Agri-environment measures were set up to accompany the 1992 CAP reform with a double objective: to provide alternative income for farmers and to respond to an increasing demand for environmental services that go beyond the application of usual Good Farming Practice.

The Agenda 2000 reforms further strengthened agri-environment measures by making them mandatory for Member States and included them in the context of a broader Rural Development Programme ((EC) 1257/1999). As the current Rural Development Regulation retains this rationale, agri-environment measures continue to be an important policy instrument aiming at 'supporting sustainable development of rural areas and responding to society's demand for environmental services' ((EC) 1698/2005, Preamble (35)).

Agri-environment measures are voluntary incentive-based measures designed to encourage farmers to protect and enhance the environmental quality on their farmland. They provide for payments to farmers in return for a service that goes beyond simply maintaining a reference level, which may come either from the mandatory standards established pursuant to Articles 4 and 5 and Annexes III (SMRs) and IV (GAEC) to the Regulation (EC) 1782/2003, or from the requirements for fertiliser and plant protection product use and other relevant mandatory requirements established by national legislation and identified in the Rural Development Programme. The agri-environmental measures are defined in the Rural Development Programme, usually along with a description of technical measures to be adopted by farmers as well as eligibility criteria and payments. The actual service is agreed between the implementation authority and a farmer through a contract of a minimum of five years. The provision of agri-environment measures represents the only compulsory measure for Member States within their Rural Development Programmes.

Agri-environment measures are designed at programme level (national or regional). While diverse in their application, they broadly respond to either or both the reduction of environmental risk associated with modern farming and the preservation and improvement of nature and cultivated landscape. Thus, agri-environment measures have varied considerably and still differ amongst the Member States in both uptake and expenditure for several reasons, including their first introduction, the degree of discretion granted to the Member States in defining the measures and the general attitude towards environment within the agricultural sector.

Agri-environment measures with the explicit objective of soil conservation, particularly addressing erosion, are common (Finn *et al.*, 2007) under Regulations 1257/1999 and 1698/2005. Additionally some schemes with other objectives like water or biodiversity protection, or landscape maintenance require or support the adoption of soil conservation practices. The following agri-environment measures are relevant to soil protection[23]:

- Input reduction, including reductions in fertilisers and plant protection products. When part of an 'integrated farming' approach, it can also be combined with crop rotation measures. The measures are expected to enhance biodiversity and soil quality.

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[23] DG AGRI (2005): Agri-environment measures, p.11s.

- Organic farming: Similarly to input reduction, this clearly defined and controlled approach to farming is expected to enhance biodiversity and soil quality through input reduction, crop rotation and extensificiation of livestock.
- Extensification of livestock: This can be expected to have positive effects on soil quality, biodiversity and landscape preservation.
- Conversion of arable land to grassland and rotation measures: Conversion of arable land to grassland can have positive effects on soil quality, biodiversity and landscape. If drawn up with clear environmental objectives, rotation measures can have positive effects on soil quality, biodiversity and landscapes.
- Undersowing and cover crops, strips (e.g. farmed buffer strips) and preventing erosion and fire: Undersowing and cover crops can have positive impacts on soil quality (controlling soil erosion in particular) and biodiversity. Field strips can also help prevent soil erosion.
- Voluntary set-aside: set-aside managed for environmental purposes could be expected to have positive impacts on biodiversity and soil erosion. Measures include both large areas of set-aside and small ones such as uncultivated field strips. Set-aside, in order to have positive environmental effects, must be implemented according to site-specific circumstances and often needs to be combined with appropriate management, as simple abandonment can cause environmental problems.

The analysis of the environmental impact of agri-environment measures based on the mid-term evaluation reports of the 2000-2006 programming period includes examples of benefits for soil protection and conservation (European Commission, 2005):

- For the Piemonte region (Italy) it is shown that hedge-planting measures have had a significant impact on soil erosion.
- In Austria, it has been shown that direct sowing techniques in maize production have resulted in a 40% reduction in soil erosion.
- In Umbria (Italy) organic farming techniques have been found to reduce soil erosion on average by 6.8 t/ha/yr. Conversion of arable to grassland is estimated to have resulted in a reduction of 30 t/ha/yr.
- Many of the measures in Niedersachsen, Germany, are designed to have positive impacts on soil quality and erosion, particularly the use of green cover, arable set-aside, and reversion of arable land to grassland (nearly 30 000 ha under these measures). Improved soil quality has also been noted on arable land farmed organically.
- In Bavaria (Germany) the vast majority of farmed land is under the agri-environment programme, many of whose measures are designed to prevent soil erosion. In Flanders (Belgium), calculations based on detailed scientific knowledge indicate that green cover of the soil reduces soil erosion by at least 50%.
- Extrapolating from detailed figures for two communes in Flanders, the mid-term report estimates that, during the period 1999-2002, green cover measures will have prevented the erosion of one million tons of soil.
- In the Piemonte region, a combination of soil analysis and modelling was used to calculate the impact of farming on soil on farms with agri-environment measures and control farms using only good farming practice. This showed considerable reductions of polluting substances in the soil for the main crops.

An important agri-environment measure relates to conversion to and maintenance of **organic farming (Regulations 2092/91 and 834/2007)**; uptake until 2005 is given in Table 4.9. One goal of organic farming is to maintain 'soil in a healthy, fertile and natural state (trying) to enhance its condition through the provision of appropriate nutrients, improvements to soil structure and effective water management'[24] through a set of appropriate farming practices such as:

- tillage and cultivation practices that maintain or increase soil organic matter, enhance soil stability and soil biodiversity, and prevent soil compaction and soil erosion;
- multi-annual crop rotation, including legumes and other green manure crops, application of livestock manure or organic material, preferably composted, from organic production. These practices maintain and increase soil fertility and biological activity of the soil.

Table 4.9: Uptake of organic farming within the Member States until 2005[1]

	Utilised Agricultural Area under Organic Farming (ha)	Share of Utilised Agricultural Area under Organic Farming (%)	Average Annual Growth Rate of Utilised Agricultural Area under Organic Farming (%/yr)
	2005	2005	2000-2005
Austria	360 369	11.03	5.50
Belgium	22 994	1.66	2.16
Bulgaria	14 320	0.52	118.73
Cyprus	1 698	1.12	100.81
Czech Republic	254 982	7.17	9.00
Denmark	134 129	5.18	-3.18
Estonia	59 741	7.21	43.34
Finland	147 587	6.52	0.04
France[2]	550 488	2.00	8.27
Germany	807 406	4.74	8.14
Greece	288 737	7.25	60.98
Hungary	128 576	3.01	22.18
Ireland	34 912	0.83	5.10
Italy	1 069 462	8.42	0.55
Latvia	118 612	6.97	93.26
Lithuania	64 544	2.31	68.81
Luxembourg	3 158	2.45	30.95
Malta	14	0.14	169.06
The Netherlands	48 765	2.49	8.57
Poland	82 730	0.56	34.87
Portugal	233 458	6.34	37.17
Romania	87 916	0.63	38.20
Slovakia	90 206	4.80	9.06
Slovenia	23 499	4.84	34.00
Spain	807 569	3.25	16.22
Sweden	222 738	6.98	5.04
United Kingdom	608 952	3.82	1.02
EU-12	926 838	1.97	24.48
EU-15	5 340 724	4.28	6.46
EU-25	6 165 326	3.97	7.36
EU-27	6 269 567	3.65	9.19

Notes: 1, 2004 for Luxembourg and Poland; 2, The data for France and therefore the European aggregates include the overseas departments.
Source: Rural Development Report (2007), p. 158

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[24] http://ec.europa.eu/agriculture/organic/environment/soil_en (Accessed: September 2008)

In the framework of the ITAES[25] project, Finn *et al.* (2007) estimated environmental performance of agri-environment measures implemented in the programming period 2000-2006 (Regulation 1257/1999). The evaluation approach adopted combines the effectiveness and efficiency perspectives and is based on expert consultation. The experts were asked to evaluate five aspects of environmental performance of the measures pair-wise with their objectives (either main or side) by associating scores 1 (low) to 5 (high) to each pair and evaluation aspect. The evaluation aspects included cause-and-effect relationships, quality of institutional implementation (administration), farmer compliance, geographical targeting and extent of participation. Finn *et al.* (7) examined two agri-environment objectives related to soil protection: reduction of soil erosion, and prevention or reduction of chemical contamination of soils. Their results are presented in Table 4.10 and Table 4.11. In general, the measures are considered to be well designed and administered, but are weaker in terms of targeting and uptake.

Table 4.10: Environmental performance of agri-environment measures related to the reduction of soil erosion

Member State/region	Causality	Institutional implementation	Farmer compliance	Targeting	Participation	Average score
Ireland	5	1	4.8	2.4	2.6	2.7
Czech Republic	3	3	5	2	4	3.2
Flanders	5	4	4	4	1	3.2
Finland	5	4.6	5	3	4.3	4.3
Basse Normandie	3	2.8	4	2.6	2.4	2.9
Veneto	3	4	3.7	3.8	2.8	3.4
Emilia Romagna	4	2.8	4.4	3	2.8	3.3
Brandenburg	3.5	2.8	5	4	2	3.3
Total	3.9	3.1	4.5	3.1	2.7	3.4

Notes: Scores range from 1 (low) to 5 (high); average score: geometric mean
Source: Finn et al. (2007)

Table 4.11: Environmental performance of agri-environment measures related to the reduction of soil contamination

Member State/region	Causality	Institutional implementation	Farmer compliance	Targeting	Participation	Average score
Ireland	3	5	4.5	2.5	2.5	3.3
Czech Republic	5	3.5	5	3.5	4	4.1
Flanders	5	3	4	3	1	2.8
Basse Normandie	2.8	4.3	4	3.3	2	3.2
England	5	4	5	2	1	2.9
Veneto	4	4	4	2.7	2.2	3.3
Brandenburg	4	2.8	5	4.3	2.3	3.5
Total	4.1	3.8	4.5	3.0	2.1	3.4

Notes: Scores range from 1 (low) to 5 (high); average score: geometric mean
Source: Finn et al. (2007)

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[25] For the ITAES (Integrated Tools to Design and Implement Agro Environmental Schemes) project, see for example http://ec.europa.eu/research/fp6/ssp/iteas_en.htm.

Also within ITAES, Mettepenningen *et al.* (2007) estimated private transaction costs of agri-environment measures by surveying 1 320 farms (covering all case study regions) and conducting a follow-up of 120 farms in six of the above-mentioned case study regions. They found that there were significant transaction costs before the actual start of conservation projects. The average time span between a farmer's decision to participate and the actual participation in the agri-environment measure was 10.6 months, ranging from 7.5 in Finland to almost 15 in France (Basse Normandie). Most of the time and costs were due to information gathering, training and negotiating the contract. From the follow-up of case study farms, Mettepenningen *et al.* (2007) derived the (additional) costs associated with running a conservation project: transaction costs related to paper work and other administration, additional operational costs, additional investment and revenue foregone. These costs were estimated by comparing plots under the scheme with reference plots. Mettepenningen *et al.* (2007) extracted cases of conservation projects relating to soil protection. Most of these concerned the reduction of erosion by applying field cover during winter. Table 4.12 shows changes in costs (operational, investment, excluding farmer's own labour), farmer's hours necessary to complete the new work and revenue due to the participation in agri-environment measures.

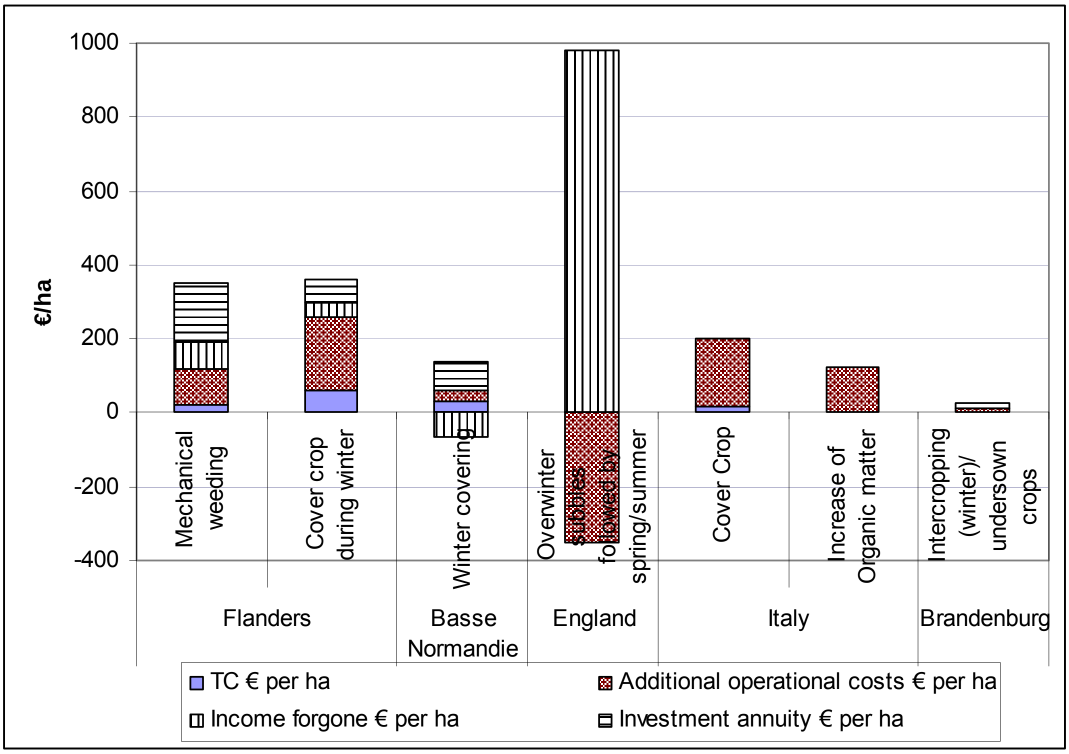
Table 4.12: Changes in costs, working hours and revenue due to agri-environment project, %

Region	Activity	Percentage change in			
		Costs	Operational hours	Administrative hours	Revenue (without premium)
Flanders	Mechanical weeding		13	8	-4
	Cover crop during winter	17	33	63	-18
Basse Normandie	Winter covering	8	185	17	
England	Overwinter stubbles followed by spring/summer fallow	-98	-100	-39	-91
IT	Cover crop		-67	-21	
	Increase of organic matter	13	100	22	
Branderburg	Intercropping (winter)/ undersown crops	-4		-4	

Source: Own presentation of Mettepenningen *et al.*, 2007.

Figure 4.7 shows the structure of costs arising from agri-environment measures. Transaction costs (TC) are rather small compared to the other costs like operational costs and investment costs. Although costs and hours vary significantly among measures (see Table 4.12 and Figure 4.7), they are not negligible and obviously might play an important role in farmers' decisions whether to take part in agri-environment measures and to adopt soil conservation practices. The level of their compensation will be critical for the uptake of a voluntary policy measure.

Figure 4.7: Additional costs associated with participation in agri-environment measures

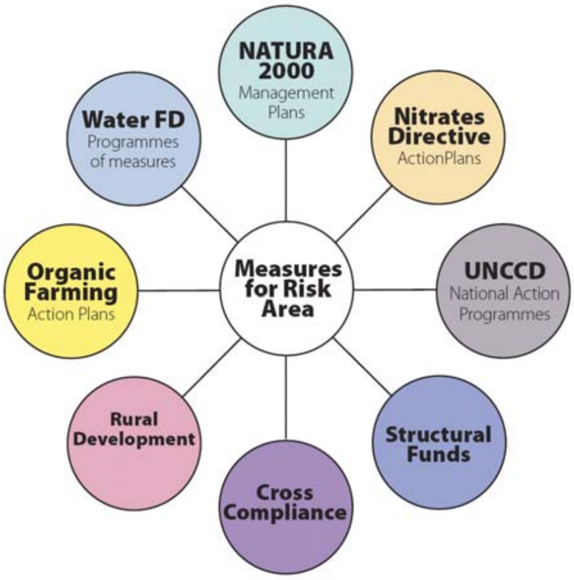


Source: Own presentation of Mettepenningen *et al*., 2007

4.3 Environmental legislation

While various EU policies may primarily target environmental objectives other than soil (for example, water, waste, chemicals or nature protection or pesticides), they may nevertheless contribute to soil protection. Figure 4.8 gives an overview of the main policies that may affect soil conservation.

Figure 4.8: Link between measures for soil protection and related activities



Source: European Commission, 2006a, p. 21.

4.3.1 Specific reference to relevant directives included in cross compliance (SMRs)

The incorporation of a number of statutory management requirements (SMRs) into the cross compliance conditions attached to Pillar 1 direct payments reinforces existing legistlation relating to (i) environment, (ii) public, animal and plant health, (iii) notification of diseases, and (iv) animal welfare (4.2.1). Some of the directives concerning the first two issues are of particular relevance to soils in an agricultural context.

Environment regulations supported by cross compliance

The **Birds Directive (79/409/EEC)** aims at long-term ***conservation of wild bird species*** across the EU by means of protection, management and monitoring of these species. Member States shall take the required measures to maintain the population of each species at a level corresponding to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adjust the population of these species to that level. The most suitable territories for wild bird conservation, which include a high proportion of wetlands, are designated as Special Protected Areas (SPAs). Conservation measures include maintenance and re-establishment of biotopes and habitats. Member States shall also take appropriate steps to avoid pollution or deterioration of habitats or any disturbances affecting birds inside the protected areas; even outside these areas, Member States shall strive to avoid pollution or deterioration of birds' habitats. As such, the Birds Directive is likely to have a positive effect on ***(local and) diffuse soil contamination***, e.g. through extensive grassland management.

The ongoing deterioration of natural habitats and the threats posed to certain species (plants and animals) are a major concern of EU environment policy. The **Habitats Directive (92/43/EEC)** is intended to ensure ***biodiversity*** by establishing a 'favourable conservation status' for natural habitats and wild species, organised in a coherent European ecological network known as Natura 2000. This network comprises Special Areas of Conservation (SACs) and the SPAs (previously mentioned in the context of the Birds Directive). Member States designate the Natura 2000 sites in partnership with the Commission, and have six years to put the necessary management measures in place. In spite of implementation delays (COM(2003) 845), the network will comprise more than 25 000 sites, covering around 20 % of the total land area of the EU, or around 800 000 km^2 by the end of 2008 (European Commission, 2008a); however, only a small fraction of this land is in agricultural use. The Directive provides for co-financing of conservation measures by the Community through integrating its funding into other relevant Community policies and the EU's broader land management policies (e.g. RDP-Axis 2). Thus, agricultural land within Natura 2000 sites has to comply with the Habitats Directive requirements to be eligible for payments related to the management of these sites through the Rural Development Regulation.

Protection and conservation of soils are not mentioned explicitly in either the Birds Directive or the Habitats Directive; however, agricultural soil protection can be considered an implicit precondition for the protection or recovery of habitats. ***Soil biodiversity*** is likely to benefit from the (extensive) farm practices that the implementation of these Directives induces. The network structure of the Natura 2000 sites (at least where interconnected) provides an additional bonus in this respect. Protecting sites such as forests and peatlands furthermore adds to the soil's ***carbon pool function***.

The **Nitrates Directive (91/676/EEC)** is designed to protect the Community's waters against nitrates from agricultural sources, which are one of the main causes of water pollution from diffuse sources. Intensive livestock farming (poultry, pigs), with its growing density of livestock building and manure/fodder storage facilities, and intensive arable farming are likely to aggravate water pollution by nitrates.

Member States must identify, within their territory, those surface waters and groundwater affected or liable to be affected by pollution (in particular when nitrate concentrations in groundwater or surface waters exceed 50 mg/l), and vulnerable zones that contribute to pollution, that is zones that drain into waters affected by pollution.

Member States must then establish codes of good agricultural practice to be implemented by farmers on a voluntary basis, as defined in Annex II to the Directive. These should cover provisions relating to:
- the use and storage of nitrate fertilisers and livestock manures, for periods when the land application of fertiliser is inappropriate;
- application of fertiliser on steeply sloping ground;
- application of fertiliser to water-saturated, flooded, frozen or snow-covered ground;
- the conditions for application of fertiliser on land near water courses;
- the capacity and construction of storage for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage;
- application practices for both chemical fertiliser and livestock manure, including rate and uniformity of spreading, that will maintain nutrient losses to water at an acceptable level.

The code may also include a set of technical measures related to soil management:
- land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;
- maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate pollution of water;
- prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems; and
- the establishment of fertiliser plans on a farm-by-farm basis and the keeping of records on fertiliser use.

Member States must define and implement action programmes for vulnerable zones (Annex III). These should include rules relating to the capacity of storage vessels for livestock manure, and limitations of the land application of fertilisers. The latter include prohibited periods for certain types of fertilisers. The limitations should also be consistent with codes of good agricultural practice, take into account the characteristics of the vulnerable zone concerned, in particular (a) soil conditions, soil type and slope, (b) climatic conditions, rainfall and irrigation, and (c) land use and agricultural practices, including crop rotation systems, and should be based on a balance between the foreseeable nitrogen requirements of and supply to (soil, fertilisers) the crops.

In addition, Member States must monitor water quality, applying reference methods to measure the nitrogen compound content. Member States must report regularly on the implementation of the Directive and eventually revise their farm management requirements.

The Nitrates Directive primarily targets ***water quality***. However, it is expected to have positive effects on ***local and diffuse soil contamination***. In particular cases, even ***soil***

compaction might be positively affected, as fertiliser spreading is banned in the winter period (with prevailing wet or water-saturated soils).

The European Union regulates the use of sewage sludge in agriculture by means of the **Sewage Sludge Directive (86/278/EEC).** Sewage sludge contains large amounts of nutrients, and is therefore regarded as a good fertiliser for agriculture. However, sludge can also be contaminated with heavy metals, bacteria, viruses and a number of organic substances. Due to harmful or even toxic effects of these substances to human beings and plants (e.g. crop contamination by pathogens), the Directive sets limits on the concentrations of certain substances in sludge, bans the use of sludge in certain cases and regulates its treatment. Thus, in using sewage sludge, account must be taken of the nutrient needs of the plants without, however, impairing the ***quality of the soil and of surface and groundwater***. The Directive specifies that it aims at 'establishing certain initial Community measures in connection with soil protection'. It addresses the ***decline of organic matter*** and ***soil contamination*** through regulating the use of sewage sludge on agricultural land, while encouraging its correct use.

The **Groundwater Directive (80/68/EEC) and new Groundwater Directive (2006/118/EC)** prohibit or limit the discharge of certain toxic, persistent and bio-accumulable substances (especially pesticides and fertilisers) into groundwater, and establish systematic monitoring of the quality of such water. They will be repealed by the Water Framework Directive (2000/60/EC) as of 21 December 2013.

There are two lists of dangerous substances drawn up for the protection of groundwater:
- List I: substances, including organohalogen, organophosphorus and organotin compounds, mercury and cadmium and their compounds, and hydrocarbons and cyanides;
- List II: substances, including certain metals such as copper, zinc, lead and arsenic, and other substances such as fluorides, toxic or persistent organic compounds of silicon, and biocides and their derivatives not appearing in List I.

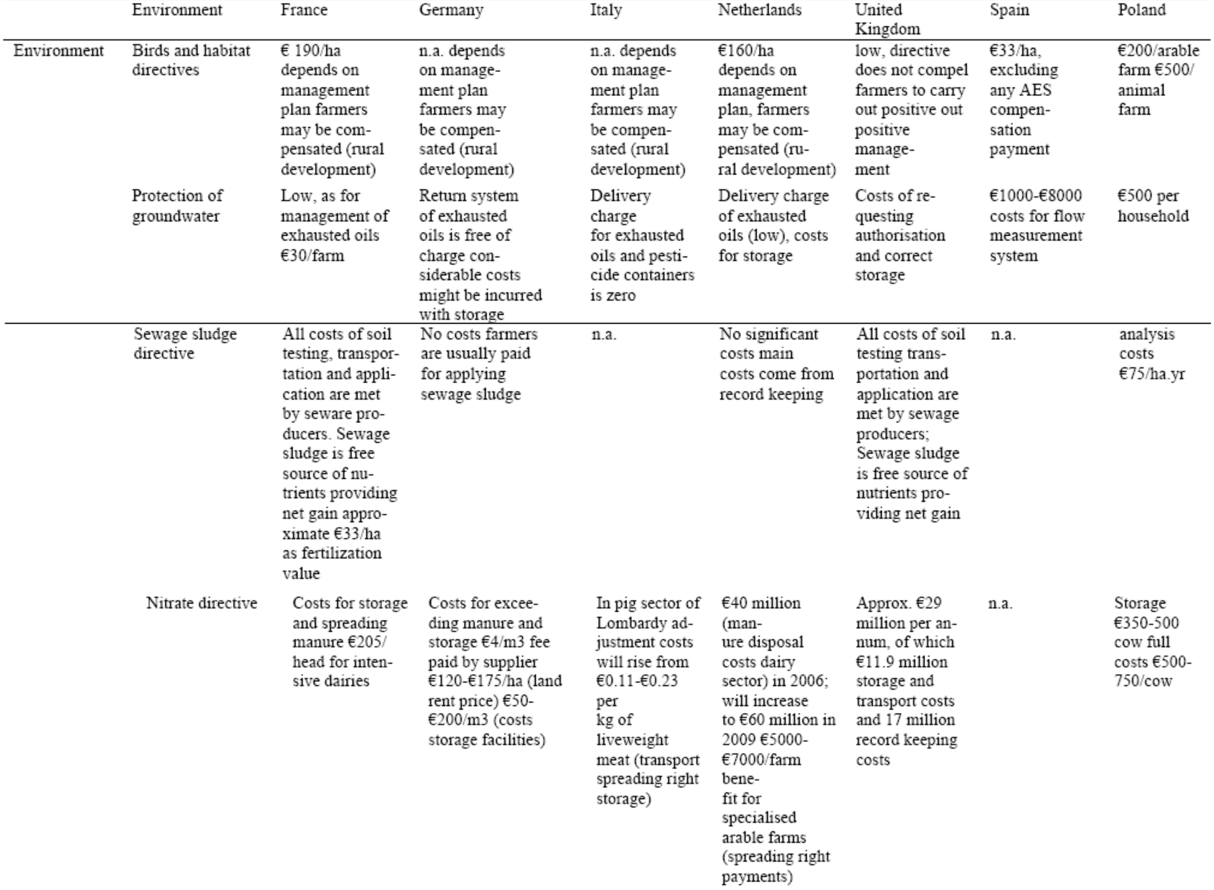
Direct discharges of substances in List I are prohibited, while indirect discharges of substances in List I as well as all direct and indirect discharges of substances in List II are subject to prior authorisation as specified in the Directive. Nevertheless, the Directive provides for exceptions, under certain conditions, to the ban on direct discharges of substances in List I.

Monitoring compliance with these conditions and the effects of discharges on groundwater is the responsibility of the competent authorities of the Member States. Again, this Directive is likely to reduce diffuse ***soil contamination*** and may have positive side-effects on ***soil biodiversity***.

Costs of compliance with environmental SMRs

Jongeneel *et al.* (2007) estimated the costs of compliance with environmental SMRs, obtaining the figures shown in Table 4.13. Different approaches have to be used to estimate these costs, and it is not clear to what extent the estimates are method-dependent. Therefore, although the figures give some indication of costs, overall the picture is rather tentative.

Table 4.13: Costs of compliance with environmental SMRs



	Environment	France	Germany	Italy	Netherlands	United Kingdom	Spain	Poland
Environment	Birds and habitat directives	€ 190/ha depends on management plan farmers may be compensated (rural development)	n.a. depends on management plan farmers may be compensated (rural development)	n.a. depends on management plan farmers may be compensated (rural development)	€160/ha depends on management plan, farmers may be compensated (rural development)	low, directive does not compel farmers to carry out positive out positive management	€33/ha, excluding any AES compensation payment	€200/arable farm €500/ animal farm
	Protection of groundwater	Low, as for management of exhausted oils €30/farm	Return system of exhausted oils is free of charge considerable costs might be incurred with storage	Delivery charge for exhausted oils and pesticide containers is zero	Delivery charge of exhausted oils (low), costs for storage	Costs of requesting authorisation and correct storage	€1000-€8000 costs for flow measurement system	€500 per household
	Sewage sludge directive	All costs of soil testing, transportation and application are met by seware producers. Sewage sludge is free source of nutrients providing net gain approximate €33/ha as fertilization value	No costs farmers are usually paid for applying sewage sludge	n.a.	No significant costs main costs come from record keeping	All costs of soil testing transportation and application are met by sewage producers; Sewage sludge is free source of nutrients providing net gain	n.a.	analysis costs €75/ha.yr
	Nitrate directive	Costs for storage and spreading manure €205/ head for intensive dairies	Costs for exceeding manure and storage €4/m3 fee paid by supplier €120-€175/ha (land rent price) €50-€200/m3 (costs storage facilities)	In pig sector of Lombardy adjustment costs will rise from €0.11-€0.23 per kg of liveweight meat (transport spreading right storage)	€40 million (manure disposal costs dairy sector) in 2006; will increase to €60 million in 2009 €5000-€7000/farm benefit for specialised arable farms (spreading right payments)	Approx. €29 million per annum, of which €11.9 million storage and transport costs and 17 million record keeping costs	n.a.	Storage €350-500 cow full costs €500-750/cow

Source: Jongeneel *et al.* (2007), pp. 77-78
Legend: n.a., not available

Public, animal and plant health Regulations supported by Cross-compliance

The **Plant Protection Products Directive (91/414/EEC)** concerns the authorisation, placing on the market, use and control within the EU of plant protection products in commercial use. Member States shall ensure that a plant protection product is not authorised unless its active substances (as listed in Annex I to Directive 91/414/EEC) are authorised for incorporation in plant protection products and any related conditions are fulfilled. Companies wanting to introduce a product on the market should apply to one Member State for the inclusion of its active substance(s) in Annex I. The application dossier (according to the requirements outlined in Annex II to Directive 91/414/EEC) should provide the information necessary for evaluating the foreseeable risks, whether immediate or delayed, which the substance may entail for humans and the environment. With respect to the environmental effects, the document should include a description of the fate and residue behaviour of plant protection products in the soil, such as rate and route of degradation, adsorption-desorption and mobility in different soil types, as well as extent and nature of the bound residues (point 7.1). The report should also cover eco-toxicological studies on the active substance (point 8.), including toxicity to earthworms and to other soil non-target macroorganisms.

In 2002, the EU launched a **Thematic Strategy on the Sustainable Use of Pesticides** to address risks entailed by the actual use of pesticides (mainly plant protection products and biocides). It includes a Communication (COM(2006) 372 final) and a legislative proposal for a Framework Directive (COM(2006) 373 final), which is intended to replace Directive 91/414/EEC, and is accompanied by a detailed impact assessment. The responsible parties adopted the Communication on 12 July 2006. Discussions on acceptance of the (amended) proposal for a Framework Directive are ongoing.

A similar approach has been adopted in the **Directive on Biocidal Products (98/8/EC)**, aiming *inter alia* at providing a high level of protection for the environment, including soils. This Directive has however not been included among the SMRs under cross compliance.

Nevertheless, given the above provisions, both Directives are expected to have repercussions for ***soil contamination*** and ***soil biodiversity.***

4.3.2 Water Framework Directive (2000/60/EC)

In order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of floods and droughts, the EU has established the Water Framework Directive (2000/60/EC) (WFD). The goal of the Directive is to establish a 'good status' for all waters (surface waters, groundwater, transitional water and coastal water) by the year 2015.

To this purpose, Member States have to identify all the river basins lying within their national territory and assign them to individual River Basin Districts. River basins covering the territory of more than one Member State are assigned to an international River Basin District. According to this concept, water bodies are no longer considered as autonomous environmental compartments; the surrounding environment including soil (river basins) is equally considered.

At the latest, four years after the date of entry into force of this Directive, Member States must have completed an analysis of the characteristics of each river basin district (Article 5), a review of the impact of human activity on water and an economic analysis of water use, and must compile a register of areas requiring special protection. Agricultural activities are listed as a possible origin of pollution (through the use of fertilisers and pesticides).

Nine years after the date of entry into force of the Directive, a management plan and programme of measures must be produced for each river basin district, taking account of the results of the analyses and studies carried out. The river basin management plans have to be reviewed every six years.

The Commission's Environment Directorate-General conducted a study looking into the ***soil protection aspects*** of amongst others this Directive (Hudec *et al.*, 2007). Fifty one (out of 61) national and international river basin district reports (WFD Article 5 reports), covering 121 river basin districts, or 99% of the area of the EU-25, were reviewed using the following key questions:

1. To what extent have soil degradation processes been identified as a negative factor for water quality in a given river basin district and, in cases where it has been, how has the soil state been characterised?
2. In how far can the basic characterisation of river basin districts be used to predict the soil degradation processes occurring in a given river basin district?

The quality of the information available on river basin districts is summarised in Table 4.14.

Table 4.14: Knowledge of soil degradation with respect to water quality protection presented in the Article 5 reports of WFD

	Pressure on water quality		**Soil degradation description**		
Soil degradation	**Identification**	**Described causality**	**Area**	**Intensity**	**Cause**
Erosion	Significant diffuse source negative for surface water bodies	Run-off of nutrients with soil; model MONERIS for phosphorus fluxes (applied for Danube RBD, about half of phosphorus fluxes due to soil erosion)	No information given except vague statements like agricultural land.	Mostly unknown; in the Czech report - potential soil loss of 0.41 t/ha and 0.3 for Elbe RBD and Odra RBD respectively, calculated by USLE.	Either not specified or vague statements like agricultural land use, topography etc.
Organic carbon decline	Mostly presented in the opposite direction: drawdown of ground water causing organic carbon decline.	(see Intensity)	No quantitative information given; usually stated in qualitative terms, wetlands, former moor areas etc.	Theoretical considerations of the drawdown of groundwater level on soil condition, but the real impact is unknown.	Drawdown of ground water level inducing mineralisation
Compaction	Reported only for RBD Rhine. Deterioration of natural flood plains due to sealing and compaction.		No information given.	The intensity is unknown.	No agricultural practices mentioned
Salinisation	Reported only for RBD Cecina and RBD Malta. Significant pressure on ground water quality.		No information given.	The level of salinisation is not given.	Improper irrigation
Diffuse contamination of soils	Significant diffuse source negative for mainly ground water bodies	Ground water leaching of nutrients; model MONERIS for nitrogen leaking (applied for Danube - about half of nitrogen diffuse input into the river system due to ground water pathway through contaminated soils)	No quantitative information given; usually stated in vague qualitative terms like agricultural land	Actual contamination of soils usually unknown.	Agricultural land use - uncontrolled use of fertilisers and chemicals (Danube RBD)

Source: based on Hudec *et al.* (2007)

With respect to the first question, ***erosion*** was identified as a negative factor for water quality to differing extents in 62 % of the reports covering 20 Member States, although mostly only in a general way. Erosion is not mentioned as negative for water resources in Estonia, Sweden, Finland, Ireland, Portugal, and Spain. ***Local contamination*** has been identified as a negative factor for water quality in all 25 Member States (covering 73 % of the reports). ***Diffuse soil contamination*** was seen as negative for water quality in 98 % of the reports; pesticide application, nutrient input into soils or atmospheric deposition were mentioned as determinants. Decline in organic matter was only in one case recognised as a negative factor for water quality. However, 21 % of the reports identified practices, such as the draining of peat soils, which can be reasonably expected to cause a decline in organic matter. Compaction was only mentioned in the Rhine river basin district report, where it was explicitly identified as increasing flood risks. Salinisation was not specifically identified as having negative consequences for water quality, whereas decline in soil biodiversity and landslides were not mentioned as soil degradation processes in any of the evaluated reports, due to their weak link with water quality.

For erosion and diffuse contamination, the causality between soil degradation and water quality is relatively well known, and the flow of of phosphorus and nitrogen into water systems has been modelled. In contrast, little or no information was availablein the source reports on the extent (in terms of affected area), intensity or causes of soil degradation; this holds for all examined degradation processes.

As to the second question, only the soil degradation processes that have been identified as putting pressure on water resources are reported. The pressures were described at a rather general level; therefore, the information value of the reports is also very limited for the assessment of such processes.

However, in spite of their poor description in the reports, one can expect that soil degradation processes (mainly soil erosion and diffuse contamination) will be directly addressed in the required management plans of river basin districts as they have been identified as significant negative factors.

4.3.3 Thematic Strategy for Soil Protection (COM(2006) 231) and Proposal for Soil Framework Directive (COM(2006) 232)

Soil provides food, biomass and raw materials. It serves as a basis for human activities and landscape, and as an archive of heritage, and plays a central role as a habitat and gene pool. It stores, filters and transforms many substances, including water, nutrients and carbon. In fact, it is the biggest terrestrial carbon store in the world (1,500 gigatonnes)[26]. Soil thus performs a number of functions for humans and ecosystems; the Commission identified the following as important: biomass production, including in agriculture and forestry; storing, filtering and transforming nutrients, substances and water; biodiversity pool, such as habitats, species and genes; physical and cultural environment for humans and human activities; source of raw materials; acting as carbon pool; and archive of geological and archaeological heritage. These functions must be protected because of both their socio-economic and environmental importance.

Soil is also subject to a series of degradation processes, including erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides. A combination of some of these degradation processes can ultimately lead to desertification under arid or sub-arid climatic conditions. There are an estimated 115 million ha, or 12% of Europe’s total land area, that are affected by water erosion, and 42 million ha are affected by wind erosion, of which 2% severely affected; around 45% of soils in Europe have a low or very low organic matter content (meaning 0-2% organic carbon) and 45% have a medium content (meaning 2-6% organic carbon)[27]. This is particularly worrying because soil organic matter is very important for maintaining soil fertility and plays a major role in the carbon cycle of the soil. Due to more than two hundred years of industrialisation, 3.5 million sites across the EU may be potentially contaminated, with 0.5 million sites being really contaminated and needing remediation[28].

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[26] Summary of the impact assessment of the Thematic Strategy for Soil Protection: SEC(2006)620.

[27] Summary of the impact assessment of the Thematic Strategy for Soil Protection: SEC(2006)620.

[28] Summary of the impact assessment of the Thematic Strategy for Soil Protection: SEC(2006)620.

Recalling the crucial functions soil performs for European society and its ecosystems, and the need to prevent further soil degradation, and additionally recognising legislative differences among Member States in dealing with soil problems that may distort competition within the single market, the Sixth Environment Action Programme called for the development of a Thematic Strategy for Soil Protection. Consequently, the European Commission thus published the Thematic Strategy for Soil Protection in September 2006.

This Strategy revolves around a proposal for a Soil Framework Directive (COM(2006) 232), which aims at striking the right balance between EU action and subsidiarity. The proposal is accompanied by a communication from the Commission to the other European Institutions (COM(2006) 231), laying down the principles of Community soil protection policy, and an impact assessment according to Commission guidelines (SEC(2006) 1165 and SEC(2006) 620), which provides an analysis of the environmental, economic and social impacts of the different options that were considered in the preparatory phase of the Strategy and of the measures finally retained by the Commission.

Objective of the Strategy

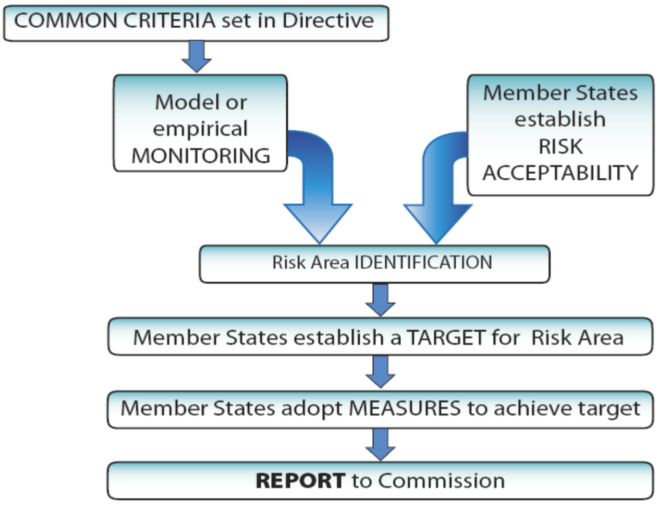
To reverse the above-mentioned unsustainable trends, the Commission has adopted the Soil Thematic Strategy, which explains why EU action is needed to ensure a high level of soil protection and what kind of action must be taken. It stresses that soil is a fundamental and irreplaceable natural resource that performs a number of fundamental functions, which ought to be protected. It takes into account all the different functions that soils can perform, their variability and complexity and the range of different degradation processes to which they can be subject, while also considering socio-economic aspects.

The overall objective of the Strategy is protection and sustainable use of soil, which can be achieved through the following:
(1) preventing further soil degradation and preserving its functions, and;
(2) restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.

To achieve these objectives, the Commission considers it important to have an overarching EU framework legislation (Proposal for Soil Framework Directive (COM(2006) 232)), despite existing initiatives at national and local level (e.g. nine Member States have specific legislation on soil protection, albeit often addressing only one specific degradation process). In parallel, it suggests integrating soil protection in the formulation and implementation of national and Community policies. Being fully aware of the need to respect the principles of subsidiarity, action is thus required at different levels: local, national and European. Soil is a prime example of the need to think globally and act locally. Research and awareness-raising complete the list of four pillars of action.

In essence, the proposal for a Soil Framework Directive (COM(2006) 232) requires Member States to preserve soil functions, to identify where degradation is already occurring and to set their own level of ambition and their own timetable to combat such degradation. Erosion, organic matter decline, salinisation, compaction and landslides are soil degradation processes that are of particular relevance to agricultural activities. They are addressed by the sequence set out in Figure 4.9. Within five years of the Directive becoming binding in a Member State, risk areas have to be identified at the appropriate level using common criteria (like soil type, textures, density, hydraulic properties, topography, land cover, land use and climate) as defined in Annex 1 of the Directive (Articles 6 and 7). Either empirical evidence (monitoring data) or modelling (preferably validated) should be used.

Figure 4.9: Procedure for addressing erosion, organic matter decline, compaction, salinisation and landslides



Within eight years of the Directive becoming binding, targets should be established and programmes of measures applied, containing at least risk reduction targets, appropriate measures for reaching those targets, a timetable for implementation, and a draft allocation of private or public funds (Article 8). The levels of risk acceptability, the level of ambition regarding the targets to be achieved and the choice of measures to reach those targets are left to Member States. Risk acceptability and measures will vary in response to the severity of the degradation processes, local conditions and socio-economic considerations. Programmes can build on measures already implemented in national and Community contexts, such as cross compliance and rural development under the CAP. Member States will be free to combine approaches to combat concurrent threats.

A slightly different approach is suggested for contamination, including the setting up of a national inventory of contaminated sites (with so-called dangerous substances), and a national remediation strategy. Soil sealing will have to be limited or its effects mitigated. However, soil contamination with dangerous substances and soil sealing are only of marginal relevance to the agricultural sector.

Both the European Parliament and the Council have to agree on a common text on the basis of the Commission proposal, taking into account the opinions of the Committee of the Regions and the European Economic and Social Committee. The Committee of the Regions (13 February 2007) and the European Economic and Social Committee (25 April 2007) formulated favourable opinions. The European Parliament has adopted its first reading opinion on 13 November 2007, endorsing with a large support (two thirds) the proposal and call for a directive on soil protection, maintaining all the key elements of the Commission proposal, while providing more flexibility in some provisions and strengthening others. However, despite amendments introducing additional flexibility for the Member States, the Council of Environment Ministers did not reach political agreement on the European Commission proposals for an EU Soil Framework Directive at the EU Environment Council meeting on 20 December 2007. From 22 Member States, there were five Member States (France, Germany, United Kingdom, Austria, The Netherlands) that voted against the compromise text prepared by the Portuguese Presidency, thus creating a blocking minority. The proposal is still under discussion in the Environment Council.

4.3.4 Relevant international environmental policies

The first important attempt to establish an international legally binding instrument came through the Convention for the Sustainable Use of Soils in 1997 (the so-called Tutzing proposal). However, this initiative did not gain international support. While the UNEP Montevideo III programme 'objective 12' supports the national legal capacities, it cannot incorporate the necessary complementary normative approach (de Kalbermatten, 2008).

De Kalbermatten (2008) explored the further potential of the **United Nations Convention to Combat Desertification (UNCCD)** (United Nations, 1994, in force since 2006). According to him, the UNCCD is the only universal normative sustainable development instrument addressing the problems of desertification and land degradation, and their effects on loss of fertility and biodiversity. National Action Programmes (NAPs) are one of the key instruments in the implementation of the Convention. Furthermore, the UNCCD 10-year (2008-2018) Strategic Plan and Framework to Enhance the Implementation of the Convention, adopted by the Conference of the 192 Parties in September 2007, provides a global strategic framework to 'support the development and implementation of national and regional policies, programmes and measures (including land use practices) to prevent, control and reverse desertification/land degradation and mitigate the effects of drought through scientific and technological excellence, raising public awareness, standard setting, advocacy and resource mobilisation, thereby contributing to poverty reduction'. It thus enlarges the scope from desertification to land degradation. Important interlinkages between soil and climate change have also been recognised. The EU Thematic Strategy on Soil Protection is seen as a potential tool for disseminating good practices and stimulating a wider international debate.

The European Commission, Environment Directorate-General (2007) conducted a study looking into the ***soil protection aspects*** of the UNCCD in the (then) 25 Member States of the EU based on the analysis of 21 national reports and three National Action Programmes (NAPs) (Greece, Italy, and Portugal). Only the NAPs contain information on implemented measures and techniques. **Error! Reference source not found.** shows how EU Member States have classified themselves according to their desertification status().

Table 4.15: Self-declaration of EU Member States within the UNCCD

Developed countries not affected	Affected developed countries	Affected recipient countries
Austria, Belgium, the Czech Republic, Germany, Denmark, Finland, France, Ireland, Luxembourg, Lithuania, the Netherlands, Poland, Sweden, UK.	Bulgaria, Cyprus, Hungary, Italy, Greece, Latvia, Malta, Portugal, Romania, Slovak Republic, Slovenia, Spain.	None

The material gathered by the study was assessed to learn which soil degradation processes have been identified as determinants of desertification. Erosion, salinisation and contamination were recognised as the main factors; however, only erosion was reported in greater detail. As a consequence, it was impossible to quantify the extent to which soil degradation processes contribute to desertification. Finally and most importantly for this study, the NAPs were scanned for measures addressing desertification in order to assess to what extent such measures are likely to contribute to preventing or reducing soil degradation processes. Unfortunately, conclusions on the actual effectiveness of the measures could not be derived, as the information was too general.

The **United Nations Framework Convention on Climate Change (UNFCCC)** (United Nations, 1992), seeking to stabilise greenhouse gas concentrations in the atmosphere, recognises in this context the role and importance of terrestrial ecosystems as sinks for greenhouse gases, and that land degradation problems and changes in land use can contribute to the emission of gases to the atmosphere. In 1998, the EU signed the Kyoto Protocol (United Nations, 1997) to the Convention (setting quantified emission limits for greenhouse gases) and ratified the Protocol in 2002. Considering soil protection, the Protocol promotes sustainable development and calls on each Annex I Party to implement policies and measures to protect and enhance sinks and reservoirs of greenhouse gases in order to help achieve its commitments on greenhouse gas reduction (Art. 2(a)). In order to implement the Kyoto Protocol, the European Commission launched the European Climate Change Programme (ECCP) in 2000 and the second ECCP was launched in 2005. The ECCP was designed to identify and develop all instruments necessary for the EU to implement its commitments under the Kyoto Protocol. Soils as carbon sinks are part of its activities.

As part of the European Climate Change Programme (ECCP), a Working Group on Sinks (Sub-group on Agricultural Soils) was established in December 2000 to consider the mitigation potential of improved use and management of agricultural soils. The Working Group on Sinks recognises that measures for carbon sequestration have to be viewed not only from the perspective of climate change mitigation, but also regarding their contribution to a European policy of soil protection. Some technical measures to help combat global warming, identified by the Working Group on Sinks, are also suitable for the European agricultural sector. These measures include organic farming and conservation tillage, and aim to increase soil carbon as well as to reduce its loss. These measures are eligible for inclusion in national Rural Development Programmes, where they can be financially supported under the agri-environment schemes.

4.4 Survey of national/regional policy implementation

The aim of this section is to show the spectrum of technical measures for soil protection and conservation implied by the current policies and level of their adoption (compliance or uptake), based on the information from the policy measure survey at national or regional level. Six items of the survey records have been selected to stratify the records: type of policy measure, main target of the policy (e.g. soil conservation, water, biodiversity), soil degradation processes being addressed by the measure, presence of specific farming practices/techniques, year of introduction and rate of compliance or uptake. Only records where the soil degradation processes and farming practices (and thus the likely effects of the measure) were explicitly mentioned, have been taken into account; records where these were described only in a general way were not considered. In addition to the information derived from the literature and policy documents, the records enabled (detailed) farming practices to be linked to particular soil degradation processes, as opposed to soil protection, conservation or improvement as a general objective. They also provide information about compliance (mandatory measures) and uptake (voluntary incentive-based measures), and in some cases provide insight into implementation problems.

Table 4.16: Classification of policy measures for further analysis

	Category	Policy package	Policy Measure cluster
1	Mandatory measures (MM)	Mandatory measures implemented as part of cross compliance	Statutory Management Requirements (SMRs)
2			Maintaining land in good agricultural and environmental condition (GAEC)
3			
4		Mandatory measures not part of cross compliance	
5	Voluntary incentive-based measures (VIBM)	Rural development measures - Axis 2	Natural handicap payments to farmers in mountain and non-mountain areas (Less Favoured Area payments)
6			Natura 2000 payments and payments linked to the Water Framework Directive
7			Agri-environment measures/payments;
8			Afforestation, and establishment of agro-forestry systems
9	Awareness-increasing measures and private initiatives (AIM+PI)		

Some records include more than one category of the Rural Development measures under Axis 2. In the following sub-section, examples from Member States or regions[29] are given in brackets; following the country abbreviation, the year of implementation is given and, where available, the compliance rate (for mandatory measures; unit: %), or the planned and actual uptake (for voluntary incentive-based measures; unit: ha or farms). Where relevant, implementation difficulties/challenges are mentioned too, especially when there is a gap between the planned and actual uptake. The interrelations between soil conservation practices (farming systems and single practices), soil degradation processes and policy measures that are presented in this section, are summarised in Table 5.5.

4.4.1 Mandatory measures

Mandatory measures implemented as part of cross compliance: Statutory Management Requirements (SMRs)

In this category, respondents mostly referred to the Sewage Sludge Directive (86/278/EEC) and the Nitrates Directive (91/676/EEC) as having ***soil conservation*** as an important target.

Legislation focussing on ***water quality*** (and quantity) also affects soil quality indirectly. For the implementation of the Nitrates Directive (91/676/EEC) (aimed at reducing nitrate leaching), storage of organic fertilisers (FI, 2005, 75-90 %; IE, 1991), livestock management (AT, 2003, 50-75 %; IE, 1991), fertiliser (organic and inorganic) spreading (FI; DK, 1980) and limits to Nitrate Vulnerable Zones (UKM, 2003: The Action Programme for Nitrate Vulnerable Zones (Scotland) Regulations 2003) are reported to tackle ***local and diffuse soil contamination***, as well as ***declining organic matter*** and ***soil biodiversity***. Ireland (IE, 1991) mentions the practices only in a general way (livestock management, cultivation methods, drilling, fertilisation, tillage, use of organic soil improvers/exogenous organic matter) but reports that they are likely to contribute to combating ***water erosion and offsite damages related to soil erosion***. Nitrate pollution (***diffuse soil contamination***) is prevented *inter alia* by manure application limits (GR, 2005, 100 %).

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[29] The reference code provided refers to NUTS codes: < http://simap.europa.eu/codes-and-nomenclatures/codes-nuts/codes-nuts-table_en.html>

Limiting the accumulation of hazardous concentrations of heavy metals in soil (***local soil contamination***) is achieved by regulating the use of (maximum quantities of) sewage sludge in agriculture (AT31, 1991: 'Oö. Bodenschutzgesetz 1991'; AT32, 2002: "Klärschlamm-Bodenschutzverordnung"; BE2, 2004; FI, 2005; UK, 1989: The Sludge (Use in Agriculture) Regulations 1989). In AT31, this conservation measure also aims at tackling the ***decline in soil biodiversity***. Apart from one case, effective sanctions are in place; compliance estimates are, however, not always given. Compliance in Finland is reported to be 75-90 %; an efficient training system providing farmers with the exact knowledge and requirements of how to use sewage sludge is reported to be lacking. ***Local contamination*** as well as ***water and wind erosion*** are addressed in Lower Austria by regulating use of exogenous organic matter, sewage sludge and urban waste water in particular (AT12, 1988: 'NÖ Bodenschutzgesetz'). However, compliance is reported to be –under 50 % due to inefficient monitoring mechanisms and sanctions.

The United Kingdom (UK, 1998) refers to the Groundwater Directive (80/68/EEC) (aimed at protecting groundwater against pollution with certain dangerous substances) but only makes a rather general reference to practices where listed substances are applied to the soil.

Referring to the Plant Protection Products Directive (91/414/EEC), ***diffuse and local soil contamination***, ***declining soil biodiversity*** (as well as ***water quality***) are addressed through regulating plant protection/pesticide use in AT31 ('Oö. Bodenschutzgestz, 1991'), FI and EE. In EE, legislation sets maximum limits to dangerous substances in soil and groundwater; however, compliance is only 75-90 %, indicating that the difficulty of locating the source of pollution can reduce incentives to comply.

Mandatory measures implemented as part of cross-compliance - Good Agricultural and Environmental Condition (GAEC)

Three GAEC standards address ***water erosion***, namely those referring to minimum soil cover, minimum land management reflecting site-specific conditions, and retaining terraces.
The minimum soil cover requirements include following practices: provision of minimum green soil cover (40 %) with winter crops or perennial feed crops, or intercropping, or stubble from 15 October to 1 March on parcels with slopes of 12 % on arable land (SK, 2007, 75-90 %); at least 40 % continuous surface of crop cover on the land under common rotation (BG, 2007, 0–50 %); or, mandatory green cover on agricultural and forest area with under-planted crops (planted or spontaneous) between 15 November and 1 March, except during soil preparation work for new crop cultivation (PT, 2005, 100 %). In Flanders (BE2, 2005) relevant measures (involving crop rotation, strip cropping, change of field patterns and sizes, construction work) are only required on highly erosion-sensitive parcels. Regarding the low level of estimated compliance in Bulgaria (despite effective sanctions), this country mentions a lack of experience in implementing environment-friendly practices, aspects of which are that farmers are presented with new possibilities and that administrative procedures have not been fully tested.

The standard requiring retention of terraces includes a ban on destruction of existing terraces in vineyards and orchards (SK, 2007, 75-90 %); maintenance of existing terraces (LU, 2005, 0-50 % for package of three measures) and maintenance of load-bearing rubble walls (that serve to retain soil on terraced land) in a good state as well as repairing them should any breaches or collapse occur as a result of soil saturation after storms (MT, 2005). In Bulgaria, in addition to the maintenance of existing terraces on a farm or parcel, the conclusion of agreements between land users within a particular area is mandatory (BG, 2007, 0-50 %). However, extreme land fragmentation and difficulties in persuading small farms to co-operate within larger areas cause major difficulties in respecting this obligation. Terracing is also considered to control ***wind erosion***.

The minimum soil maintenance standard reflecting the site-specific conditions includes the following:

- Carrying out ploughing, cultivation and planting across the direction of the slope on parcels having a slope greater than 10 % (with the result-oriented note that there should be no evidence of sheet, rill or erosion gullies on site) (MT, 2005). However, presence of small land parcels is signalled as an implementation problem.
- Measures to prevent arable land from gully erosion (with gullies exceeding 20 cm) (SK, 2007, 75 - 90 %), ban on ploughing permanent grassland if the slope is more than 12 % and the length is more than 50 m (LU, 2005).
- Maintenance of surface water drainage systems, except in areas that are designated as environmentally sensitive (LV, 2004); temporary channelling of surface water through drainage furrows (after the sowing) on sloping ground with clear erosion phenomena (e.g. wide-spread presence of rills) (IT/ITD1, 2000, 100 %; ITF6, 2005, 100 %).
- Green cover on terrace slopes between 15 November and 1 March (PT, 2008, 75-90 %).
- Restrictions on crop use for parcels with high risk of soil erosion (IQFP 5) (. On these parcels, (except for terrace plots or plots in areas integrated into flood plains), no temporary crops or the plantation of new permanent pastures are allowed. The improvement of natural permanent pastures is allowed, but without soil tillage; the plantation of new permanent crops is only allowed in situations considered to be technically adequate by the regional services of the Ministry of Agriculture (PT, 2005, 100 %).
- Prohibition on intensive crop production on river banks within less than 5 m of the watercourse (BG, 2007, 0–50 %). The low compliance rate reflects poor knowledge of the farming obligations and restrictions, and of the consequences (sanctions) in the case of non-compliance.

In response to site-specificity, Germany (DE, 2006, 75-90 %) mentions the initiative to create a land register of potential erosion with special measures addressing the potential hazard: prohibition of tillage on 40 % of the arable farm land from each agricultural enterprise during the winter months, from post-harvest time up to 15 February in the following year. However, implementation is hampered by farmers' fear of problems with weeds or their lack the necessary technical equipment; in some cases, they are not aware that erosion is a possible side-effect of cultivation.

The maintenance of olive groves standards is reported to have positive effects on combating ***water erosion*** and ***floods and landslides*** (ITF6, 2005, 100 %). Farmers are requested not to grub up olive trees, to prune olive trees at least every three years or more frequently and to remove multiyear offshoots, brambles and weeds.

Maintaining a crop cover, using coarse seedbeds, shelter belts, nurse crops, or by taking other appropriate measures that have an equivalent effect, are promoted as suitable techniques in areas prone to wind erosion (in spring). (UKM, 2005). Arable stubble management, in particular delaying the incorporation of livestock manures (that should usually happen within two weeks after spreading on stubbles) in areas prone to ***wind erosion*** is another control technique. The positive side-effect on maintenance of ***soil organic matter*** and guarding against nutrient losses is recognised too (UKM, 2005).

Arable stubble management is mostly specified as restrictions or prohibitions on stubble or straw, and/or crop residue burning (AT, 2005; FR, 2005, 100 %; UK, 2005, 100 %); in some Member States, the former practice should be accompanied by working the crop residues into the soil (BG, 2007, 0–50 %; LV, 2004). Some regions, however, report ***water quality*** (rather than soil conservation) to be the main beneficiary of such practices (BE2, 2005). Some Member States or regions specify the arable crops concerned, e.g. burning is prohibited after harvesting grains, legume and oilseed crops in Slovakia (SK, 2007, 75-90 %). Others extend its applicability to farming types other than arable farming, where stubble and crop residue burning (dead grass, hay and straw) is also forbidden on grassland (natural or sowed) and pastures (IT/ITD1/ITF6, 2005, 100 %; ITE32005, 75-90 %) or on agricultural land in general (EE, 2007, 100 %). Despite full compliance, both countries report implementation problems: in Italy (IT/ITD1/ITE3), it is hard to persuade farmers of the damaging effects of stubble and residue burning, a traditional practice, whereas in Estonia (EE) it is difficult to define whether the farmer or third parties started the fire. ITF6/ITE3 also recognise the positive side-effect of not burning stubble on ***declining soil biodiversity*** , whilst nevertheless signalling a problem in ITF6 of dissemination of this measure to the local level. Some countries or regions add restrictions or suggest corrective action in cases when the burning ban is breached (for example, with the aim of preventing transmission of plant diseases). In the latter case, Malta (MT, 2005) restricts the burning to a limited area of the field (10 m^2) and/or proposes green manuring or application of organic material prior to the establishment of the following crop.

Crop rotation standards are country- or region-specific, or even site-specific. When specified for an entire country or region, they consist of prohibiting mono-cropping of cereals for more than five years (FR/ITE3, 2005, 100 %; IT/ITD1, 2007), not cultivating the same root crop on the same spot for two consecutive years (SK, 2007, 75-90 %), prohibiting mono-culture of flax, sunflower (*Helianthus annuus*), sugar beet and peas on a single parcel for more than two consecutive years (BG, 2007, 0-50 %), or using suitable break crops in the arable rotation (UKM, 2005). In addition, use of organic materials should be optimised based on soil and crop needs, and records of added organic materials (where break cops are not used) should be kept for five years (UKM, 2005). Breaking mono-succession of cereals is also reported to have a positive side-effect on avoiding ***soil compaction*** (FR, 2005, 100 %; IT/ITD1, 2007). A further degree of fine-tuning is foreseen in Flanders (BE2, 2005) where crop rotation specifications (such as green cover in winter) depend on the soil organic carbon content of individual arable plots (of 10 ha). Standards for crop rotation are also applied on irrigated land with ***water quality*** as the primary target, whilst also expecting a positive side-effect on ***soil organic matter*** content. Crop rotation should be practised regularly, and crops belonging to the same botanical family should not be grown successively on the same parcel. Preferably, crops belonging to the same soil humus-depleting category should not be grown for more than three successive years on the same parcel, and have to be put into rotation with at least one year of the soil-improving crops or with at least one year of set-aside (MT, 2005).

Compared to the other examples, Luxemburg (LU, 2005, 0-50 %) takes a somewhat more holistic approach to ***organic matter*** preservation. Recommendations depend on specific conditions, such as fertilising application rates, proportion of arable land over the total agricultural surface or the organic matter balance. In addition, soil structure preservation, in particular reducing the susceptibility to ***soil compaction***, is recognised as a positive secondary effect of organic matter preservation.

Farming practices addressing ***soil compaction*** refer mainly to the GAEC standard of appropriate machinery use, aimed at maintaining soil structure. This includes not entering agricultural land at times when it is compacted or muddy (SK, 2007, 75-90 %), and prohibiting the use of a manure spreader (BE2, 2005), tillage (AT, 2005) or cultivation in general (MT, 2005; UKM, 2005) on water-saturated, frozen, snow-covered and/or flooded agricultural land. Additional positive effects of respecting the cultivation stability of the soil, that is, cultivating fields at a time when the machinery used will not leave deeper traces than the cultivation depth, are equally important with regards to ***offsite damages related to soil erosion*** (EE, 2007, 100 %). Other standards relating to soil compaction include livestock-related measures (not further specified) (UKL, 2005) or maintenance of an efficient surface water drainage system and cleaning of existing water channels, outfall ditches and drains by removing natural vegetation, ground and sediments (ITF6, 2005, 100 %).

Ensuring a minimum level of maintenance contributes to combating the ***decline in soil biodiversity.*** In most cases, ***biodiversity*** as a wider objective is, however, indicated as the primary objective. The corresponding GAEC standards are (i) minimum stocking rates and/or appropriate regimes, (ii) protection of permanent pasture, (iii) retention of landscape features, and, (iv) avoiding encroachment of unwanted vegetation on agricultural land.

Only the minimum stocking rate standard is listed with ***soil conservation*** as its main purpose. It is specified as maintaining a minimum load of livestock units of polygastric animals per hectare of permanent grassland, increasing this minimum over subsequent years, or avoiding mulching the declared areas (SK, 2007, 75-90 %), and maintaining all grasslands by appropriate cutting or grazing (period delineations depending on altitude).

Protection of permanent pasture is primarily aiming at ***biodiversity***, nevertheless including ***soil biodiversity*** (ITE3, 2005, 75-90 %). Forbidding conversion of permanent grassland to arable land is, in addition, likely to contribute to overcoming ***floods and landslides*** (SK, 2007, 75-90 %). Restrictions on ploughing up pasture of high environmental or archaeological value, such as species-rich grassland, Machair habitats, pastoral woodland and heather moorland (UKM, 2005), and converting it to any other land use on Natura 2000 sites (ITD1, 2005, 100 %; ITF6, 2005) further contributes to preventing ***water erosion*** and ***soil organic matter decline***.

Also, conservation of landscape elements**,** in particular alleys, windbreaks and solitary trees, is reported to contribute primarily to ***biodiversity,*** as well as having a positive effect on ***soil biodiversity*** (SK, 2007).

The same is valid for the standard to avoid encroachment. Relevant practices are, for example, establishing a green cover throughout the year,mowing grass or carrying out an equivalent operation at least once a year, in areas no longer in agricultural use (i.e. set-aside) (IT/ITD1, 2000, 100 %; ITF6, 2005, 100 %), and maintaining green cover (natural or artificial) all year round and implementing agronomic practices to protect the state of fertility, wildlife and fire prevention (ITE3, 2005, 75-90 %). Safeguarding land and its wildlife on abandoned agricultural land are important reasons for policy implementation here. In the "Provincia Autonoma Bolzano/Bozen" (ITD1, 2005, 100 %) it is forbidden to reduce the permanent pasture area; on Natura 2000 sites, permanent pasture cannot be converted into a different type of land use and soil may not be tilled. Combating ***soil organic matter decline*** and ***water erosion*** might be additional positive effects of these practices.

Mandatory measures not part of cross compliance

Examples of mandatory measures not part of cross compliance tend to be ***general soil protection, soil monitoring*** (AT31, 1991: 'Oö. Bodenschutzgesetz 1991'; AT32, 1989) and ***soil information reporting*** (AT31, 1991: 'Oö. Bodenschutzgesetz 1991'") initiatives. As such, they address a diverse range of soil degradation processes; farming practices are not described in detail. Examples are:

- Plan for regeneration and improvement of the soil: if soil is damaged or soil functions are affected, the user of the soil has to submit (in co-operation with the advisory service for soil protection) a plan with improvement measures to the authority (AT31, 1991: 'Oö. Bodenschutzgesetz 1991').
- General obligations for soil protection aimed at protecting and restoring soil functions on a permanent sustainable basis and measures for soil improvement, whereby the property owner and the occupant of a property shall be obliged to prevent harmful soil changes and improve the soil conditions (AT32, 2001: 'Gesetz zum Schutz der Böden vor schädlichen Einflüssen (Bodenschutzgesetz) LGBL 80/2001').
- General principles of good practice in agricultural soil use aimed at permanent protection of the soil's fertility and of the soil's functional capacity as a natural resource (AT32, 2001: 'Gesetz zum Schutz der Böden vor schädlichen Einflüssen (Bodenschutzgesetz) LGBL 80/2001').
- Protection of agricultural and forestry soils (land) aimed at limiting high quality agricultural and forestry land being used as building investment areas. This act regulates all aspects related to fees paid if high-quality land is converted into non-agriculture or non-forestry functions and also introduces obligations for reclamation of degraded soils and provides protection for organic soils. However, there is ongoing dispute with the developers' lobby that are against this regulation. (PL, 1995: 'Ustawa z dnia 3 lutego 1995 r. o ochronie gruntów rolnych i leśnych wraz z przepisami wykonawczymi').
- Precautionary soil protection enabling to react when certain limit values of heavy metals in soil are exceeded, targeting ***local and diffuse soil contamination*** (AT31, 2006: 'Oö. Bodengrenzwerte-Verordnung 2006', 100% compliance).

The UK (2002, updated in 2007, 100 %) mentions the National Emission Ceilings Regulations 2002 as part of a European Parliament and Council Directive (2001/81/EC relating to national emission ceilings for certain atmospheric pollutants) aiming at reducing ***acidification*** and ***eutrophication (soil contamination)*** of soils and ground-level ozone by regulating pollutant emission. Important agricultural practices involved are related to agricultural ammonia emissions. This measure is reported to be relevant for extensively used, nitrogen sensitive upland habitat (such as large areas of upland Scotland).

The Nature Conservation (Scotland) Act 2004, primarily aimed at ***biodiversity***, is likely to have beneficial effects on declining in ***soil biodiversity*** (UKM, 2004). Twenty-six percent (26 %) of Scotland's land area has at least one nature conservation designation, and many areas have several, although soil conservation is not one of the reasons for the designation (for example, the area may be targeted because of the habitat provided by its peat soils). Sites of Special Scientific Interest (SSSIs) form the backbone of conservation sites in the UK. These have been designated on biological, geological and mixed criteria with no explicit consideration of pedological features. Many of these are also designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) under the EU Habitat and Birds Directives respectively. Although there is no provision in UK law for the conservation of particular soils through site designation, it can be argued that soils within SSSIs are protected from potentially damaging operations and that management agreements will implicitly conserve ***soil functionality***.

Two measures are reported to primarily target ***water quality***, but address particular soil protection objectives as well. The Waste Management Licensing Regulations (UK, 1994, 100% compliance) ensure that wastes are used properly when applied to soils and are as such controlling ***local and diffuse soil contamination***. Risks caused by diffuse pollution from agriculture and forestry through water erosion processes are the subject of the Water Environment (Diffuse Pollution) (Scotland) Regulations (UKM, 2008). These regulations consist of a number of 'General Binding Rules' that managers should comply with in order to reduce the risk of diffuse pollution, including measures such as non-cultivated strips alongside water courses.

Examples of measures without a specific environmental objective but nevertheless having relevance for ***(broader) soil protection*** are:

- Land Consolidation Law (AT12, 1975: 'Flurverfassungs-Landesgesetz 1975, LGBl. 6650-6', 100% compliance);
- Regulation of Forestry, covering afforestation (AT, 1975: 'Forstgesetz 1975, BGBl. Nr. 440/1975 in der Fassung BGBl. I Nr. 55/2007');
- Environmental Permitting Regime, i.e. a regulatory regime for controlling pollution from certain high-intensity agricultural activities, such as pigs and poultry (e.g. aerial deposition of pollutants on soils) (UKL, 2008);
- Waste Management Law of Lower Austria, specifically addressing local soil contamination (AT12, 1992: 'NÖ Abfallwirtschaftsgesetz 1992, LGBl. 8240-4').

4.4.2 Voluntary incentive-based measures: rural development measures (Regulation (EC) 1698/2005)

Natural handicap payments to farmers in mountain and non-mountain areas (Less Favoured Area (LFA) payments)

The Romanian National Rural Development Programme 2007-2013 (RO, 2008, planned uptake > 1 Mio. ha) provides financial compensation for setting up green cover crops on arable land during winter time in its other less favoured areas (areas with handicaps, other than mountain areas). This technique is likely to contributes to controlling ***water and wind erosion***.

The Slovakian measure providing natural handicap payments in mountain areas and payments in other areas with handicaps (SK, 2007: Rural Development Programme of the Slovak Republic 2007-2013; uptake area >1 Mio. ha, or 1-10 thousand eligible farms) is primarily targeting ***biodiversity***, but may address ***declining soil biodiversity*** too. Slovakia is a predominantly mountainous country with a high share of low productivity soils and soils with specific disadvantages (water-logged soils, sandy soils and skeletal soils). Required farming techniques/production methods are only mentioned in a general way.

Support for LFAs (areas with handicaps, other than mountain areas) in the Estonian Rural Development Plans 2004-2006 and 2007-2013 (EE, 2004; uptake area between 100 000 and 1 Mio. ha, or 1-10 thousand farms) aims at maintaining the countryside through continuous use of agricultural land, and promoting systems of sustainable agricultural production, including the improvement of the environment and the countryside by the maintenance of lands. Tillage and crop rotation are reported to contribute to tackling ***declining organic matter***.

National Handicap Payments to Farmers in Mountain Areas and Payments to Farmers in Areas with Handicap other than Mountain Areas in France (1970; 10-100 thousand farms) are intended to maintain extensive farming in areas affected by natural handicaps (with low soil productivity or difficult climatic conditions) and are likely to contribute to controlling ***water erosion***.

In Piemonte (ITC1, 1991; uptake 10-100 thousand ha, or 1-10 thousand farms), farmers in mountain areas are entitled to compensatory LFA payments and receive management support to ensure that they continue sustainable agricultural practice while observing environmental requirements. Farming practices, which are not specified but affect land consolidation, are reported to address ***water erosion, soil compaction*** and ***declining soil biodiversity***.

Natura 2000 payments and payments linked to the Water Framework Directive (2000/60/EC)

Natura 2000 and Water Framework Directive payments are mostly mentioned in combination with at least one other type of Axis 2 measures.

In Slovakia (SK, 2007; uptake 1-10 thousand ha, less than 100 farms) these payments aim at helping farmers to solve the specific disadvantages resulting from the implementation of the Natura 2000 network (5th level of protection) and the Water Framework Directive through sustainable use of agricultural land with high nature value areas and protection and improvement of the state of water sources. The farming practices involved are livestock management, pesticide use, cultivation methods and fertilisation. Although this measure primarily targets ***biodiversity***, it nevertheless reports likely positive effects on ***declining soil biodiversity***.

The Finnish 'establishment of multifunctional wetlands and initial clearing and enclosing of valuable traditional biotopes' measure (FI1, 2008; uptake 1-10 thousand ha and 100 to 1 000 ha, the latter corresponding to 1-10 thousand farms)is subject to payments for support for non-productive investments and Natura 2000 and Water Framework Directive payments. This measure primarily promotes ***water conservation*** and maintenance and improvement of ***biodiversity*** in the agricultural environment, but is also reported to address ***water and wind erosion***, ***decline in organic matter***, ***decline in soil biodiversity*** and ***offsite damages related to soil erosion***.

In the Estonian Rural Development Plan 2004-2006 (EE, 2004; less than 1 000 farms affected), the Natura 2000 and Water Framework Directive payments cover prescriptions and standards for manure storage facilities, which must be leak-proof in order to prevent soil and water pollution, and must have a likely positive effect on ***local and diffuse soil contamination***. Monitoring is hampered by lacking the ability to define whether the underground part of the storage is leak-proof.

Support for non-productive investments in Natura 2000 areas in the Marche region (ITE3, 2008) contributes to the protection and improvement of ecosystems (marches in particular) and the rural landscape, reducing the risk of erosion and disruption, and having likely positive effects on ***water erosion, floods and landslides, soil compaction, diffuse soil contamination,***

decline in organic matter and ***decline in soil biodiversity*** too. The farming practices and types of farm infrastructure involved are drainage, rearrangement of the field size, establishment of linear elements, crop rotation, strip cropping and technical constructions (ditches, terraces, retention ponds).

Agri-environment measures

Amongst the range of agri-environment measures targeting primarily ***soil conservation***, some support agricultural production methods, rather than specific or particular soil conservation techniques (mostly within the context of conventional agriculture). Examples of the former are the promotion of organic farming and conservation agriculture techniques, such as no-tillage. Most measures are aimed at arable farming types, although some target livestock farming, viticulture or horticulture.

A number of measures have a likely positive effect on controlling ***water erosion***, with likely positive effects on related soil degradation processes, such as ***offsite damages related to soil erosion*** and/or ***floods and landslides*** and/or ***soil compaction*** and/or ***soil organic matter*** and/or ***soil biodiversity decline***.

In zones with high risk of ***soil erosion***, Calabria (ITF6) offers farmers the possibility to adopt techniques to reduce run-off, such as drainage facilities, rearrangement of field size, strip cropping or change of field patterns and sizes (ITF6, 2007). Flanders (BE2, 2004, uptake: 1-10 thousand ha or <1 000 farmers) proposes a number of commitments to combat ***(water and tillage) erosion***, such as installing and maintaining grass buffer zones, grass corridors or erosion ponds and dams (to reduce the consequences of soil erosion) and direct sowing and non-inversion tillage erosion (can be tackled at the source).

On arable land, Romania (RO, 2008, planned uptake: 100 000 - 1 Mio. ha) offers payments for green cover crops during winter time.

In the context of conservation tillage (arable farming), mulch or direct seeding is promoted (DE, 1996, uptake: 1-10 thousand ha or 100 - 1 000 farmers; DE, 2003, uptake: 10-100 thousand ha or 1-10 thousand farmers). This technique consists of leaving rests of crops, mostly straw, on the field (usually) during the winter months and directly drilling/putting the new seed under the mulch. However, some countries or regions report implementation problems, such as weed and disease (*fusarium*) infestation (DE, 1996; LU, 2002; DED, 2007), and the cost of investing in new equipment (DE, 1996) as well as too short a contracting period (5 years) (LU, 2002). Sachsen and Luxemburg correspondingly report a gap between planned and actual uptake (DED: 10-100 thousand ha and 1-10 thousand ha or <100 farmers; LU: 1-10 thousand ha and 100 - 1 000 ha respectively). In the case of Luxemburg, this gap probably also has to do with the laws related to the new programming period not having entered into force yet. In some regions with additional problems of nitrates in the groundwater (e.g Rheinland-Pfalz, Germany), this policy measure is in particular promoted in areas with water bodies at risk (in response to Directive2000/60/EC); here a positive impact on ***water protection*** and ***diffuse soil contamination*** is expected (as P-losses are reduced due to the reduced run-off) too.

Farmers on irrigated land in Greece (GR, 2005) get support to build or rebuild soil retention structures, such as terraces and walls, on the boundaries of sloping fields.

In livestock farming, stocking density is reduced in pastures in order to minimise adverse effects of overgrazing (GR, 2004, planned uptake: 100 000 - 1 Mio. ha).

In vineyards, it is suggested to cover the soil with straw or organic material, or perform some form of extensive tillage, or have grass vegetation between the vine rows (LU, 2000, uptake: 1-10 thousand ha). A similar measure for arboreal crops (ITF, 2007) is expected to have a positive effect on ***soil compaction*** problems.

Some policy measures aim to control ***water and wind erosion*** at the same time. Brandenburg (DE4, 2000) supports the development and advancement of soil functions through legumes on recultivated agricultural land (uptake: 1-10 thousand ha or <100 farmers). Conservation tillage measures, such as mulch or direct seeding and grass strips, are reported also to address both types of erosion (DEA, 2000, uptake: 1-100 thousand ha or 1-10 thousand farmers, ended in 2006, payments ongoing until 2011). The experience in Nordrhein-Westfalen shows that farmers have to be committed to changing their tillage system beyond the 5-year contract period in order for the measure to have sustainable effects (even in areas with high risk of soil erosion).

A number of agri-environment measures addressing both ***water and wind erosion*** aim to tackle ***soil organic matter and/or soil biodiversity decline*** at the same time. The Lower-Austrian Land Consolidation Law (included in agri-environment measures) promotes planting of soil protection plants and windbreaks (e.g. trees) (AT12, 2002). Catch and under-sown crops (DEC, 2007, uptake: 100 - 1 000 ha or <1 000 farmers) or increasing the diversity of crop rotations (FR, 2007, actual uptake: <10 000 farmers) are alternative soil conservation techniques. The conservation tillage technique of mulch or direct sowing, combined with no-tillage measures, is also in this respect seen as efficient (DEC, 2005, uptake: 100 - 1 000 ha or 100 - 1 000 farmers).

Examples of measures that address ***decline in organic matter*** and ***decline in soil biodiversity*** in particular are:

- use of exogenous organic matter to increase the soil organic matter content (ITF6, 2007);
- (for arable farming) conservation agriculture techniques, such as no-tillage on areas of high biodiversity value (PT, 2007);
- (for livestock farming) forage culture, where farmers are requested to protect water by not using mineral fertilisers and herbicides (ITD1, 1994, uptake: 1-10 thousand ha or 100 - 1 000 farmers);
- (for vineyards) restricted use of pesticides, use of herbicides only on strips (ITD1, 1994, uptake: <100 ha or <100 farmers).

Some countries or regions give support to (conversion to) organic farming in order to address particular soil degradation processes (DK, 1990, planned uptake: 10-100 thousand ha, actual uptake: 100 000 -<1 Mio. ha or 1-10 thousand farmers; SE, 2007, uptake: 100 000 - 1 Mio. ha or 10-100 thousand farmers). Organic farming is expected to have positive effects on ***declining organic matter and soil biodiversity***, as well as on ***local and diffuse soil contamination***. Specific techniques of this agricultural production method affect a range of farming practices (including pesticide and fertiliser use, cultivation methods, crop rotation, strip cropping, use of organic soil improvers/exogenous organic matter, fallow); however, details are however not mentioned. Despite the (relative) success of these measures, farmers in Sweden claim that the rules are difficult to fulfil and that there are obstacles for the organic farmer to reach the market with his products.

A number of measures that primarily target ***water quality*** are nevertheless likely to have a positive effect on soil degradation processes.

Conversion of arable land to permanent pasture (meadow) is designed to reduce ***water erosion and offsite damages related to soil erosion*** and the volumes of nitrogen and phosphorus reaching water bodies at risk (LT, 2007). It is reported as an effective measure, but it is not very popular among farmers (uptake: 1-10 thousand ha or <1 000 farmers). Extensification of riverbanks (buffer strips), i.e. seeding of different grass-types on riverbanks, and very extensive grassland use with limited fertiliser application and grazing restrictions for a minimum duration of five years are similar soil erosion control techniques (DE, 1988, uptake: 1-10 thousand ha or farmers). However, high economic pressure (rise of commodity prices) has decreased farmers' acceptance of the latter techniques. Especially in drinking water-catchment areas, farmers are encouraged to grow catch crops before spring-crops, and thus maintain the cover over winter time (LU, 2002, 1-10 thousand ha or <1 000 farmers). This technique is expected to have a positive effect on soil compaction too. However, bad climatic conditions at the end of the summer and beginning of autumn often cause delay in sowing time, producing bad results; also, the five-year contract period is sometimes considered inappropriate.

A Bavarian extensification measure called 'Protection and environmental improvement of the ***cultural landscape***' contains similar techniques as the above and addresses ***organic matter decline*** in addition to ***water erosion***. The grassland measures differ according to the production branch and include extensification of grassland usage by abandoning the use of mineral fertilisers, and a general prohibition of ploughing up of grassland (DE2, 2007, planned uptake: 100 000-1 Mio. ha). The cultivation measures (on a single field basis) consist of as sowing (winter) green cover, conversion of fields to grassland and green strips (DE2, 2007, planned uptake: 100 000 - 1 Mio. ha).

Examples of measures that target both ***water and wind erosion*** are grassland extensification, (including minimum livestock density, limited fertilisation and plant-protective agents) (DEC, 2000, uptake: 1-100 thousand ha). Maintenance of grassland with a prohibition on turning grassland into arable land ***additionally*** contributes to ***organic matter build-up*** (AT32, 1998, uptake: 10-100 thousand ha). Integrated horticultural production, whereby vegetation is planted during the wintertime and on machine and irrigation tracks, addresses ***declining soil biodiversity*** and ***soil compaction*** in addition to the actually mentioned water and wind erosion (DE4, 2007, uptake: 1-10 thousand ha).

A number of measures that target primarily water quality have likely beneficial effects on ***local and diffuse soil contamination***. The establishment and management of non-cultivated border strips alongside lakes and open watercourses aim at reducing the leaching of phosphorus and pesticides into surface water (DK, 1994, planned and actual uptake: respectively 1-10 thousand ha and 100 - 1 000 ha, corresponding to 100 - 1 000 farms). However, there is a lack of interest in applying for support, mainly due to the small areas concerned on each farm (10- to 20-metre buffer zones alongside lakes and watercourses) resulting in small compensation for each farm (contract); this probably explains the gap between planned and actual uptake. Promoting pesticide-free farming and extensive production on agricultural land provides another means of controlling ***soil contamination*** (as a supplement to the conversion to organic farming measure but open to both organic and conventional farmers) (DK, 1990, uptake: 100 000 - 1 Mio. ha or 1-10 thousand farms).

Establishment and management of wetlands in especially sensitive agricultural areas are also primarily aimed at reducing the use of plant protection products and nutrients leaching into the aquatic environment (DK, 1987, uptake: 1-10 thousand ha or 100 - 1 000 farms). However, despite a relatively high compensation (> 500/ha), the Danish government is experiencing problems in persuading farmers to agree on wetland projects, as the conversion to wetland is permanent. Conversion of conventional to organic farming is also advocated for contributing to the control of soil contamination and offering ***additional*** benefits for ***declining soil biodiversity*** (DE8, 1992, uptake: 10-100 thousand ha or 100 - 1 000 farms; GR, 2000, uptake: 100 000 - 1 Mio. ha).

Most measures that primarily target ***biodiversity*** also have beneficial effects on ***soil biodiversity***, such as Malta's, environment-friendly plant protection products in vineyards, which includes reductions in chemical inputs (MT, 2008, uptake: 1-10 thousand ha, or –1-10 thousand farms). Protecting permanent pastures and meadows by means of continued grazing or cutting, and by banning pesticides and fertilisers (other than the manure left by grazing animals) additionally contributes to controlling ***diffuse soil contamination*** (DK, 1990, uptake: 10-100 thousand ha or 1-10 thousand farms). Organic farming, i.e. avoiding the use of herbicides, pesticides and using only organic fertilisers, contributes additionally to ***soil organic matter*** build-up and supposedly to control ***diffuse soil contamination*** (ITD1, 1994, uptake: resp. <100 ha and 100 - 1 000 ha, the latter corresponding to less than 100 farms). Establishment and maintenance of conservation buffer strips target ***water and wind erosion***, next to ***declining soil biodiversity*** (MT, 2008, uptake: 1-10 thousand ha or 1-10 thousand farms).

On the other hand, water margins and enhanced riparian buffer zones aim at protecting water margins from ***water erosion*** and ***diffuse pollution***, whilst encouraging the development of waterside vegetation that stabilises the banks and enhances biodiversity (without specifically mentioning soil biodiversity) (UKM, 2008). Farmers and land managers must submit proposals for approval before funding can be guaranteed as part of a competitive scheme. The funding is, however, limited and the large increases in commodity prices in 2008 made it less attractive for farmers to take strips of land out of production for environmental reasons. Extensification of farming practices on pastures also addresses ***water erosion*** and ***offsite damages related to soil erosion*** along with ***local soil contamination*** (DE2, 2007, planned uptake: 10-100 thousand ha).

In a number of cases (conversion to) organic farming is mentioned without a specified environmental aim, but nevertheless addressing ***water erosion*** (DEC, 2000, uptake: respectively 1-10 thousand ha and 10-100 thousand ha, the latter corresponding to 1-10 thousand farms; DE2, 2007, planned uptake: 100 000 - 1 Mio. ha), ***wind erosion*** (DEC, 2000, uptake: idem as above), ***organic matter decline*** (DEC, 2000, uptake: idem as above; DE2, 2007, uptake: idem as above; ITC1, 1995, uptake: 10-100 thousand ha, or 1-10 thousand farms; UKL, 2007), ***soil biodiversity decline*** (DEC, 2000, uptake: idem as above; GR, 2000, planned uptake: 100 000 - 1 Mio. ha), ***local*** (GR, 2000, uptake: idem as above; ITC1, 1995, uptake: idem as above) ***and diffuse*** (DE8, 1992; GR, 2000) ***soil contamination***. Farming practices are, however, not specified.

Another measure where the main target has not been mentioned, is the cultivation of intercrops, which is aimed at protecting the soil against ***water and wind erosion*** and washout of nutrients (nitrates in particular), and promoting biological activity and structuring of the soil and the protection of groundwater. This practice is promoted after the main harvest (DE, 2004, uptake: 10-100 thousand ha or 100 - 1 000 farms).

Afforestation of agricultural land, and establishment of agroforestry systems

Only one record explicitly refers to payments linked to the first establishment of agroforestry systems on agricultural land; other records mention agroforestry as part of a bigger package (e.g. the Rural Development Programme). ***Soil conservation*** is mentioned as the primary target of first afforestation of agricultural land (except pasture) (ITF3, 2007, uptake: 1 000 - 10 000 ha or 100 - 1 000 farms) and reconstitution of damaged forests (ITF3, 2007, uptake: 100 000 - 1 Mio. ha). Other countries do not specify the main target (ITC1, 1992 uptake: 1 000 - 10 000 ha/farms; RO, 2008, uptake: 100 000 - 1 Mio. farms; SK, 2007, uptake: 100 - 1 000 ha or <100 farms) but, nevertheless, they expect these measures to prevent and mitigate ***water erosion***, ***wind erosion, floods and landslides***, ***offsite damages related to soil erosion***, ***decline in soil biodiversity,*** and also, in the case of Romania, ***decline in organic matter***, ***acidification*** and/or ***salinisation***. Romania stresses, howeve, the aspect of vocational training, information actions and diffusion of knowledge.

4.4.3 Awareness-increasing measures and private initiatives

In this category, most reported measures and initiatives primarily targeting ***soil conservation*** aim at increasing soil awareness and involve advisory and information services for soil protection and conservation. They are often linked to a regulatory framework. Examples of the latter are the 'Oö. Bodenschutzgesetz 1991' (AT31, 1991); the Defra Soil Strategy (Draft) (UK, 2008), a follow up to the Soil Action Plan; the Soil Code 1998, a code to avoid long-term damage to soils on farm and in mineral extraction (UKL, 1998); or; the Welsh Soils Action Plan (proposed) (UKL, 2008). Some of the measures tend towards evaluation, such as the 'Soil workshops for farmers' where farmers learn to understand and estimate their soils (DE9, 2006); the 'Farm soils plan", a guidance document assisting farmers to assess whether they were complying with cross-compliance requirements and advising on best practice (UKM, 2005); or the development of soil quality objectives with regard to contamination, erosion and soil sealing, compaction and organic matter for advisors and public authorities (DE9, 1997). The information flow can be a transfer between farmers, scientists, officials, municipalities and so on; the established system then often acts as a platform or network (DE, DE9). The European Land and Soil Alliance (ELSA) is an example of the latter (AT12, 2007).

The previous examples mostly envisage a range of soil degradation processes and are operational at the level of farming systems; particular farming techniques are, however, not described. Some measures even focus on particular agricultural production methods, such as organic farming (AT32, 2007) or conservation agriculture (DE, DE9); as such, the initiatives could be promotional in nature. However, some measures address only one (or a few) soil degradation process, suggesting one (or a set of) particular technique(s), e.g. the 'Regional Advisory Programme on Irrigation'" of the Campania region, aimed at rationalising the use of irrigation water (ITF3, 2006); appropriate livestock management, cultivation methods or exogenous organic matter to control local and diffuse soil contamination (DE9, 2004); use of models to calculate water erosion risk (DE9, 2007); or voluntary crop rotation, planting shelter belts or appropriate time of manure spreading to control wind erosion and organic matter decline (DK, 1900)

Reported implementation problems are:

- (with regard to raising soil awareness) limited visibility of soil degradation processes, resistance to change (of attitude) and the long-term nature of the awareness-creating process (AT32, 2003);
- (with regard to promoting conservation agriculture) resistance to change, limited know-how, lack of EU subsidies, policies or other institutional support, risk aversion, lack, low economic pressure, lack of problem-oriented practical research (current research seen as too academic), farm management problems due to prevailing mono-culture of cereals, inadequate crop rotation and/or excessive or low crop residues cause (DE);
- (with regard to organic farming) farmers' concern with their income, prices, bureaucracy, coping with environmental standards and so on; part-time (even week-end) farming and the concomitant need for a second income; and/or lack of visible signs of soil degradation processes (AT32, 2007).
- (with regard to the 'Farm soils plan' (UKM, 2005)) getting sufficient farmers to undertake a full farm soils audit without financial incentives being in place.

The listed measures that mainly target ***water quality*** are mostly of an advisory nature too; hence, concrete farming techniques are not or poorly specified.

The 'Agri-environment plan', a mandatory document for farmers who apply for agri-environment measures in PL (2004), highlights ***biodiversity*** as its major aim, but nevertheless contributes to addressing almost the entire suite of soil degradation processes. Its aim is to be a source of information about the agri-environment programme participation rules, to ease the controls and programme evaluations.

The 'Nature protection plan for the entire agricultural enterprise' (DEB, 2007) is worth mentioning in the group of measures where the environmental objective is not specified. It is more organisational in nature and aims at selecting the best measure for each field (without having a minimum field-size or lowest public sponsorship), as opposed to implementing environmental measures in all fields of the farm. The drawback of this 'tailored' measure is the need for a very intensive and complete consultation to find the best mixture of measures and for a complex evaluation to measure/estimate the effects.

About half of all 35 reported awareness-increasing measures and private initiatives were organised by government (top-down) and half by farmers' organisations (bottom-up).

4.4.4 Frequency and distribution of selected farming practices by type of policy measure

The distribution of farming practices in the responses of the policy survey roughly illustrates their uptake. Twenty farming practices or categories of practices were offered in the questionnaire to the respondents (mostly officials from agricultural ministries). **Error! Reference source not found.** shows frequencies of a selection of categories of practices[30] representing slightly more than 70 % of the entries. There were more than 15 hundred entries of practices in specifications of Mandatory Measures (231 records) and Voluntary Incentive-Based Measures (167 records). It can be concluded that, on average, a single policy measure

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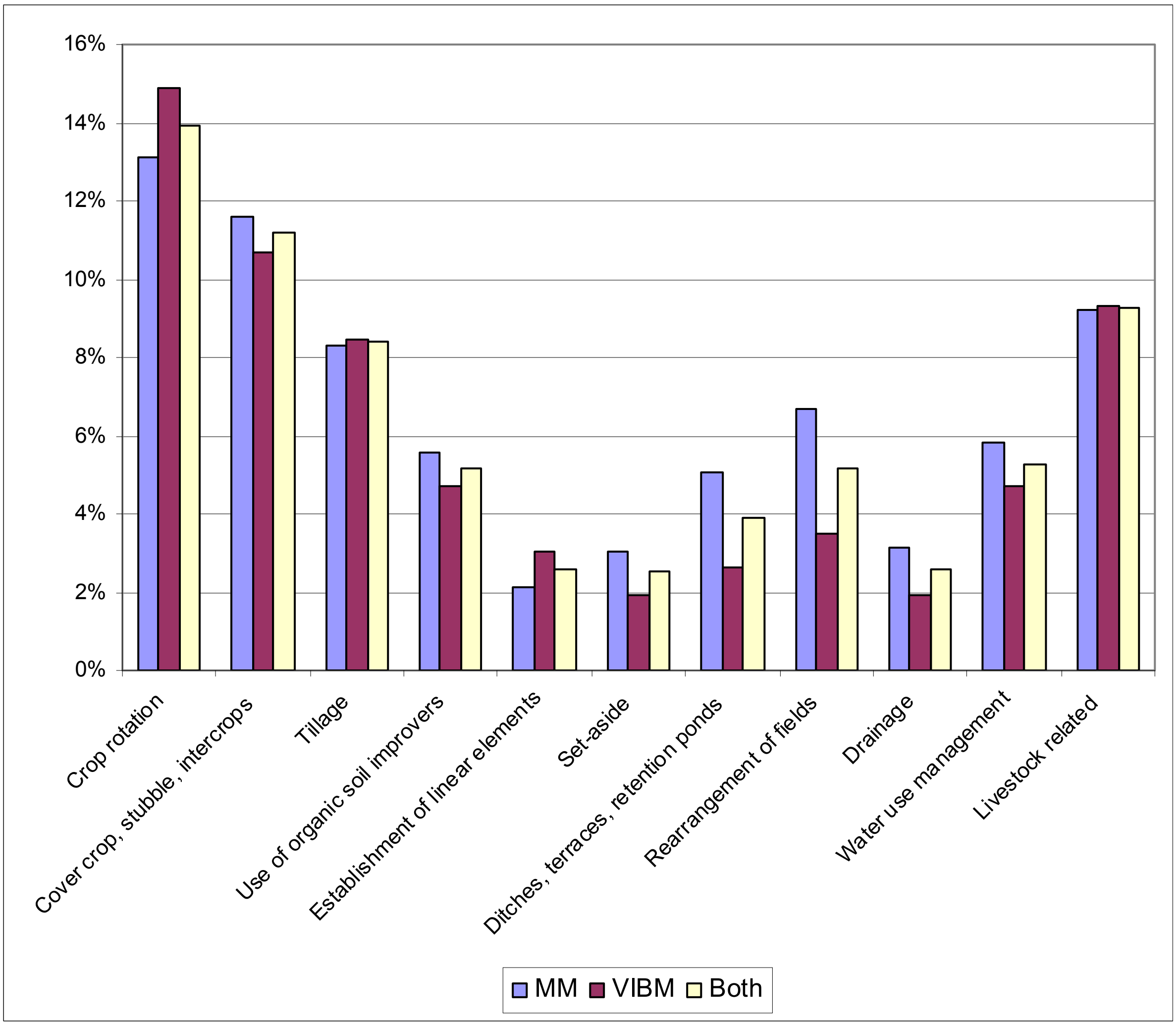
[30] Practices not included in these categoriesinclude fertilisation, pesticide use, strip cropping, drilling and other.

defined or included three farming practices. However, there is large variability, also depending on whether a respondent included a particular operational policy measure or a category of measures (e.g. agri-environment measures).

As can be seen in **Error! Reference source not found.**, the difference in the use of practices along the categories of policy measures is low. Crop rotation and soil cover practices are most widely distributed (11- 13 %). Having in mind that there were twenty practices offered in the questionnaire, these figures are considerably higher than 5 % (expected percentage with assumed equal distribution of the practices). Also requirements on tillage are frequently presented, as well as livestock-related practices. The remaining practices are used less frequently, which is probably due to the particularity of the soil degradation process they address.

Figure 4.10: Frequency and distribution of selected farming practices by type of policy measure



Legend: MM, Mandatory Measures; VIBM, Voluntary Incentive-Based Measures
Source: Own presentation of policy survey

4.5 Conclusion of the policy survey

To date, soil protection is not a specific objective of any EU legislation but it features in some legislation as a secondary objective. To close this gap, the Commission launched a Thematic Strategy on soil protection in September 2006, including a proposal for a Soil Framework Directive. Currently, the most important EU environmental directives with respect to soil quality are the Nitrates Directive and the Water Framework Directive. Others, such as the Birds and Habitats Directives, the Sewage Sludge Directive and the Plant Protection Products Directive, are expected to have beneficial effects on soil quality but to a lesser extent, owing to a more focused set of objectives.

In the framework of the Cardiff Process, environmental objectives are to be integrated into EU sectoral policies, including the Common Agricultural Policy (CAP). The CAP comprises two principal forms of budgetary expenditure: market support and direct income payments (Pillar 1), and a range of targeted, incentive-based payments for rural development measures (Pillar 2).

Compulsory cross compliance, a horizontal tool for both pillars and compulsory since 2005, plays an important role in soil protection and conservation. Inclusion of some statutory management requirements (SMRs) under cross compliance helps to enforce a number of relevant EU environmental directives, in particular the Nitrates Directive. The requirement to keep land in good agricultural and environmental condition (GAEC) aims at preventing total abandonment of land and ensuring a minimum maintenance level. In many Member States, the GAEC requirements specifically include protection against soil erosion, maintenance or improvement of soil organic matter, and maintenance of a good soil structure.

Within Pillar 2 (Council Regulation (EC) 1698/2005), a wide range of measures can be supported. Member States or regions are obliged to spread their rural development funding across three thematic axes: (1) competitiveness; (2) environment and land management; and (3) economic diversity and quality of life. "LEADER" is a horizontal axis complementing the three thematic axes. All axes contain measures which offer Member States the possibility to support actions to reduce soil degradation when such a need has been identified in their territories. Some of the most important are in Axis 2 where agri-environment measures have the capacity to support appropriate farming practices and farming systems such as organic farming. Measures should be well targeted and focussed on actions above the reference level. As such, a range of rural development measures provide the Member States or regions with the possibility of encouraging farmers to go voluntarily beyond the reference level of soil quality, established through the requirements under SMRs, GAEC and national legislation.

The Commission published the Soil Thematic Strategy in 2006. Its overall objective is the protection and sustainable use of soil, based on the prevention of further soil degradation, preserving soil functions and restoring degraded soils to a level of functionality consistent with current and intended use. The proposed Soil Framework Directive (COM(2006) 232) requires Member States to identify areas at risk of soil degradation, as well as to set up an inventory of contaminated sites. Subsequently Member States have to adopt measures, which could be built on measures already implemented in national and Community contexts. The proposed Directive is currently under discussion.

SoCo conducted a survey of policy implementation at Member State and regional levels across the EU-27 (a summary of which is provided in Table 5.5), which was extensive although not fully comprehensive. The results indicate that the existing policy measures have the potential to address all recognised soil degradation processes across the EU-27, although not all policy measures are implemented in all Member States or regions. Measures are implemented at the Member State and regional levels, using the flexibility provided within the legislative framework of the EU. Adaptation to local conditions influences the implementation but not always to the desired degree. The link between available policy measures, implied soil conservation practices and soil degradation processes can be either two-stage, by supporting or requiring a specific farming practice which positively affects soil quality, or one-stage with a direct link to soil quality and a free choice of farming practices. Typically, the two-stage policy intervention is either through support for beneficial farming practices, or through the prevention or prohibition of damaging practices. Especially with regard to voluntary incentive-based measures (VIBM), it is important to monitor the uptake, as this provides an indication of their relevance to the social, economic and natural environment of farms and of their expected effect. Compliance with prescriptions (mandatory measures) and levels of uptake of voluntary incentive-based measures, in particular, are both strengthened through increasing awareness and advice.

5 Summary of soil degradation processes, soil-friendly farming practices and relevant policy measures

5.1 Classification of soil degradation processes and soil conservation practices

In order to synthesise and analyse results from a large number of diverse sources, SoCo developed a classification of soil conservation practices and policy measures that address soil degradation processes.

The relationships between soil degradation processes and farming practices are provided by three consecutive tables summarising the knowledge reviewed in Chapters 2 and 3:

1. the soil characteristics and soil-forming factors that influence the soil degradation processes: Table 5.1;
2. the effect (positive, neutral or negative) of farming practices on soil characteristics: Table 5.2;
3. the effect (positive, neutral or negative) of farming practices on soil degradation processes and related environmental quality issues: Table 5.3.
4. In addition, interlinkages between soil degradation processes and related environmental issues (water, air, biodiversity and landscape) are provided in Table 5.4.

The tables have to be interpreted within the scope and limitations of the stock-taking. While the mapping cannot be fully comprehensive, it schematises the main relationships.

Table 5.1 describes how soil characteristics (soil response properties) and soil formation factors (external factors of degradation) influence soil degradation processes. The links are potential, while the actual occurrence of the indicated relationship is site-specific. Most of the links are relatively straightforward; however some deserve additional explanation to be fully understood:

- With respect to the effect of texture on organic matter decline: sandy soils usually have a low initial soil organic carbon content, as opposed to soils rich in clay or amorphous products that can accumulate stable forms of soil organic carbon (humus).
- Water erosion is influenced, in particular, by pore number, size and continuity, the presence or absence of topsoil compaction, as well as by landslides and floods risk. The drainage direction (vertical or horizontal) of the pore system affects the salinisation or sodification risk. Aeration is important for preserving soil biodiversity.
- The better the aggregate stability, the better the resistance to the impact of raindrops and surface sealing, and thus to water erosion. Aggregate stability is also closely linked to organic carbon content. Soil structure (composed of pedality[31] and porosity) and soil organic matter (amount and distribution) are also the main factors influencing soil biodiversity.
- With respect to the effect of moisture content and moisture-holding capacity on organic matter decline: anaerobic and wet conditions favour accumulation of undecomposed vegetation residues.

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[31] i.e. arrangement of soil constituents into discrete units

Table 5.1: Summary of soil characteristics and soil-forming factors that determine soil degradation processes

			Soil degradation processes								
			Water erosion	Wind erosion	Tillage erosion	Organic carbon decline	Com-paction	Salini-sation/ Sodifi-cation	Contami-nation	Soil biodi-versity decline	Land-slides and floods
Determining soil characteristics	Physical	Texture	x	x	x	x	x	x	x	x	x
		Porosity	x	x	x	x	x	[x]	[x]	x	x
		Infiltration rate/capacity	x	[x]	[x]		[x]	x	[x]	x	x
		Gas permeability								x	
		Aggregate stability (/size)	x	x	x		x		[x]		x
		Moisture content/-holding capacity	x	x	x	x	x	x	x	x	
		Soil temperature				[x]				x	
	Chemical	pH/Acidity/Alkalinity						x	x	x	
		Organic carbon	x	x	x		x		x	x	x
		Nitrogen (cycle)				x				x	
		Phosphorus (cycle)				x				x	
		Potassium (cycle)				x				x	
		Electrical conductivity (EC)						x		x	
	Biological activity		x	x	x	x	x				
Determining soil forming factors	Parent material and substratum		x	x	x	x	x	x	x	x	x
	Climate		x	x		x	x	x	x	x	x
	Landform and topography		x	x	x	x		x	x	x	x
	Hydrology and soil moisture regime		[x]	x	x	x	x	x	x	x	x
	Vegetation type/Soil cover		x	x	x	x	x	x	x	x	x
	Human influence[1]		x	x	x	x	x	x	x	x	x

Legend: x, essential factor in the process; [x], factor that expectedly has an influence on the process; empty field: no particulars mentioned within the context of this stock-taking exercise; [1]Human influence here often refers to (change of) land use. However, other farming practices, such as stocking density, cultivation techniques or field size can also play a role.

The soil-forming factors refer to natural and anthropogenic processes that, in combination, affect all soil degradation processes. The distinction between natural and anthropogenic factors is particularly important because soil degradation processes may be accelerated or decelerated by human activities. A detailed explanation is given for some of the links below.

- Salts originating from the parent material and substratum may induce salinisation, involving water-soluble salt accumulation. As parent material indeed influences which minerals are present in the soil, it will have an influence on the biodiversity that naturally occurs in the soil.
- Climate and climate variability or change will influence all soil degradation processes, since climate influences the water-holding capacity. This has a snowball effect on other soil properties and in turn, on soil degradation processes. Climate's erosivity has an effect on wind erosion. Mainly temperature and precipitation have a critical influence on carbon mineralisation and accumulation. The water balance in a soil, in which the proportion between precipitation and evapotranspiration play an important role, affects primary salinisation.
- Landform and topography, in particular slope, affect tillage erosion.
- Groundwater can act as a carrier (or medium of transport) of water-soluble salts. Accumulation of the latter may lead to salinisation.
- Surface roughness or resistance, in particular, and thus the presence or absence and/or type of soil cover, influences the soil's erodibility. Land use decisions determine vegetation type and/or soil cover to a large extent.
- Finally, other human activities (including farming practices) affect many soil degradation processes; examples include: deforestation, drainage, irrigation with salt-rich water, overgrazing, inappropriate cultivation and the application of phosphate- and lime-based fertilisers. Policy intervention can in its turn affect farmer's actions, in particular their farming practices.

Farming practices affect soil characteristics and thus soil degradation processes. Table 5.2 gives an overview of the effects of soil-friendly farming practices on soil characteristics. The effects of farming systems as a whole (e.g. conservation agriculture, organic farming) are not presented, nor are those conservation practices which address one particular soil degradation process (e.g. appropriate irrigation practices to control and/or avoid salinisation and sodification).

Table 5.2: Summary of the effect of farming practices on (a) physical, (b) chemical and (c) biological soil characteristics

(a)

		Soil physical characteristics					
		Porosity	Infiltration rate/capacity	Gas permeability	Aggregate stability/size	Moisture content/ -holding capacity	Soil temperature
Farming practices	No-tillage	+ (macro-porosity)	+	-	+	+	-
	Reduced tillage	+ (macro-porosity)	+	-	+	+	-
	Cover crops	[x]	+	[x]	+	+	-
	Crop rotation						
	Ridge tillage					+	-
	Contour farming		+				
	Subsoiling	(0/+)	+				
	Intercropping	+					
	Grasslands, esp. permanent	[x]	[x]		+	[x]	[x]
	Agroforestry					+	[x]
	(Conservation) Buffers						
	Terracing		+				

(b)

		Soil chemical characteristics					
		pH/Acidity/ Alkalinity	Organic carbon	Nitrogen (cycle)	Phosphorus (cycle)	Potassium (cycle)	Electrical conductivity (EC)
Farming practices	No-tillage	-	+	+	+		
	Reduced tillage	-	+	+	+		
	Cover crops	-	+	+	[+]		
	Crop rotation		(+)	0/+	0/+	0/+	
	Ridge tillage		+	x			
	Contour farming		(+)				
	Subsoiling			(0/+)	(0/+)		
	Intercropping		+	+			
	Grasslands, esp. permanent		+	+	+	+	
	Agroforestry		+	+	+	+	
	(Conservation) Buffers			[+]	[+]		
	Terracing						

(c)

		Soil biological characteristics				
		Macro-fauna	Meso-fauna	Micro-fauna	Mycorrhiza	Microbial activity
Farming practices	No-tillage	+	+	+	+	+
	Reduced tillage	+	+	+	+	+
	Cover crops	+	[x]	[x]	[x]	[x]
	Crop rotation	+				
	Ridge tillage			+		+
	Contour farming					
	Subsoiling					
	Intercropping	(+)	(+)	(+)	(+)	(+)
	Grasslands, esp. permanent	+	+	+	+	+
	Agroforestry	[x]	[x]	[x]	[x]	[x]
	(Conservation) Buffers	[+]	[+]	[+]	[+]	[+]
	Terracing					

Legend: +, positive observed effect; 0, neutral observed effect; -, negative observed effect; [x], expected effect; (x), limited (e.g. short-term) or indirect effect; empty field: no particulars mentioned within the context of this stock-taking exercise

The way in which farming practices affect soil characteristics is complex; nevertheless it is useful to summarise the essentials of these relationships (as demonstrated in Chapter 3).

- No- and reduced tillage both result, after a transition phase, in a higher macro-porosity with vertical orientation and high connectivity of the pores (as a consequence of increased earthworm activity); soil aeration also increases. The bulk density of the top horizon increases only slightly, and does not exceed the production limits for most crops. These practices also induce a higher aggregate stability, especially in soils with low clay content, and an increase of up to 40 % in aggregate size in the surface horizon (0-5 cm). As no- and reduced tillage reduce soil evaporation and thus water loss, they can lead to an increase in the soil moisture content of up to 300 % and 35 % respectively. Soil temperature is reduced as a consequence of the crop residues left on and in the soil. The pH in the surface horizon (0-10 cm) can be reduced by <0.5 pH units; also, pH is negatively correlated to organic carbon content. No- and reduced tillage result in a higher organic carbon content of the surface horizon (especially the top 5 cm), with annual increases of 4-120 g C/m^2/yr. However, it mainly concerns organic matter with a rapid turnover, sensitive to mineralisation. At the same time, the mineralisation rate is reduced to 0.017 and 0.032 respectively (as compared to 0.046 when ploughing the top 25 cm). The organic matter under no- or reduced till has a higher proportion of particulate matter and shows more stratification, with a decreasing gradient from surface to bottom and more apparent with time. Both no- and reduced tillage result in a higher N and P content of the surface horizon, reduced N mineralisation and increased P stratification. These practices favour earthworm populations and activity (macro- and meso-fauna), no-tillage even more so than reduced tillage, and result in an increased biomass (important for recycling) of up to 30-100 %, and support mycorrhizal and enzymatic (microbial) activity.
- Systematic use of cover crops leads to an annual increase in organic carbon of up to 160 kg C/ha/yr. Due to the positive correlation between organic carbon content on the one hand and aggregate stability, moisture content and biodiversity abundance on the other hand, the effect of cover crops on the latter characteristics is also expected to be positive. However, the effect of soil temperature is expected to be negative, as soil cover protects the soil from direct light impact.
- Generally speaking, crop rotation improves soil fertility due to its recycling effect and through ensuring reduced leakage of nutrients. Depending on the type of rotation, however, it has a neutral or positive effect on nutrient (N/P/K) content and cycles. By

definition, rotations also encourage greater biodiversity and have a positive effect on macro-fauna.

- Ridge shape has an important effect on soil moisture; for example, soil moisture in maize increased in the top 10 cm of the interrows by 3.5-5.6 %. Ridge shape also has an important effect on radiation absorption (in the same example, soil temperature decreased by 3.5-5.6 % in the interrows), and it dramatically affects organic carbon production and decomposition. Furthermore, ridge tillage leaves residues among the ridges, and has therefore the same effect as reduced tillage. The soil microbial biomass under ridge tillage is 2 to 3 times higher and thus may affect N turnover, micro-fauna and microbial activity.
- There is limited evidence that contour farming positively affects soil organic carbon.
- Subsoiling combined with conservation agriculture practices can result in increased porosity, hence its positive to neutral effect. There is limited evidence of positive effects of subsoiling on N/P content and/or cycles.
- Examples from Ireland and the UK show that temperate winter wheat-white clover intercropping resulted in an increased input of organic matter, and supported much larger earthworm (*Lumbricidae*) populations than conventional wheat mono-cropping. These animals are responsible for the creation and maintenance of soil macro-porosity. Legumes contribute to soil fertility via symbiotic N_2 fixation in legume-cereal intercropping. Examples of improved biological characteristics also exist.
- Agroforestry results in better soil cover and in more moderate soil temperatures. It also has a positive effect on the maintenance of soil fertility and thus positively affects nutrient content and cycles, as well as soil biological characteristics.
- Buffers result in reduced leaching of N and P and thus positively affect N and P content and cycles. These reinforced nutrient cycles positively affect biological life and activity.

Table 5.3 sets out the effects of farming practices on multiple soil degradation processes and related environmental issues.

Table 5.3: Summary of the effect of farming practices on (a) soil degradation processes and (b) related environmental issues

(a)

		Soil degradation processes								
		Water erosion	Wind erosion	Tillage erosion	Organic carbon decline	Com-paction	Salini-sation/ Sodifi-cation	Contami-nation	Soil biodi-versity decline	Land-slides and floods
Farming practices	No-tillage	-/+	+	++	+	(-/)+		+	+	
	Reduced tillage	-/+	+	[+]	+	(-/)+		+	+	
	Cover crops/Vegetation cover	+	++	[+]	+			+	[+]	
	Crop rotation	+	+		+	+		+		
	Ridge tillage	+	[+]	[x]	+				+	
	Contour farming	+		+						
	Subsoiling					(+)				[+]
	Intercropping				+			+	+	
	Grasslands, esp. permanent	+	+	+	+					
	Agroforestry	x	x	x	(+)					(+)
	(Conservation) Buffers	+	+					[+]	[+]	
	Terracing	+	0							-/+

(b)

		Related environmental quality/quantity issues							
		Water quality				Air quality[1]	Energy	Biodiversity	Landscape[2]
		Pesticides	Nitrogen	Phosphorus	Potassium				
Farming practices	No-tillage	-/+	+	-/+		-/+	+	[+]	
	Reduced tillage	-/+	+	-/+		-/+	+	[+]	
	Cover crops/Vegetation cover	[+]	++	[-/+]		+	+	[+]	
	Crop rotation	+	+	+	+	(+)	+	+	+
	Ridge tillage	+	+	+			+		
	Contour farming								x
	Subsoiling						[-]		
	Intercropping	+	+					+	[+]
	Grasslands, esp. permanent	+	+					+	+
	Agroforestry	+	+	+		+		+	+
	(Conservation) Buffers	+	+	+				+	+
	Terracing						[-]		-

Legend: +, positive observed effect; 0, neutral observed effect; -, negative observed effect; [x], expected effect; (x), limited (e.g. short-term) or indirect effect; empty field: no particulars mentioned within the context of this stock-taking exercise; [1] The term air quality mostly refers to greenhouse gas emissions here.; [2] The term landscape refers to a group of characteristics that cannot be described as abiotic (water, soil, air) neither as biotic resources (genetic, species and habitat diversity) but refer to visual aspects/aesthetics, cultural heritage, etc.

The most important effects of farming practices on soil degradation processes (Table 5.3) are highlighted below.

- No- and reduced tillage (NT and RT) can diminish spring time run-off and erosion. Provided the soil is sufficiently covered (mulch, green manure, catch crops, etc.) and has significant biological activity, run-off and erosion can be reduced by a factor 1 to 5 and 1 to 10 respectively, compared to conventional tillage. However, higher run-off and erosion may occur in cases of severe soil compaction and soil crusting; no-tillage combined with no soil cover can even result in a significant increase in water erosion. Wind erosion can be reduced by creating larger soil clods (both under no- and reduced tillage) and thus protecting the leeward side of clods or furrows from wind erosion and particle impact. As mentioned above, no-tillage also counteracts organic carbon decline. The reduced number of tractor passages on fields under NT or RT should result in a reduced compaction risk. Vertical orientation of pores and aggregate stability also improve soil resistance to severe soil packing. However, both practices are known to cause local compaction problems, especially on clay soils at the edges of fields, where the machines turn around[32]. In relation to the increased organic carbon content and biological activity, adsorption and breakdown of pesticides is higher under no- and reduced tillage (with soil cover), despite the higher macro-porosity and preferential vertical transport, which is positive in preventing soil and water pollution. Furthermore, surface water contamination by pesticides is directly linked to run-off. Reduced run-off using no- and reduced tillage can result in a pesticide flow reduction of 29-100 %, depending on the type of pesticide and cultivation practice used. However, in a period of high drainage (after significant rainfall), preferential vertical transport could lead to groundwater pollution; on the contrary, the absence of a draining period could support the biological breakdown of pesticides. The risk of nitrogen pollution also increases with increased leaching under preferential vertical transport. However, soil cover shows significant effects in reducing nitrate losses, irrespective of the tillage system used. The situation with respect to phosphorus is more complicated because it is both soluble and particulate, the latter property causing it to accumulate on soil organic matter. Despite reduced total P losses under no- and reduced tillage, soluble P losses increase, resulting in an increased risk of eutrophication. Fuel

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[32] Written communication A. Arnoldussen.

savings have a positive impact on greenhouse gas emissions and air quality in general: reduced CO_2 emissions of 27-162 kg CO_2/ha/yr; reduced N_2O emissions, at least when no-tillage is combined with a cover crop (for green manure, etc.), especially a leguminous one. However, increased N_2O emissions as well as NO_x have alsp been reported, the latter as a consequence of reduced soil aeration. Bird populations are likely to increase due to the higher seed availability and presence of crop residues.

- Cover crops are considered to be the best measure against wind erosion. They also provide additional organic matter (up to 160 kg C/ha/yr) and thus contribute to reversing organic matter decline. So-called catch crops, in particular, reduce nutrient leaching and thus have a positive impact on soil contamination. Soil cover in general shows significant effects in reducing nitrate losses, whatever the tillage system used, and thus improves water quality. Reduced emissions of N_2O (greenhouse gas emission) were observed when no- and reduced tillage was combined with cover crops, especially leguminous ones. Cover crops also result in fuel savings and thus reduced energy use.
- Crop rotation contributes to controlling erosion because of better soil cover. Inclusion of grass and legumes improves the organic carbon status of soils. Crop rotation also reduces reliance on agricultural chemicals and thus prevents contamination. Due to reduced use of herbicides and pesticides, it improves water quality; however, the longest possible rotation of 5-10 years is necessary to minimise risks of weed, pest and disease development. Furthermore, nutrient (N/P/K) recycling allows reduced fertiliser use and thus reduces the risk of leaching nutrients into the water. The lower use of N fertilisers also reduces N_2O emissions and saves fuel (energy use), with knock-on effects on CO_2 emissions. Introducing leguminous plants additionally contributes to reduced energy dependence. In addition, crop rotation also promotes biodiversity by varying crop species and types of farmland habitats, with long rotations composed of many varieties contributing to genetic biodiversity and an aesthetically pleasing landscape.
- Ridge tillage may reduce erosion; for example, maize grown on a 3 % slope using this tillage practice resulted in an 85 % reduction in water erosion compared to traditionally tilled areas. However, tillage erosion is likely to arise because of the yearly formation of ridges. At the same time, residues left in the furrows counteract organic carbon and biodiversity decline. Increased yield and profitability allow for lower fertiliser and pesticide- use, and reduced leaching of inorganic N[33], with ensuing positive effects on water quality. An example of ridge tillage in cotton cultivation resulted in machinery savings of over 20 %.
- Contour farming slows down run-off due to the increased infiltration capacity and thus controls water erosion. On slopes less than 10 % and below a given threshold level of rainfall intensity, contour farming may help to reduce tillage erosion. However, tillage speed and depth are reported to be as important as slope gradient. Slope farming inevitably affects the landscape too. There are technological limits to contour farming; for example, root crops might be significantly damaged during the harvest, resulting in lower yield as well as affecting product quality.
- Subsoiling has a very short-term positive effect on soil compaction, i.e. compaction can occur again after subsoiling if the causes (e.g mouldboard ploughing) are not eliminated. It is also associated with high energy costs.
- Increases in organic matter and earthworms from particular combinations of intercropping help to reverse the decline in organic carbon and soil biodiversity. For example, faba

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[33] Given the conformation of ridges, precipitation slips away on the ridge's side, thereby reducing the leaching of inorganic N applied in the middle (ridge) and increasing N use efficiency by plants (Schlinker *et al.*, 2007; Henriksen *et al.*, 2006). In northern Europe, as N leaching is a major concern in agriculture, the implementation of ridge tilling in autumn and winter could greatly ease the problem.

bean-pea and faba bean-cereals intercropping reduced *Orobanche crenata* infestation (thanks to the production of allelochemicals), thus reducing the need for pesticides, and maize-grass intercropping reduced NO_3 by 15 and 20 mg/l compared to conventional catch crop and fallow soil, respectively. Lower pesticide and N use both potentially improve water quality. The mixture of crops results in higher biodiversity, and the landscape is also likely to benefit.

- Agroforestry has a positive effect on soil fertility maintenance and thus on organic carbon decline. Some trees (namely willows, poplars and certain eucalyptus trees) can potentially help to reduce water-logging and thus contribute to preventing landslides and floods. Agroforestry has a positive effect on nitrate leaching due to the potential of tree roots to recover N from below the crop rooting zone; it thus favours watershed protection. This practice may also increase carbon sequestration and improve the soil's CO_2 sink potential.
- Soil contamination in (conservation) buffers is potentially reduced by plant absorption. The reduced drift of pesticides and leaching of nutrients (abatement of 70-95 % in N, abatement of 70-98 % in P) results in improved water quality. Buffer zones or strips also contribute to diversifying the landscape.
- When combined with other conservation practices, such as contour ploughing, strip cropping or permanent soil cover, terracing can reduce water erosion. However, severe piping or tunnel erosion may occur when terraces are abandoned. The effect on landslides and floods depends on the slope stability per se, i.e. terraces might either contribute to stabilisation or cause instability. On the downside, terrace creation requires a lot of energy. Terracing also produces significant landscape transformation, and a loss of original soil profiles.

Table 5.4 describes the interlinkages between soil degradation processes and related environmental issues. All soil degradation processes are interrelated; however, not all relationships between soil degradation processes are direct and the occurrence and degree of effects depends on site-specific conditions.

Table 5.4: Summary of the effects of soil degradation processes on (a) other soil degradation processes and (b) related environmental issues

(a)

		Soil degradation processes								
		Water erosion	Wind erosion	Tillage erosion	Organic carbon decline	Com-paction	Salini-sation/ Sodifi-cation	Contami-nation	Soil biodi-versity decline	Land-slides and floods
Soil degradation processes	Water erosion		x		x	x	x	x		x
	Wind erosion	x			x			x		
	Tillage erosion	x	x					x		
	Organic carbon decline	x	x			x		x	x	x
	Compaction	x	x		x		x	x	x	x
	Salinisation/Sodification	x	x		x	x		x	x	x
	Contamination								x	
	Soil biodiversity decline	x	x		x	x		x		
	Landslides and floods	x	x		x			x	x	

(b)

		Related environmental quality/quantity issues						
		Water quality				Air quality	Biodiversity	Landscape[1]
		Pesticides	Nitrogen	Phosphorus	Potassium			
Soil degradation processes	Water erosion	x	x	x	x		x	x
	Wind erosion	x				x	x	x
	Tillage erosion	x	x	x				
	Organic carbon decline	x					x	x
	Compaction	x	x	x	x		x	x
	Salinisation/Sodification						x	x
	Contamination	x	x	x	x	x	x	
	Soil biodiversity decline	x	x	x			x	
	Landslides and floods						x	

Legend: x, observed/measured effect; [x], expected effect; (x), limited (e.g. short-term) or indirect effect; empty field: no particulars mentioned within the context of this stock-taking exercise; [1] The term landscape refers to a group of characteristics that cannot be described as abiotic (water, soil, air) neither as biotic resources (genetic, species and habitat diversity) but that refer to visual aspects/aesthetics, cultural heritage, etc.

The following relationships can be emphasised:

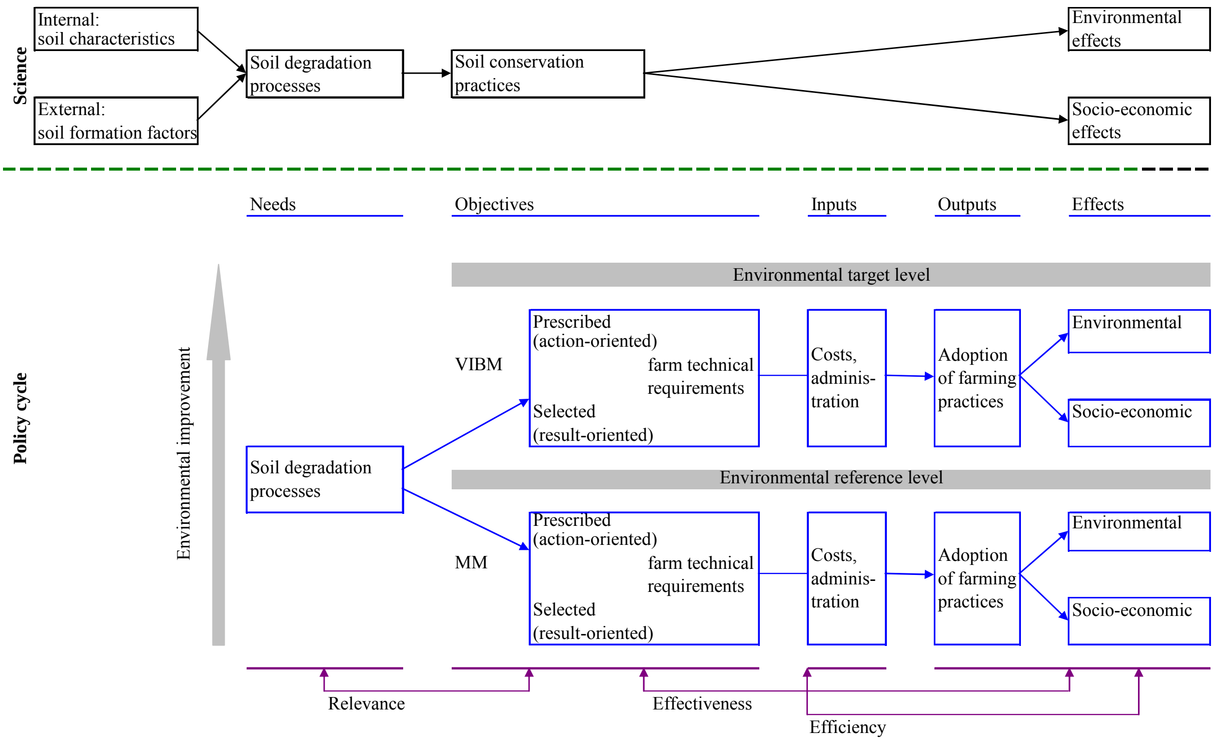
- Water erosion is linked to the occurrence of floods. If as a consequence of soil loss, the saline horizon comes to the surface, erosion has a negative impact on salinisation. Water erosion is equally linked to soil contamination, as soil removal includes nutrient removal; soil nutrient pollution can also affect water quality. Surface water contamination by pesticides is directly linked to run-off. Simplified cultivation practices can result in a reduction of the pesticide flow by 29-100 %, depending on the type of pesticide and practice used.
- Organic carbon decline results in reduced aggregate stability and thus an enhanced risk of wind erosion. During wind erosion events pesticides can be displaced together with soil particles, potentially resulting in water contaminated with pesticides. Aerosols cause changes in the atmospheric radiation balance; wind erosion thus has an additional effect on the aesthetics of the landscape (perceived in a broad sense).
- Soil organic carbon enhances the water retention capacity and allows excess water to drain freely from the soil, thus reducing overland flow and water erosion. As such, organic carbon decline exacerbates water erosion. As organic carbon supports the soil structure, organic carbon decline may also contribute to compaction. Loss of organic carbon results in decreased aggregate stability with a negative impact on the denitrification potential for biomass productivity, thus resulting in soil contamination. Organic carbon contributes to soil biodiversity; organic carbon and soil biodiversity decline are thus interrelated. Conversely, increased organic carbon content and biological activity may enhance pesticide fixation and/or adsorption in the soil or their breakdown in the surface horizon, and thus reduced risk of surface run-off, with an expected positive effect on water quality.
- (Surface) compaction creates significant damage to infiltration rate and can thus accelerate erosion and landslides.
- Contamination of surface and groundwater affects water quality in all its aspects (pesticides, nutrients). Pesticide accumulation may also affect all genetic and species biodiversity, including soil biodiversity, as the food chain may be affected.
- Biological activity and soil biodiversity increase the breakdown of pesticides and thus reduce the risk of their removal through surface run-off, and negatively affecting water quality.

5.2 Classification of soil degradation processes, soil conservation practices and policy measures

This section aims at exploring the relationships between soil degradation processes and soil conservation practices. Soil degradation processes imply a need for protection, maintenance and improvement of soil quality. This corresponds to protecting from 'bad', maintaining 'good' and applying 'best' practice respectively. However, due to the public good characteristics of the desired soil quality, its optimal level of provision is not assured through the market (market failure). Thus, policy intervention is required to reach adequate levels of soil protection through appropriate practices. The policy process includes allocation of property rights through the establishment of a reference level which distinguishes between what is mandatory and what exceeds the reference level and should therefore be obtained contractually (voluntary incentive-based).

Figure 5.1: illustrates the process of adopting soil conservation practices (farming systems and/or practices) under social demand for soil protection, conservation and improvement. It outlines the parallel processes of science and policy (making), which ideally interact with one another.

Figure 5.1: Adoption of soil conservation practices (farming systems and/or practices) for soil quality protection, conservation or improvement



Legend: MM, mandatory measure; VIBM, voluntary incentive-based measure; – – –, exchange between science and policy process; ▒, environmental quality objectives
Sources: EC (2004); Scheele (2008)

As mentioned in 5.1, soil degradation processes are driven by the internal properties of the soil as well as by external soil-forming factors such as climate, land use, soil management, and so on. Certain farming systems and practices aim at addressing soil degradation processes, at times as a consequence of inappropriate farm management. Both the environmental and the economic (cost-benefit) effects of such practices can be monitored, providing empirical evidence for cause-effect links. Such empirical models feed into the policy cycle.

Policy seeks to address society's expressed needs of dealing with soil degradation processes. The main instruments used are mandatory and voluntary incentive-based measures. The reference level separates both types of policy measures by defining what is considered a minimum (mandatory) requirement, and what goes beyond that level. These policy measures can be either action- or result-oriented, meaning that either the farm technical requirements, or the required soil quality objective are prescribed. The latter leaves the farmer with the choice of selecting those actions that suit the farm context best, in order to reach the required soil quality level. In both cases, however, adoption of farming practices or a farming system, will usually involve costs and/or additional administration. Furthermore, the adopted farming practices are expected to have an environmental, and in particular, a soil quality effect.

- An analysis of the intervention logic (which was adopted for the policy analysis) breaks a measure down into different steps, from society’s needs to policy formulation and design, implementation and effects. This, in turn allows one to assess the relevance and effectiveness of a measure. Relevance is the extent to which the policy is responsive to the underlying needs, and is assessed by comparing the policy objectives with the soil protection, conservation and improvement problems to be addressed. Effectiveness is the extent to which the policy output matches the objectives, whereas efficiency depends on the amount of policy output per unit of input (i.e. financial and/or administrative resources). However, the latter will be hard to measure in the current study due to unavailability of data (not least the different costs associated with an intervention).

These evaluation aspects can only be quantified (measured or estimated) using appropriate indicators.

In order to identify the cause-effect links activated by policy measures that are relevant to soil protection, conservation and improvement, it is necessary to confront the scientific evidence on soil degradation and farming practices with the policy measures in operation.

Table 5.5 presents the interrelationships between soil conservation practices (farming systems and single practices), soil degradation processes and policy measures. It describes (expected) effects of farming systems (integrated, organic and conservation farming) and farming practices on soil degradation processes and related environmental issues. The colours indicate which types of policy measures encourage the different practices that seek to address one or more particular soil degradation processes. The survey on national and regional policy implementation (4.4) provided the evidence supporting most of the links presented. Furthermore, the colours indicate whether or not the link has ever been observed regardless of its frequency. The synthesis nevertheless highlights the potential of the existing EU policy framework (through its national or regional implementation) and other national policies for supporting soil conservation practices.

Table 5.5: (Expected) effects (positive, neutral or negative) of farming systems and practices on soil degradation processes and related environmental issues and their link with policy measures

		Soil degradation processes													Related environmental quality/quantity issues							
		Water erosion	Wind erosion	Tillage erosion	Related offsite damages	Organic carbon decline	Compaction	Salinisation/ Sodification	Acidification	Contamination (local)	Contamination (diffuse)	Soil biodiversity decline	Landslides and floods	Water quality	Water quality				Air quality (Greenhouse gas emissions)	Energy	Biodiversity	Landscape
														General	Pesticides	Nitrogen	Phosphorus	Potassium				
Farming systems	*Integrated horticultural production*	[+]	[+]				[+]					[+]			[+]	[+]					[+]	
	(Conversion from conventional to) Organic farming					+/0		0				+			+	+/0	+/0			+	+	+/0
		[+]/+				[+]	[+]			[+]	[+]	[+]			[+]						[+]	[+]
Farming practices	**ARABLE LAND**																					
	No-tillage	-/+	+	++		+	(-)/+				+	+			-/+	+	-/+		-/+	+	[+]	
		[+]																				
		[+]/+	[+]		[+]	[+]	[+]				[+]	[+]					[+]				[+]	
	Reduced tillage	-/+	+	[+]		+	(-)/+				+	+			-/+	+	-/+		-/+	+	[+]	
		[+]																				
		[+]	[+]		[+]	[+]	[+]				[+]											
	Cover crops/Vegetation cover	+	++	[+]		+					+	[+]			[+]	++	[-/+]		+	+	[+]	
		[+]	[+]			[+]																
		[+]/+	[+]		[+]	[+]	[+]				[+]	[+]	[+]	[+]	[+]	[+]	[+]	[+]			[+]	[+]
		[+]	[+]																			
	Crop rotation	+	+			+	+				+				+	+	+	+	(+)	+	+	+
		[+]	[+]			[+]	[+]					[+]		[+]							[+]	[+]
		[+]	[+]			[+]	[+]					[+]									[+]	[+]
						[+]																
	Ridge tillage	+	[+]	[-]		+						+			+	+	+			+		
	Contour farming	+		+																		x
		[+]																				
	Subsoiling						(+)						[+]							[-]		
	Coarse seedbeds		[+]																			
	Intercropping					+					+	+			+	+					+	[+]
		[+]																				
		[+]	[+]			[+]	[+]					[+]		[+]		[+]					[+]	[+]
	Strip cropping	[+]	[+]																			
		[+]				[+]	[+]					[+]									[+]	[+]
	Restrictions on growing row crops	[+]																				
	Legumes on recultivated agricultural land	[+]	[+]																			
	Maintenance and incorporation of stubble and crop(s) (residues)	[+]	[+]			[+]						[+]		[+]							[+]	
	Delayed manure incorporation		[+]																			
	(Appropriate) Use of exogenous organic matter	[+]	[+]							[+]	[+]	[+]									[+]	
						[+]						[+]									[+]	
	(Limited or no) Fertiliser use					[+]					[+]	[+]				[+]					[+]	
						[+]						[+]				[+]	[+]	[+]			[+]	
	Reduced (or no) plant protection/pesticide use									[+]	[+]	[+]			[+]						[+]	
						[+]				[+]	[+]	[+]			[+]						[+]	
	Restrictions on intensive crop production in riverside areas	[+]	[+]		[+]									[+]							[+]	
	Grazing crop remains and stubble					[+]																

Farming practices	Soil degradation processes													Related environmental quality/quantity issues							
	Water erosion	Wind erosion	Tillage erosion	Related offsite damages	Organic carbon decline	Compaction	Salini-sation/ Sodifi-cation	Acidification	Conta-mination (local)	Conta-mination (diffuse)	Soil biodi-versity decline	Land-slides and floods	Water quality	Water quality				Air quality (Green-house gas emissions)	Energy	Bio-diversity	Landscape
													General	Pesticides	Nitrogen	Phosphorus	Potassium				
GRASSLAND																					
Conversion arable farming to (permanent) pasture	[+]/+	[+]		[+]	[+]						[+]		[+]	[+]	[+]	[+]				[+]	[+]
Grasslands, esp. permanent	+	+	+		+									+	+					+	+
	[+]	[+]	[+]		[+]									[+]	[+]						[+]
	[+]	[+]	[+]		[+]									[+]	[+]						[+]
Extensive grassland management	[+]			[+]	[+]				[+]	[+]	[+]		[+]		[+]					[+]	
	[+]				[+]	[+]					[+]	[+]								[+]	
	[+]	[+]		[+]	[+]				[+]	[+]	[+]		[+]	[+]	[+]					[+]	[+]
Temporary restrictions on grazing	[+]					[+]															
Establishment of (permanent) wetlands									[+]	[+]				[+]	[+]	[+]					
	[+]	[+]		[+]	[+]						[+]			[+]	[+]	[+]	[+]			[+]	
FOREST																					
Agroforestry	x	x	x		(+)							(+)		+	+	+		+		+	+
	[+]			[+]							[+]	[+]								[+]	
Afforestation of agricultural land	[+]			[+]	[+]		[+]	[+]			[+]	[+]								[+]	
NON-AGRICULTURAL LAND																					
Avoid encroachment	[+]				[+]						[+]									[+]	
LINEAR LAND ELEMENTS																					
(Conservation) Buffers	+	+								[+]	[+]			+	+	+				+	+
	[+]	[+]									[+]									[+]	[+]
	[+]/+	[+]		[+]	[+]	[+]					[+]		[+]							[+]	[+]
Extensification of bufferstrips	[+]			[+]					[+]	[+]			[+]	[+]	[+]	[+]	[+]			[+]	[+]
FARM INFRASTRUCTURE																					
Rearrangement of field size	[+]										[+]									[+]	[+]
Terracing: maintenance or reconstruction	+	0										-/+							[-]		-
	[+]	[+]																			
	[+]				[+]																
Efficient surface water drainage system	[+]					[+]															
Appropriate irrigation system						[+]															
Adequate storage of organic fertiliser									[+]						[+]						
									[+]	[+]					[+]	[+]	[+]				
Appropriate machinery use				[+]		[+]															

Legend: +, positive effect; 0, neutral effect; -, negative effect; x, actual/observed/measured effect; [x], expected effect; (x), limited (e.g. short-term) or indirect effect; empty field: no particulars mentioned within the context of this stock-taking exercise; [1] The term landscape refers to a group of characteristics that cannot be described as abiotic (water, soil, air) neither as biotic resources (genetic, species and habitat diversity) but that refer to visual aspects/aesthetics, cultural heritage, etc.; ⬚, Conservation agriculture; 🟪, SMR; 🟨, GAEC; 🟩, RDP – Axis 2: LFA; 🟫, Natura 2000 (and Water Framework Directive); ■, RDP – Axis 2: Agri-environment measures; □, RDP - Axis 2: Agroforestry and Afforestation

The information on soil degradation processes and soil conservation practices is based on scientific literature, which mostly concerns *observed or measured* effects under particular geo-climatic and farming conditions. As regards the incorporation of the policy review results, the survey did not illuminate the extent to which the links between farm technical requirements (i.e. mandatory farming practices or those prescribed under voluntary contracts) and soil degradation processes are based on actual measurements. Being aware of local specificities of most scientific studies, these causal links may not necessarily produce the same effect in the diverse and more complex agri-environment reality. As a consequence, Table 5.5 indicates *expected* (rather than *observed*) effects of policy measures.

Rural development policy (Rural Development Regulation (EC) 1698/2005) refers to Statutory Management Requirements (SMRs) and Good Agricultural and Environmental Condition (GAEC) as part of the reference level for a number of measures under Axis 2. It can be seen from Table 5.5 that in some Member States or regions rural development measures support practices that in other countries are required by SMRs or GAEC. Therefore, what is considered mandatory in one context is apparently seen in another context as an environmental outcome that goes beyond the reference level, and for whose provision farmers should be compensated. This could indicate different equity considerations or different approaches towards specifying farmers' property rights. In this respect, the scope for harmonisation remains to be explored.

Evaluating the effectiveness of policy measures with respect to soil quality would be facilitated if a (quantified) framework for soil quality objectives existed. This would require a complex database that takes into account the wide variability of geo-climatic conditions and of farming types in the EU-27. This complexity could be addressed, however, if soil quality objectives were defined following common criteria according to the function of the soil (for example, for agricultural soils, the soil erosion risk is acceptable if it does not seriously impede crop production), but allowing quantitative differences from context to context.

For a proper understanding of Table 5.5 some explanation regarding the required farming practices as prescribed in the policies is needed; for example:

- Integrated horticultural production covers practices like planting vegetation during the winter time, or on machine and irrigation tracks. It is supported under agri-environment payments.
- (Conversion from conventional to) organic farming includes requirements like no or limited pesticide use, crop rotation including legumes and other green manure crops, strict conditions on fertilisation (with emphasis on application of livestock manure or organic material) and tillage practices. Organic farming is encouraged under agri-environment payments. In Umbria, Italy, mid-term evaluations of agri-environment measures (2000-2006) indicate that organic farming practices were found to reduce soil erosion on average by 6.8 t/ha/yr. Conversion of arable to grassland was estimated to have resulted in a reduction of 30 t/ha/yr.
- Mid-term evaluations of agri-environment measures (2000-2006) in Austria have shown that direct sowing practices in maize production resulted in a 40 % reduction of soil erosion.
- Cover crops, i.e. any crop grown to provide soil cover, regardless of the period or soil incorporation, include catch crops and green cover. Catch crops are especially used in drinking water catchment areas and thus serve water quality objectives too. In addressing water erosion in particular, the practice may refer to minimum soil cover

during winter or after the main harvest, such as green cover (on terrace plots). In controlling wind erosion, it could mean using coarse seedbeds or shelter belts, or the spring-planting of nurse crops (i.e. an annual crop used to establish a perennial crop), especially when sowing on light soils. GAEC, as well as agri-environment measures and LFA payments specify the use of cover crops to reach their respective aims. The mid-term evaluation of agri-environment measures (2000-2006) in Flanders, Belgium, found that green cover of the soil reduces soil erosion by at least 50 %.

- Intercropping, i.e. growing one or more crops in proximity and in the same field during a growing season to promote interaction, is perceived to control water erosion as it provides minimum soil cover in winter. This practice is believed to have a structuring effect on soils and, as such, may prevent soil compaction. Undersown crops are considered as a particular type of intercropping. Intercropping is used under GAEC and agri-environment measures.
- Strip cropping, i.e. alternating strips of closely sown crops (e.g. hay, wheat, or other small grains) with strips of row crops (e.g. corn, soybeans, cotton, maize, or sugar beets), can be seen as a special type of intercropping. So-called bio-strips, which involve sowing (a mixture of) weeds (e.g. white clover and perennial grasses, wild herbs, wildflowers) between crop rows (e.g. lettuce, tomatoes, peppers in raised beds), are also considered under this practice. This integration of weeds into cropping systems creates the following benefits: (i) a diverse, protective habitat and food supply for beneficial insects and microorganisms in the field alongside the crops; (ii) a source of organic matter or mulch from the clippings of the plants (making sure to mow before any wildflowers go to seed); and (iii) confinement of potential compaction to bio-strips, where the soil is supported by the root system of this mix (SARE, 2008). Strip cropping is also covered by GAEC and agri-environment measures.
- Maintenance and incorporation of stubbles and crop residues (including mulch) refers to either the prohibition of stubble and crop residue burning, or stubble maintenance (on arable and grassland), or the working of plants (including legumes) or plant residues into the soil to maintain fertility. This practice is part of GAEC.
- Livestock manure should usually be incorporated within a limited time (e.g. two weeks) after spreading on stubbles. However, in areas prone to wind erosion, incorporation may be delayed, specifically to control this soil degradation process (practice applied under GAEC).
- Fertiliser use refers to both organic and inorganic fertilisers. The implementation of the Nitrates Directive should lead to restrictions on:
    - periods when the application of fertiliser to soil is inappropriate;
    - applying fertiliser on steeply sloping ground or on water-saturated, flooded, frozen or snow-covered ground and conditions for land application near water courses;
    - the rate and uniformity of spreading, of both chemical fertiliser and livestock manure, such that nutrient losses to water are kept to an acceptable level.
- Reduced (or no) use of plant protection products or pesticides refers amongst other things to the Plant Protection Products Directive (91/414/EEC), a Statutory Management Requirement (SMR) (dealing with public, animal and plant health).
- The same expected effects of establishing or maintaining permanent grasslands as described under agri-environment schemes (survey national and regional implementation) can be expected under GAEC.
- Extensive grassland management (and extensification in general) can cover the following farm management actions: restricting livestock density or maintenance of

minimum livestock density, avoidance of cutting or mulching on permanent grasslands, and using limited fertilisation or plant protection products.
- Temporary restrictions on grazing (supported through agri-environment measures) may consist of seasonal removal of cattle in areas prone to waterlogging, compaction and poaching, or even changing the location of feeders.
- Establishment of (permanent) wetlands is especially promoted in sensitive areas, such as those used for drinking water extraction. This practice was reported under agri-environment schemes and in Natura 2000 areas.
- Avoiding encroachment on land that is not or no longer used for agricultural production is often attained through maintaining a minimum amount of livestock on the land.
- Conservation buffers, i.e. areas or strips of land maintained in permanent vegetation, can include riparian buffers, windbreaks, shelterbelts or hedgerows. Mid-term evaluations of agri-environment measures (2000-2006) in the Piemonte region, Italy, have shown that planting hedges had a significant positive impact on soil erosion.
- Efficient surface water drainage systems (e.g. drainage furrows) are particularly relevant on sloping ground and on sites that are vulnerable to erosion.
- With respect to adequate storage of organic fertiliser the implementation of the Nitrates Directive should cover provisions for the capacity and construction of storage for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage.
- Appropriate machinery use (under GAEC) is of utmost importance on water-logged or frozen soils where a ban might be required.

Although conservation agriculture is supported explicitly in only a few rural development programmes (e.g. Andalucía, Nordrhein-Westfalen, Saarland), individual soil-conserving practices (no-tillage, reduced tillage, soil cover, and crop rotation) are covered under a number of national GAEC and rural development programmes.

Table 5.5 also provides *information weaknesses* relevant to the policy process. The policy survey showed that soil protection, conservation and improvement measures are mostly defined in terms of farming practices rather than specific environmental objectives. This means that policy makers need detailed knowledge of the cause-effect links between farming practices and soil degradation processes. However, our review of the research literature showed that scientific models based on field experiments and actual measurements of the effects of farming practices on soil characteristics and degradation processes, do not provide a sufficient base for reliable policy models. This is mainly due to their context-specificity, which makes their generalisation problematic given the diversity of European soil, climatic, farming, etc. conditions.

Furthermore, even if some models are accurate enough to provide a reliable assessment of soil protection, conservation and improvement effects on a national or EU scale, the detailed database required to run these models is often lacking. This holds not only for the effects but also for the assessment of the state of soil degradation across the EU as a whole. Although the state of the soil can be directly observed, for example while inspecting farms for cross-compliance purposes, nevertheless, most models used for calculating the occurrence and extent of soil degradation, or the risk thereof, do not take into account precise farm elements beyond Corine Land Cover. The challenge of mitigating or at least adapting to natural disasters like floods, long-term threats such as global warming and unsatisfactory progress in improving the quality of European waters, highlights the need for more action in the field of soil protection, conservation and improvement.

These observations also call for agri-environment monitoring based on reliable and comprehensive indicators of (i) the state of soils (soil degradation), (ii) the social impact (cost) of soil degradation, and (iii) the effects of soil protection, conservation and improvement practices. The development of operational indicators requires sound indicator selection criteria and designing a monitoring system with a related database. In this spirit, the ENVASSO consortium (Kibblewhite *et al*., 2008) has developed 'a system to harmonise existing, mostly national soil monitoring networks and databases, to form a European-wide reference that can assess current and future soil status and support the sustainable management of soil resources'. The current absence of systematic monitoring and operational indicators is mirrored by the proposed Soil Framework Directive. Even though the proposal suggests common criteria and factors (such as soil type, texture, hydraulic properties, land use, topography and climate) for a harmonised definition of risk areas[34], it leaves the responsibility for selecting indicators to the Member States or regions. Also the definition of threshold, reference and target levels is shifted to the implementation level, which is appropriate, as it is impossible to set threshold levels centrally. Nevertheless, it should be emphasised that the proposed Soil Framework Directive strongly recommends collecting information and monitoring the state of soils.

Despite the policy survey review not being fully comprehensive across the EU-27 and the fact that not all policy measures are implemented in all regions or Member States, the review nevertheless highlights that the implementation of current EU and national policy measures has the potential to address all recognised soil degradation processes at EU level. It is also consistent with the use of the wide variety of relevant soil conservation practices (farming practices and systems). However, the lack of monitoring and a (quantitative) database hinders a comprehensive evaluation of effectiveness and efficiency of the applied measures. The analysis at local and farm level appears necessary to clarify what drives successful adoption of proposed measures. The latter is especially relevant for understanding the adoption of whole farming systems, rather than a number of unco-ordinated individual practices.

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[34] In a technical report to DG Environment, Eckelmann *et al*. (2006) provided elaborate common criteria for risk area identification for the following soil degradation processes: soil organic matter decline, erosion, compaction, salinisation and landslides.

6 Workshop summary report

Following the draft WP1 report, a stakeholder workshop at EU level (involving farmers, land owners, actors affected by soil degradation, policy makers, policy implementing institutions and relevant NGOs) was held in Brussels on 22 May, 2008. The workshop was jointly organised by the Joint Research Centre and DG Agriculture and Rural Development, and gathered about 120 stakeholders. Its aim was twofold: (i) to inform stakeholders about the SoCo study and establish a platform for project cooperation, and (ii) to gather stakeholder opinions and experience in the area of soil conservation. A summary of the presentations and the discussions is provided in the following sections.

6.1 Opening

Welcome address (Commissioner M. Fischer-Boel)
In her welcome address, Marian Fischer-Boel, Commissioner for Agriculture and Rural Development, recalled that the project, carried out jointly by DG AGRI and the JRC, following an initiative of the European Parliament, aimed to investigate issues of good soil conservation practices and to analyse how policy can be used to encourage farmers to adopt such practices.

The Commissioner welcomed the project in the context of the concurrent Health Check of the common agricultural policy (CAP), since theCAP Health Check analysis showed that the current provisions for maintaining agricultural land in good agricultural and environmental condition provide a good basis for soil conservation. Furthermore, soil conservation would be part of the 'new challenges' section in the Health Check aiming at helping farms take on future challenges and opportunities. Under this chapter, the Commissioner informed the meeting that she had proposed to boost funding for rural development projects that improve soil conservation practices as part of the effort to help farmers curb climate change[35].

Moreovoer, she considered that the workshop had a role to play, regarding the environment and climate change, in bridging the gap between citizens' concerns and farmers' practices, and helping to improve farmers’ understanding of what society expects from agriculture. Furthermore, citizens also should understand the vital role that agriculture plays in preserving the rural environment, including soils, habitats and landscapes.

As for the increase in world population and Europe’s responsibility in assuring food security, the Commissioner saw the solution for reconciling increasing environmental and food demands in the development of innovative techniques. She stressed the importance of research in this context, and pointed out that the EU is already funding such innovative projects under the rural development policy.

The Commissioner emphasised that the mandatory policy instruments under cross compliance, in particular, the scheme's provisions for maintaining agricultural land in good agricultural and environmental condition that directly address soil conservation, complement the voluntary rural development measures, making it a dynamic duo of stick and carrot.

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[35] An increase in modulation by 5%, distributed over 4 steps beginning in 2009, has been agreed as part of the Health Check CAP revision.

Finally, she recalled that the Commission has proposed the Soil Framework Directive, saying that, so far, no agreement has been reached by the Member States.

Keynote address (Member of the European Parliament S. Le Foll)
MEP Stéphane Le Foll introduced the background of SoCo, initiated as a pilot project from the European Parliament within the 2007 budget. The idea was born from a realisation of the need to rethink agriculture, since the discussion surrounding agriculture remained unchanged in Europe, although the worldwide context had rapidly and fundamentally shifted.

Le Foll expressed his conviction that the old model of agriculture has reached its limits, constrained by natural resource availability. He cited his involvement in the Groupe Saint Germain, composed of European researchers, experts and farmers, keen to develop the concept of a new agricultural paradigm to replace the dominant post-war production model. Le Foll went on to enumerate a number of examples where energy dependency and unsustainable agriculture were in collision with, or were even exacerbating, the constraints of limited resources.

In order to face these challenges, agriculture should be fundamentally rethought, exploiting research and knowledge leading to appropriate new technologies, which then have to be integrated into the common agricultural policy. This represents for le Foll what Michel Griffon called a 'double green revolution'[36], becoming the core of the new agricultural paradigm.

In this context, le Foll referred to conservation agriculture as one example of these new forms of agriculture that aim to optimise the functioning of the ecosystem, energy cycle and protection from erosion through soil conservation and permanent cover. Conservation agriculture also provides energy savings and cost reductions. At the European level, le Foll called for innovative research in this field and for the broad dissemination of the results.

Regarding the common agricultural policy, le Foll appealed for a switch from a 'logic of control' to a 'logic of contract', which would integrate and involve farmers in the process of change.

Concluding, le Foll recalled the final step of the project, the dissemination of the results and of the acquired knowledge, hoping that dissemination would help change mentalities and mobilise stakeholders, thereby bringing agriculture and society closer together.

Presentations: SoCo project: Background and Objectives (M. Scheele, Head of Unit DG AGRI.H1)**;** SoCo project: Methodology and Management (P. Sørup, Head of Unit JRC/IPTS, AGRILIFE).

Martin Scheele introduced the project by first outlining the initiative of the European Parliament. He then presented the policy context, the project's overall objectives and finally the administrative and organisational structure (work packages).

After introducing the Joint Research Centre, Per Sørup clarified the internal JRC arrangement of the project. He then concentrated on the general conceptual approach by which the project

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[36] Fok, M., Griffon, M., (1998): 'Double green revolution: a challenging contribution towards sustainable development of agriculture in the 21st century'. *Science & Technology Review* 4, pp. 37-39.

objectives would be achieved and how this was translated into individual work packages. Finally, Per Sørup briefly introduced the case study areas.

6.2 Session 1: Agricultural soil conservation context

Presentation: Soil Conservation problems, agriculture and policies: EU-wide review (SoCo): first results (T. Ratinger and S.H. Gay, JRC/IPTS).

The coordinator of the SoCo project, Tomas Ratinger presented the current status of the EU-wide stock-taking (WP1) of soil degradation processes, soil conservation techniques and policy measures relevant to agricultural soil protection and conservation designed at EU-level.

Wind and water erosion, loss of soil organic matter, compaction, salinisation/sodification and soil biodiversity decline are the five soil degradation processes that were taken into account. Currently, the extent of the various soil degradation risks is assessed mostly through static models using the European Soil Database and CORINE Land Cover. Consequently, issues to be addressed from the methodological point of view are the lack of information on farming practices at the required scale, which renders an actual (rather than a risk) assessment of soil degradation processes difficult, the need for clear thresholds for policy practice, and insufficient knowledge on impacts (causalities).

For the project, two farming systems (conservation agriculture (CA) and organic farming (OF)) and eleven conservation practices (no-tillage, reduced tillage, cover crops, ridge tillage, agroforestry, buffers, contour farming, intercropping, subsoiling, terracing, water management) were undergoing assessment from the environmental and economic perspectives, and regarding their effectiveness in addressing soil degradation processes. These practices appear to have varying capacity for achieving environmental objectives, and knowledge regarding their economic implications is limited. Furthermore, with the exception of CA and OF, information on the uptake and continuing use of conservation practices is limited.

The policy analysis within the project is based on a literature review (ranging over the entire EU) and a policy survey at national and regional scale, covering the two CAP pillars (market and income support and rural development). While the EU policy provides the framework, sufficient flexibility in the national/regional implementation is left to the Member States to address their needs. National implementation of CAP measures is mostly action-oriented, focussing on farming practices. Literature on the evaluation of policy effectiveness and efficiency is scarce, and the available studies lack consistency between each other.

It was concluded that information for the different aspects of the stock-taking was available, albeit with gaps. Literature on linking the fields (policy measures – farming practices – soil degradation processes) is, however, scarce. The ongoing SoCo case studies would provide the level of detail required to address the links between these elements at regional/farm level and the factors (including property rights and farmers' awareness) affecting these links.

Discussion

There was not unreserved agreement that LFA payments always help to prevent soil degradation, because the continuation of farming (especially arable farming) can – like abandonment - have negative consequences for soil protection.

A policy response to the issues surrounding the management of peatland under agriculture, given its high carbon content and vulnerability to drainage practices, was demanded. Identifying peatlands at a European scale is, however, difficult since adequate data are not available. The issue (including its link with drainage practices and greenhouse gas emissions) is covered in the proposed Soil Framework Directive (SFD).

The Driving force-Pressure-State-Impact-Response (DPSIR) framework was recommended as a successful tool for moving from the strategic to the operational level. The SoCo project is using a similar methodological approach in its case studies, identifying problems, state and action at the operational level. Farming practices and their link with soil conservation are indeed crucial in helping Member States to address soil quality issues when designing policy measures.

There was an appeal for greater recognition of the potential roles for other interested parties apart from policy makers and farmers. It was agreed that machinery suppliers, for example, generally follow the trends in agriculture and agricultural policy very quickly and can contribute effectively to soil conservation.

6.3 Session 2: Soil conservation practices – agricultural perspective

Presentation: Conservation Agriculture: The sustainable response for soil conservation and other challenges facing European Agriculture (G. Basch, Universidade de Évora, Portugal/European Conservation Agriculture Federation).

Referring to the eight soil degradation processes as defined in the Soil Thematic Strategy (erosion, organic matter decline, compaction, soil biodiversity decline, landslides and floods, contamination, salinisation and sealing), Gottlieb Basch elaborated upon the first five in addressing their direct link with agricultural land use and different farming systems. He advocated soil management as being the key to soil conservation. Conservation agriculture (CA) in particular promotes soil protection by causing no or minimum soil disturbance, using cover crops or continuous cover residues, and adopting crop rotation. Moreover, it responds to the CAP objectives of protecting abiotic and biotic natural resources and landscape, whilst maintaining profitability and competitiveness. The speaker stressed that the effective implementation of CA is supported by GAEC requirements, the Water Framework Directive, the Air Quality Framework Directive and the proposed Soil Framework Directive (SFD). He subsequently gave an overview of the extent of CA (no-tillage, minimum tillage and cover crops) in Europe (15 countries) with estimates of its uptake area (no-tillage) worldwide; in total, 15.5 % of the arable land in the reported European countries was under CA management in 2005/06 (Source: ECAF). He closed by calling for more accurately defined standards that would oblige Member States to mitigate soil threats, whilst recognising the benefits of the CA concept, incentivising farmers to adopt soil conservation measures with an emphasis on CA and compensating farmers during the transition period.

Presentation: Position of farmers on soil conservation practices (A. Reinl, Austrian Chambers of Agriculture, Austria/Vice-Chairman of COPA-COGECA Working Group on Environment).

Against the background of the current legislation on soil protection, Anton Reinl gave an overview of the achievements of European agriculture with respect to the environment. He emphasised the rich landscape diversity, the increase in protected areas and organic production, the strong improvement in water quality in several Member States, the reduction in greenhouse gas emissions from agriculture (with a drop of 11 % and 20 % since 1990 for the EU-15 and EU-27 respectively), and the increase in renewable energy production from agricultural and forestry sources.

He mentioned the remaining challenges for soil conservation, including the private ownership status of soil (unlike resources such as air, wild flora and fauna), soil as a carbon sink in adapting to climate change, the increasing demand for agricultural products (food and energy), the maintenance of agricultural production in all regions and quantitative soil protection. Despite possible conflicts between different environmental targets, the speaker pointed out that agri-environment measures are being successfully adopted by farmers and obtaining environmental improvements, soil erosion control and nutrient leaching. He closed by recommending continued education, training, advice and research; a regional approach through incentives (such as agri-environment measures, or stakeholder consultation in water services), special contracts for 'hot spots' through sponsoring, investment aid for environmental techniques (e.g. equipment for direct seed drilling) and coherent environmental legislation, duly reflected in trade rules.

Discussion

Stakeholders expressed their concern that, even over time, adoption of CA would not necessarily allow new equilibria (for example, in organic carbon levels) to be reached, and that the use of phyto-pharmaceutical products could well increase under CA. Other stakeholders considered that herbicide use does not necessarily decrease under CA and, furthermore, CA uses so-called contact herbicides, which are of a different type.

Stakeholders also emphasised the importance of standards and indicators for good agricultural practice. The OECD was mentioned as providing criteria and the proposed Soil Framework Directive (SFD) as providing clear standards/indicators for farmers and policy makers (as opposed to the existing GAEC). The speakers agreed on the need to identify indicators, and recognised the challenge involved in collecting sufficient information in order to establish standards and to make indicators region-specific. They also suggested that the agricultural supply industry can provide farmers with technical means to meet standards and restrictions on farming practices. Another stakeholder called for adapting indicators to regional conditions, considering the dynamic nature of indicators like organic carbon content.

The diversity of agricultural systems and agro-climatic conditions throughout Europe was highlighted and a case-by-case, site-specific approach was recommended as regards developing and recommending solutions such as CA. Agri-environment measures and organic farming were welcomed as enabling such site-specific approaches. Site-specificity was also referred to regarding research into possible trade-offs between different environmental objectives.

In response to reservations expressed regarding the progress of agriculture on environmental matters, the COPA-COGECA speaker highlighted the importance of extension services and science in providing farmers with the necessary information in order to cope with responding to the policy changes and adopting new practices. Research findings and farmers' expertise were seen as important inputs into soil and environment conservation and for creating the 'new agicultural model' advocated by MEP Le Foll in his speech, the latter requiring a global or at least a concerted European approach.

One stakeholder asked for analyses of the economic sustainability of technical requirements, for example, in reconciling no-tillage with other aspects of sustainable production systems exploiting soil as a carbon sink.

6.4 Session 3: Costs and benefits of soil conservation practices

Presentation: Environmental and economic perspective (J. Labreuche, ARVALIS Institut du vegetal, France).

Jérôme Labreuche emphasised the importance of long-term experiments in assessing the environmental and economic impact of farming practices. Experiments on non-inversion tillage techniques indicate a positive impact on environmental components, as reduced energy needs and greenhouse gas emissions, reduced erosion along with reduced run-off of nutrients and pesticides subsequently affecting water quality, and farm management aspects like reduced time and cost of production. As negative side-effects, he mentioned crop protection aspects (use of herbicides, pesticides), (somewhat) increased drainage of phosphorus and pesticides into groundwater and the specialised knowledge required to apply conservation agriculture. Despite the overall positive balance, the speaker nevertheless emphasised the gap between the outcome of experiments and daily farming practice.

Presentation: Conservation Agriculture: an answer to European challenges (K. Schreiber, Association pour la Promotion d'une Agriculture Durable (APAD)/AgriBretagne Agriculture Sol et Environnement (BASE), France).

Referring to the European challenges in terms of food production, resource preservation and climate change and Europe's dependence on food, feed and energy, Konrad Schreiber addressed the potential of CA as a possible response. After having outlined the environmental and economic benefits of CA, he argued that CA is in line with the principles of the sustainable agriculture ecosystem model: producing (economy) for consumption (society) while recycling (environment).

He subsequently illustrated his view of the reality of soil degradation with soil chemical characteristics (pH, C, N, cations) from soils under different management techniques: plough, reduced tillage and no-tillage (Source: the Coopagri laboratory in Bretagne). With time, ploughing proved harmful, showing decreasing levels of organic C and total N. By contrast, soil conservation technologies present a high potential for both production of biodiversity as well as biomass for food, feed and energy, together with an enhanced CO_2 sink function. In this sense APAD/BASE applied no-tillage (with permanent soil cover) in a five-year rotation ('Semis direct sous Couvert Végétal Énergie '). Extrapolated to the European Union and applying the successful sequence to half of the total arable area, this would result in a potential energy production of 60 and 100 million tons of grain and biomass respectively. The speaker concluded that soil protection and maintenance of the carbon cycle are crucial in adapting Europe's agriculture to climate change and providing society with ecological services.

Discussion

Stakeholders referred to the limitations of CA in dealing with animal husbandry and mixed farming. Others stated that CA does not adequately address the biological function of the soil, as ecosystems consist of a range of organisms and are not limited to earthworm activity. CA further requires a medium-term transition period (3-5 years) before economic benefits can arise; more holistic systems offering a wide spectrum from intensive to no-tillage were thus called for to address these time issues. Correspondingly, stakeholders expressed the opinion that the CAP should establish a range of systems and models, including other relevant farming practices as well as CA.

One representative was concerned that the dynamics of micro-economic units (individual households) as well as macro-economic outcomes should be taken into account. Regarding the latter, it was questioned whether money spent on Pillar 2 of the CAP was justified.

6.5 Session 4: Existing policy framework

Presentation: The Policy Framework for Soils: Design, Implementation and Institutional Issues (D. Baldock - Institute for European Environmental Policy).

David Baldock began by focussing on the necessity for a policy intervention with regard to soil protection. Soils are in the process of being degraded by avoidable anthropogenic, as well as natural, causes. At the same time, the value of the resource is likely to increase over time with growing demands for both crop production and ecosystem services, such as carbon sequestration. Experience indicates that it is not sufficient to rely on market forces and the predominantly shorter-term perspective of land owners and occupiers to achieve good management. Whilst farmers and other land managers have an interest in soil conservation, they do not necessarily have the knowledge, motivation or means to adopt good practice and meet wider social objectives.

Historically, policy measures to protect soil have not been adopted or implemented with the vigour that might be expected, compared to policy measures related to other environmental media. The great variety of soil conditions, contexts and management practices, and the importance of local factors in determining outcomes is only one reason for this. There is also a sense that private owners should be sufficiently self-interested and long-sighted to manage their own soil.

There is a wide variety of policy interventions affecting soils, based on the agricultural and environmental policy framework. Many are concerned with environmental aspects of agricultural land management without necessarily including very specific provisions for soils. Policy interventions on the EU-level include a range of environmental regulations (such as the Sewage Sludge and Nitrates Directives), mandatory requirements arising from agricultural policy (especially those within the GAEC requirement), incentives for appropriate land management (such as agri-environment measures), investment aid for productive or 'unproductive' investments affecting soil, mainly through Pillar 2 of the CAP, guidance, advice, information on good practice and training for farmers.

In principle, agri-environment schemes will tend to benefit soils, but most of the prescriptions focus on other parameters. GAEC refers explicitly to soils and there is some information about how Member States have translated these requirements into specific standards and guidelines. Guidance and advice may be quite specific, for example about input use or the management of vulnerable soils.

There is a wide range of targeted agri-environment measures, with an extensive application in the EU but not necessarily in the areas with the greatest soil conservation challenges. The evidence of impacts on soils is not readily available but some case studies have provided insights.

Within GAEC, a wide range of obligations relating to soil erosion exist within Member States. The most common requirement is to maintain soil coverage beyond a minimum level (17 Member States). Requirements to introduce measures that respond to site-specific conditions are also widespread (e.g. areas with high erosion risk). Nine Member States have introduced requirements to maintain terraces. The impact on the ground of all GAEC obligations is not yet clear.

Agri-environment measures are developed by a combination of agricultural and environmental authorities. Agricultural ministries and agencies are in the lead on most soil specific measures. They are typically advised by technical institutions, some with dedicated soil expertise. Advice is usually offered via extension services with a general remit, not by soil specialists.

It is necessary to have a robust evidence base and adequate data to respond to the soil challenges. Monitoring of the status of soils, and the effect and efficiency of political and technical measures are especially important as a basis for successful soil protection. The political will and engagement requires local, national and EU commitment to ensure the enforcement of soil protection.

Discussion

During the discussion, the involvement of farmers in the policy making and implementation process was stressed by several stakeholders. The need for support in training farmers in order to face the technical complexity of farming techniques was reiterated. Here, the issue of property rights was also mentioned as private ownership of land may limit public intervention. The balance between different and partly conflicting policy aims should be considered. Flexibility for Member States and even regions in the implementation allows for maintaining the diversity of Europe and catering for the local agri-environmental conditions. This context-specificity also includes a challenge for soil monitoring and database set-up. On the other hand, soil protection aims are, at the moment, not legally coordinated at the EU level and appear in different policies. In the framework of the Rural Development Regulation and especially regarding agri-environment measures, specific reference to soil protection was proposed by stakeholders.

References

Abildtrup, J., Dubgaard, A. and Andersen, K.S. (2006): Support to organic farming and bio-energy as rural development drivers. In: Saxe, H. and Rasmussen C. (eds.): *Green roads to growth*, proceedings of expert and policy maker forums, Copenhagen, 1-2 March 2006. Institute for miljøvurdering, pp. 348-393. Available at: http://orgprints.org/13198/01/13198.pdf.

Acs, S. (2006): *Bio-economic modelling of conversion from conventional to organic farming*. PhD Thesis, Wageningen University, The Netherlands, 152 pp. Available at: http://library.wur.nl/wda/dissertations/dis4002.pdf.

AEAC.SV. (2006): Consumo de gasoil y maquinaria agrícola: ahorro gracias a la Agricultura de Conservación. *Revista de la Asociación Española de Agricultura de Conservación/Suelos Vivos* 3. Available at: http://www.aeac-sv.org/pdfs/revistaac3.pdf.

Aibar, J. (2006): The control of weeds in cereals under no-tillage conditions: Main problems. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 19-26.

Alakukku, L., Weisskopf, P., Chamenc, W.C.T., Tijink, F.G.J., van der Linden, J.P., Pires, S., Sommer, C. and Spoor, G. (2003): Prevention strategies for field traffic-induced subsoil compaction: a review Part 1, machine/soil interactions. *Soil and Tillage Research* 73, pp. 145-160.

Alegre, J., Alonso-Blázquez, N., de Andrés, E.F., Tenorio, J.L. and Ayerbe, L. (2004): Revegetation and reclamation of soils using wild leguminous shrubs in cold semi-arid Mediterranean conditions: Litterfall and carbon and nitrogen returns under two aridity regimes. *Plant and Soil* 263, pp. 203-212.

Alliance Environment (2007a): *Evaluation of the application of cross compliance as foreseen under regulation 1782/2003.* Part I: descriptive report; Available at: http://ec.europa.eu/agriculture/eval/reports/cross_compliance/index_en.htm.

Alliance Environment (2007b): Evaluation of the application of cross compliance as foreseen under Regulation 1782/2003. Part II: Replies to evaluation questions. Deliverable prepared for DG Agriculture. Available at: http://ec.europa.eu/agriculture/eval/reports/cross_compliance/part2.pdf.

Álvarez, M.A., González-Barragán, M.I., de Benito, A. and Sombrero, A. (2004): *Tillage systems and crop rotation effect on soil properties in a semi-arid region of the Duero basin*. Actas VI Congreso SEAE. II, Congreso Iberoamericano Agroecología. Almería, Spain.

Alvaro-Fuentes, J., López, M.V., Cantero-Martínez, C., Garcias, R. and Arrue, J.L. (2006): No-tillage, soil organic matter and soil structure: relationships and implications. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 149-153.

Ancelin, O., Bonafos, A., Caboulet, D., Cahurel, J.Y., Darboux, F., Derancourt, F., Duval, R., Heddadj, D., Labreuche, J., Le Bissonnais, Y., Longueval, C., Luce, M., Martin, P. and Ouvry, J.F. (2007): *Impact des TCSL sur le ruissellement et l'érosion. Assessment of the environmental impact of non-inversion tillage methods in France.*

Anderson, J.E., Brady, D.W. and Bullock, C.S. (1978): *Public Policy and Politics in America*. North Scituate, MA.

Andrén, O. and Lagerlof, J. (1983): Soil fauna (microarthropods, enchytraeids, nematodes) in Swedish agricultural cropping systems. *Acta Agriculturae Scaninavica* 33, pp. 33-52.

Andrén, O., Lindberg, T., Paustian, K. and Rosswall, T. (eds.) (1990): *Ecology of arable land. Organisms, carbon and nitrogen cycling.* Ecology Bulletin. Munksgaard, Copenhagen.

Angelici, L.G., Mazzoncini, M. and Tonioni, A. (1997): Long-term effects of reduced tillage practices and differential nitrogen fertilization on yield and nutrient uptake of winter wheat. *Fragmenta Agronomica* 2, pp. 27-30.

Antle, J.M., Valdivia, R.O., Crissman, C.C., Stoorvogel, J.J. and Yanggen, D. (2004): Spatial heterogeneity and adoption of soil conservation investments: Integrated assessment of slow formation terraces in the Andes. Preliminary version of a paper published in 2005. *Journal of International Agricultural Trade and Development* 1(1), pp. 29-53. Available at: http://www.tradeoffs.montana.edu/pdf/soilcons.pdf.

APAD (Association pour la Promotion d'une Agriculture Durable) (2008): Web site. Available at: http://www.apad.asso.fr/sommaire.html.

Arbieri, J.L., Alleoni, L.R.F. and Donzelli, J.L. (1997): Agronomic and economic analysis of soil tillage systems for sugarcane. *Revista brasileira de ciência do solo* 21 (1), pp. 89-98.

Archer, D.W., Pikul, J.L. and Riedell, W.E. (2002): Economic risk, returns and input use under ridge and conventional tillage in the northern Corn Belt, USA. *Soil and Tillage Research* 67 (1), pp. 1-8.

Argilés, J.M. and Duch Brown, N. (2008): *A comparison of the economic and environmental performances of conventional and organic farming: Evidence from financial statements*. University of Barcelona, Institut d'Economia Barcelona. Available at: http://www.pcb.ub.es/ieb/aplicacio/fitxers/2007/12/Doc2007-8.pdf.

Arnal Atarés, P. (2006): Semis direct dans la vallée moyenne de l'Ebre: résumé des résultats et analyse économique. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 77-85.

Arnoldus, H.M.J. (1980): An approximation of the rainfall factor in the Universal Soil Loss Equation. In: de Boodt, M., Gabriels, D. (eds.): *Assessment of Erosion*, Wiley, Chichester, pp. 127-132.

Arrouays, D., Balesdent, J., Germon, J.C., Jayet, P.A., Soussana, J.F. and Stengel, P. (2002): *Increasing carbon stocks in French agricultural soils?* Synthesis of an assessment report, Editions INRA.

Arrúe, J.L., López, M.V., Moreno, F., Murillo, J.M., Cantero-Martínez, C., Sombrero, A., Tenorio, J.L., Zambrana, E., Pérez de Ciriza, J.J., Mrabet, R., Cardarelli, A. and Kavvadias, V. (2005): *Comprehensive inventory and assessment of existing knowledge on sustainable agriculture*. KASSA project, Mediterranean platform, assessment report R 1.2, work package 1.1, 26 p.

Arrue, J.L., Cantero-Martínez, C., Cardarelli, A., Kavvadias, V., Lopez, M.V., Moreno, F., Mrabet, R., Murillo, J.M., Perez de Ciriza, J.J., Sombrero, A., Tenorio, J.L. and

Zambrana, E. (2007a): *Comprehensive inventory and assessment of existing knowledge on sustainable agriculture*. KASSA project, Mediterranean platform.

Arrue, J.L., Cantero-Martínez, C., López, M.V., Moreno, F., Murillo, J.M., Pérez de Ciriza, J.J., Sombrero, A., Tenorio, J.L. and Zambrana, E. (2007b): *Conservation agriculture research in Spain.* KASSA project, Mediterranean platform, deliverable 1.2, appendix A1.

Auerswald, K. and Schmidt, F. (1986): *Atlas der Erosiongefährdung in Bayern.* GLA Fachberichte 1, Bayerisches Geologisches Landesamt, München.

Baker, C.J. (2007): Some economic comparisons. In: Baker, C.J. and Saxton K.E. (eds.): *No tillage seeding and conservation agriculture*, 2nd edition, FAO and CAB International 2007, pp. 268-277.

Bakker, M.M., Govers, G., Jones, R.A. and Rounsevell, M.D.A. (2007): The effect of soil erosion on Europe's crop yields. *Ecosystems* 10 (7), pp. 1209-1219. Springer, New York.

Balesdent, J. (2002): Estimations chiffrées, par unité de surface, du stockage de carbone dans le sol associé aux changements de pratiques agricoles. In: Arrouays, D., Balesdent, J., Germon, J.C., Jayet, P.A., Soussana, J.F. and Stengel, P. (2002): *Increasing carbon stocks in French agricultural soils?* Synthesis of an assessment report, Editions INRA, pp. 115-200.

Bardgett, R.D. and Cook, R. (1998): Functional aspects of soil animal diversity in agricultural grasslands. *Applied Soil Ecology*, 10, pp. 263-276.

Bartholomé, E. and Belward, A.S. (2005): GLC2000: A new approach to global land cover mapping from earth observation data. *International Journal of Remote Sensing* 26 (9), pp. 1959-1977.

Baruth, B., Genovese, G. and Montanarella, L. (2006): *New soil information for the MARS crop yield forecasting system,* Office for Official Publications of the European Communities, Luxembourg, 95 p.

Barz, P., Edwards, T., Campbell, T.I. and Hood, D.W. (2007): *Alternative agricultural systems in the United Kingdom*. KASSA project, European Platform, deliverable 1.1, appendix A8.

Barzel, Y. (1997): *Economic analysis of property rights*. 2nd edition, Cambridge, Cambridge University press.

Baumol, W.J. and Oates, W.E. (1979): *Economics, environmental policy and the quality of life*. Englewood Cliffs, N.J., Prentice-Hall.

Beaufoy, G. (1998): The EU habitats directive in Spain: can it contribute effectively to the conservation of extensive agroecosystems? *Journal of Applied Ecology* 35, pp. 974-978.

Beck, D.L. (2005): *An emphasis on rotations*. Dakota Lakes Research Farm. Available at: http://www.notill.org/KnowledgeBase/03_emphasisrotations_Beck.pdf.

Beinhauer, R. and Kruse, B. (1994): Soil erosivity by wind in moderate climates. *Ecological Modelling* 75/76, pp. 279-287.

Bellamy, P.H., Loveland, P.J., Bradley, R.I., Lark, R.M. and Kirk, G.J.D. (2005): Carbon losses from all soils across England and Wales 1978-2003. *Nature*, Letters 437, pp. 245-248.

Bellows, B. (2004): *Irrigation*. National Sustainable Agriculture Information Service, http://attra.ncat.org/downloads/water_quality/irrigation.pdf.

Benedetti, A. and Ciavatta, C. (1998): Cuoio idrolizzato e/o torrefatto. I fertilizzanti organici. *Edizioni L'Informatore Agrario*, pp. 49-66.

Bescansa, P., Imaz, M.J., Virto, I., Enrique, A., Pérez de Ciriza, J.J., Delgado, J., Irañeta, I. and Díaz, E. (2006a): Laboreo de conservación y calidad de suelos. Un ensayo de larga duración en Olite (Navarra), *Navarra Agraria* 157 (in Spanish).

Bescansa, P., Imaz, M.J., Virto, I., Enrique, A. and Hoogmoed, W.B. (2006b): Soil water retention as affected by tillage and residue management in semi-arid Spain. *Soil and Tillage Research* 87, pp. 19-27.

Birkás, M., Gyuricza, C., Percze, A. and Szalai, T. (1998): Experiments with ridge tillage for maize in a brown forest soil. *Novenytermeles* 47(5), pp. 559-571.

Birkás, M., Szalai, T., Gyuricza, C., Gesce, M. and Bordas, K. (2002): Effects of disk tillage on soil condition, crop yield and weed infestation. *Rostlinna Vyroba* 48 (1), pp. 20-26.

Birkás, M., Jolánkai, M., Gyuricza, C. and Percze, A. (2004): Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. *Soil and Tillage Research* 78, pp. 185-196.

Boame, A.K. (2005): *Zero tillage: a greener way for Canadian farms*. Agriculture Division of Statistics Canada, Catalogue no. 21-004-XIE. Available at: http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/21-004-X/21-004-XIE2005006.pdf.

Bonari, E., Mazzoncini, M. and Peruzzi, A. (1995): Effects on conventional and minimum tillage on winter oilseed rape (Brassica napus L.) in a sandy soil. *Soil and Tillage Research* 33 (2), pp. 91-108.

Bradbury, R.B. and Kirby, W.B. (2006): Farmland birds and resource protection in the UK: Cross-cutting solutions for multi-functional farming? *Biological Conservation* 129, pp. 530-542.

Bromley, D.W., Hodge, I. (1990): Private property rights and presumptive policy entitlements reconsidering the premises of rural policy. *European Review of Agricultural Economics* 17(2), pp. 197-214.

Canenbley, C. (s.a.): *Evaluating the Common Agricultural Policy*. Presentation. European Commission, Agriculture and Rural Development Directorate General, AGRI G.4. Available at: http://www.rlg.nl/english/publications/downloads/canenbly.ppt.

Cantero-Martínez, C., Angás, P. and Lampurlanés, J. (2003): Growth, yield and water productivity of barley (Hordeum vulgare L.) affected by tillage and N fertilization in Mediterranean semiarid, rainfed conditions of Spain. *Field Crops Research* 84, pp. 341-357.

Cantero-Martínez, C., Angás, P., Ameziane, T. and Pisante, M. (2004): Land and water management technologies in the Mediterranean region. *Options Méditerranéennes* Serie A 60, pp. 35-50.

Carter, M.R. (2004): Researching structural complexity in agricultural soils. Advances in soil structure. *Soil and Tillage Research* 79(1), pp. 1-6.

Castillon, P., Dorioz, J.M. and Hanocq, D. (2007): Impacts des TCSL sur le transfert de phosphore vers le réseau hydrographique. In: *Assessment of the environmental impact of non-inversion tillage methods in France*, p. 19.

Cenci, R. M. and Sena, F. (eds.) (2006): *BIO-BIO Project. Biodiversity-Bioindication to evaluate soil health.* EUR 22245 EN, 148 p.

Centemero, M. and Corti, C. (2000): *Impiego e commercializzazione del compost da matrici organiche selezionate, produzione ed impiego del compost di qualità*. Atti del 4° Corso nazionale di base, Consorzio italiano compostatori, pp. 219-250.

Challen, R. (2001): *Non-government approaches to the provision of non-commodity. agricultural outputs: a transaction-cost perspective.* OECD-Workshop on Multifunctionality, Paris, 2-3 July 2001.

Chan, Y. (2008): Defining carbon in soil, *Agriculture Today* 3. NSW Department of Industries. Available at: http://www.dpi.nsw.gov.au/aboutus/news/agriculture-today/march-2008/defining-carbon-in-soil.

Chapin, F.S. III, Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. and Diaz, S. (2000): Consequences of changing biodiversity. *Nature* 405, pp. 234-242.

Chepil, W.S. (1955): Factors that influence clod structure and erodibility of soil by wind. IV. Sand, silt and clay. *Soil Science* 80, pp. 155-162.

Cooper, T., Baldock, D., Rayment, M., Kuhmonen, T., Terluin, I., Swales, V., Poux, X., Zakeossian, D. and Farmer, M. (2006): *An evaluation of LFA measure in the 25 Member States of the European Union.* IEEP report, London.

Core 4 Conservation for Agriculture's Future (2002): *Tillage type definitions*. Available at: http://www2.ctic.purdue.edu/Core4/CT/Definitions.html.

CORINE (COoRdination of INformation on the Environment) (2008): Web site. Available at: http://reports.eea.europa.eu/COR0-landcover/en.

Cots-Folch, R., Martínez-Casasnovas, J.A. and Ramos, M.C. (2006): Land terracing for new vineyard plantations in the north-eastern Spanish Mediterranean region: Landscape effects of the EU Council Regulation policy for vineyards' restructuring. *Agriculture, Ecosystems and Environment* 115, pp. 88-96.

Curry, J.P. (1994): *Grassland invertebrates*. Chapman and Hall, London.

De Alba, S. (2003): Simulating long-term soil redistribution generated by different patterns of mouldboard ploughing in landscapes of complex topography. *Soil and Tillage Research* 71, pp. 71-86.

De Alba, S., Borselli, L., Torri, D., Pellegrini, S. and Bazzoffi, P. (2006): Assessment of tillage erosion by mouldboard plough in Tuscany (Italy). *Soil and Tillage Research* 85, pp. 123-142.

De Alba, S. and Barbero, F. (2007): Effectiveness of contour tillage to reduce water erosion during extreme rainfall events. *Geophysical Research Abstracts* 9, 11328.

De Benito, A., Sombrero, A., Escribano, C. (1998): *Soil moisture evolution and its relation with cereal yield in different tillage systems in the Duero Basin.* In: Zima, M. and Bartosova, M.L. (eds.): IV Congress European Society of Agronomy. Nitra, Slovakia, pp. 49-50.

De Benito, A., Sombrero, A. and Escribano, C. (1999): Influence of conservation tillage on soil properties. *Agricultura* LXVIII, pp. 538-541.

De Kalbermatten, G.G. (2008). *Implementing the UNCCD Strategy: Reflections on how better to integrate science's contribution on soil and land issues*. Oral presentation at the EuroSoil conference, Vienna, 27 August 2008.

De Tourdonnet, S., Chenu, C., Straczek, A., Cortet, J., Felix, I., Gobtier, L., Heddadj, D., Labreuche, J., Laval, K., Longueval, C., Richard, G. and Tessier, D. (2007a): Impact des TCSL sur la qualité des sols et la biodiversité. In: *Assessment of the environmental impact of non-inversion tillage methods in France*, p. 39.

De Tourdonnet, S., Nozières, A., Barz, P., Chenu, C., Düring, R.A., Frielinghaus, M., Kõlli, R., Kubat, J., Magid, J., Medvedev, V., Michels, A., Müller, L., Netland, J., Nielsen, N.E., Nieves Mortensen, C., Picard, D., Quillet, J.C., Saulas, P., Tessier, D., Thinggaard, K. and Vandeputte, E. (2007b): *Comprehensive inventory and assessment of existing knowledge on sustainable agriculture in the European platform*. KASSA project, European platform, deliverable 1.1.

DEFRA (Department for Environment, Food and Rural Affairs) (2008): *A review of the literature on the strategic placement and design of buffering features for sediment and P in the landscape*, DEFRA Project PE020, Appendix B. Available at: http://randd.defra.gov.uk/Document.aspx?Document=PE0205_6736_FRA.pdf.

DeJong-Hughes, J., Moncrief, J.F., Voorhees, W.B. and Swan, J.B. (2001): *Soil compaction: causes, effect and control.* Communication and Educational Services; University of Minnesota Extension Service. Available at: http://www.extension.umn.edu/distribution/cropsystems/components/3115s02.html#summary (Retrieved: April 2008).

Dersch, G. and Boehm, K. (1997): Bodenschutz in Österreich. In: Blum, W. E. H., Klaghofer, E., Loechl, A. and Ruckenbauer, P. (eds.): *Bodenschutz in Österreich*, Bundesamt und Forschungszentrum für Landwirtschaft, Wien, pp. 411-432.

Díaz, A.R., Sanleandro, P.M., Soriano, A.S., Belmonte Serrato, F. and Faulkner, H. (2007): The causes of piping in a set of abandoned agricultural terraces in southeast Spain. *Catena* 69, pp. 282-293.

Dimopoulos, D., Fermantzis, Y., Vlahos, G. and Farmer, M. (2006): The responsiveness of cross compliance standards to environmental pressures, *Cross Compliance Network Bulletin*. Available at: http://www.ieep.eu/publications/pdfs/crosscompliance/Cross%20Compliance%20Network%20Bulletin%20Autumn%202006.pdf.

DISME (Desertification Indicators System for Mediterranean Europe) project (2004): *Tillage direction.* Available at: http://www.geog.leeds.ac.uk/people/m.kirkby/DIS4ME_1104/indicator_descriptions/tillage_direction.htm.

Dorren, L. and Rey, F. (2004): *A review of the effect of terracing on erosion*. Soil Conservation and Protection for Europe (SCAPE) project.

Dumanski1, J. Peiretti, R., Benites, J.R., McGarry, D. and Pieri, C. (2006): *The paradigm of Conservation Agriculture.* Proceedings of World Association of Soil and Water Conservation P1, pp. 58-64. Available at: http://www.unapcaem.org/admin/exb/ADImage/ConservationAgri/ParaOfCA.pdf.

Duveskog, D. (2003): *Soil and water conservation. The farm level applied research methods for East and Southern Africa*, GCP/RAF/334/SWE. Available at: ftp://ftp.fao.org/agl/agll/farmspi/FARMESA_SWC1.pdf.

ECAF (European Conservation Agriculture Federation) (2008a): *What is Conservation Agriculture?* Available at: http://www.ecaf.org/news.html#3.

ECAF (European Conservation Agriculture Federation) (2008b): *Situation of Conservation Agriculture in Europe.* Available at: http://www.ecaf.org/Situation.htm.

Eckelmann, W., Baritz R., Bialousz, S., Carre, F., Jones, R.J.A., Kibblewhite, M., Kozak, J., Le Bas, C., Tóth, G., Várallyay, G., Yli Halla, M. and Zupan M. (eds.) (2006): *European Soil Bureau research report* No.31. EUR 22185 EN, 103 p. Office for Official Publications of the European Communities, Luxembourg.

EEA (European Environment Agency) (2003): *Environmental assessment report No 10*, Chapter 9, Soil Degradation, Copenhagen, Denmark.

EEA (European Environment Agency) (2006): *Integration of environment into EU agriculture policy*, *the IRENA indicator based assessment report*, Copenhagen, Denmark.

EEA (European Environment Agency) (2007): *Progress in management of contaminated sites* (CSI 015), assessment published August 2007. Available at: http://themes.eea.europa.eu/IMS/ISpecs/ISpecification20041007131746/IAssessment1152619898983/view_content.

EEA (European Environment Agency) (2008): *Support for agri-environmental analysis at the EEA*, EEA/EAS/06/002 Framework Contract.

EEB (European Environmental Bureau) (2006): *EU soil policy "From neglect to protection". The need for EU level legal protection.* Available at: http://www.eeb.org/activities/Soil/documents/EEBpositionpaperonaSoilThematicStrategy_002.pdf (retrieved: April 2008).

EGF (European Grassland Federation) (2007): *Permanent and temporary grassland plant, environment and economy*. Proceedings of the 14th Symposium of the European Grassland Federation Ghent, Belgium 3-5 September 2007. Available at: http://www.ilvo.vlaanderen.be/NGdec07/Boeken.htm.

Eggers, J., Mettepenningen, E., Beckmann, V., Kunz, A. and Hagedorn, K. (2005): *Analysing institutional arrangements of agri-environmental schemes in Europe.* Final Report.

Eggers, J., Beckmann, V., Mettepenningen, E., Ehlers, M.H., Hurrelmann, A., Kunz, A. and Hagedorn, K. (2007): *Analysing institutional arrangements for agri-environmental schemes in Europe.* ITAES WP4 final report. Available at: http://merlin.lusignan.inra.fr/ITAES/website/Publicdeliverables.

Eichler, H. (1994): Ackern und Forschen im Kraichgauer Löss. Bemerkungen zu Problemen und Phänomenen der Bodenerosion und der Bodenerosionforschung in einer sich wandelnden agrarischen Welt. *Heidelberger Geographische Gesellschaft,* Journal 7/8, pp. 58-88.

Escribano, J. (2006). Study of the effects of conservation agriculture compared to traditional agriculture. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 57-61.

ESDB (European Soil Database) (2004): European Soil Portal, version 2.0. EUR 19945 EN, European Soil Bureau Network and the European Commission. Web site. Available at: http://eusoils.jrc.it.

ESSC (European Society for Soil Conservation) (2005): Directory of European organisations and persons working on soil protection, Bratislava. Available at: http://www.essc.sk/news/directory_eo.pdf.

European Commission (2006a): *Soil protection – The story behind the strategy*. Office for Official Publications of the European Communities, Luxembourg.

European Commission (2006b): *Germany, France, Italy, United Kingdom, Ireland, Austria – Analysis of the requirements for soil and biodiversity protection as well as for greenhouse gas mitigation within the rural development programmes*, final deliverable. Available at: http://ec.europa.eu/agriculture/analysis/external/soil_biodiv/.

European Commission (2007): *Report from the Commission to the Council and the European Parliament on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources for the period 2000-2003*.

European Commission (2008a): *Environment fact sheet: Natura 2000*. Available at: http://ec.europa.eu/environment/pubs/pdf/factsheets/natura2000_en.pdf.

European Commission (2008b): *Standing Committee on Agricultural Research Portal*. Web site. Available at: http://ec.europa.eu/research/agriculture/scar/index_en.cfm.

European Commission, Agriculture and Rural Development Directorate-General (2005): *Agri-environment measures, overview on general principles, types of measures, and application*. Available at: http://ec.europa.eu/agriculture/publi/reports/agrienv/rep_en.pdf.

European Commission, Agriculture and Rural Development Directorate General (2006): *Fact sheet, the EU Rural Development Policy 2007–2013*.

European Commission, Agriculture and Rural Development Directorate-General (2007): *Rural development in the European Union, statistical and economic information, report 2007*. Available at: http://ec.europa.eu/agriculture/agrista/rurdev2007/index_en.htm.

European Commission, Agriculture and Rural Development Directorate-General (2008a): *Beneficiaries of CAP payments*. Web site. Available at: http://ec.europa.eu/agriculture/funding/index_en.htm.

European Commission, Agriculture and Rural Development Directorate-General (2008b): *EU farming: meeting society's needs and expectations*. Available at: http://ec.europa.eu/agriculture/publi/eufarming2008/text_en.pdf.

European Commission, Budget Directorate-General (2004): *Evaluating EU activities. A practical guide for the commission services*. Available at: http://ec.europa.eu/agriculture/eval/guide/eval_activities_en.pdf.

European Commission, Environment Directorate-General (2007): *Evaluation of soil protection aspects in certain programmes of measures adopted by member states*. Final Report, including Executive summary and Annexes.

EUROSTAT (Statistical Office of the European Communities) (2007a): *Farm structure survey 1999-2005*. Web site. Available at:

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=3075,68081472&_dad=portal&_schema=PORTAL.

EUROSTAT (Statistical Office of the European Communities) (2007b): Different organic farming patterns within EU-25, an overview of the current situation. *Statistics in focus, Agriculture and Fisheries* 69. Available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-069/EN/KS-SF-07-069-EN.PDF.

FADN (Farm Accountancy Data Network) (2008): Web site. Available at: http://ec.europa.eu/agriculture/rica/index_en.cfm.

Falconer, K. (2000): Farm level constraints on agri-environmental scheme participation: a transaction cost perspective. *Journal of Rural Studies* 16(3), pp. 379-394.

Falconer, K., Dupraz, P. and Whitby, M. (2001): An investigation of policy administrative costs using panel data for English environmental sensitive areas. *Journal of Agricultural Economics* 52(1), pp. 83-110.

Falloon, P., Smith, P., Coleman, K. and Marshall, S., (2000): How important is inert organic matter for predictive soil modelling using the Rothamsted carbon model? *Soil Biology and Biochemistry* 32, pp. 433-436.

FAO (Food and Agriculture Organization of the United Nations) (1993a): Soil tillage in Africa: needs and challenges. *FAO soils bulletin* 69. Available at: http://www.fao.org/docrep/t1696e/t1696e09.htm.

FAO (Food and Agriculture Organization of the United Nations) (1993b): *Report of the first external programme and management review of the International Centre for Research in Agroforestry (ICRAF).* Available at: http://www.fao.org/wairdocs/TAC/X5812E/x5812e00.htm#Contents.

FAO (Food and Agriculture Organization of the United Nations) (2000): Manual on integrated soil management and conservation practices, *FAO land and water bulletin*. Available at: ftp://ftp.fao.org/agl/agll/docs/lw8e.pdf.

FAO (Food and Agriculture Organization of the United Nations) (2001): *Agricultural biological diversity: Soil biodiversity and sustainable agriculture*, paper submitted by the FAO to the UNEP Convention on biological diversity subsidiary body on scientific technical and technological advice, Seventh meeting, Montreal, 12-16 November 2001, (UNEP/CBD/SBSTTA/7/INF/11). Available at: http://www.cbd.int/doc/meetings/sbstta/sbstta-07/information/sbstta-07-inf-11-en.doc.

FAO (Food and Agriculture Organization of the United Nations) (2004): Conservation of natural resources for sustainable agriculture: training modules. *FAO land and water digital media series*, CD-ROM 27. Partially available at: http://www.fao.org/ag/ca/5.html.

FAO (Food and Agriculture Organization of the United Nations) (2005): *Management of irrigation-induced salt-affected soils.* Available at: ftp://ftp.fao.org/agl/agll/docs/salinity_brochure_eng.pdf.

FAO (Food and Agriculture Organization of the United Nations) (2006): *Conservation agriculture (CA).* Available at: http://www.fao.org/sd/Teca/tools/lst/LSTP10_en.html.

FAO (Food and Agriculture Organization of the United Nations) (2007): *The state of food and agriculture*. Available at: http://www.fao.org/docrep/010/a1200e/a1200e00.htm.

FAO (Food and Agriculture Organization of the United Nations) (2008a): *The main principles of conservation agriculture.* Available at: http://www.fao.org/ag/ca/1b.html.

FAO (Food and Agriculture Organization of the United Nations) (2008b): *Organic agriculture, frequently asked questions on organic agriculture.* Web site. Available at: http://www.fao.org/organicag/faq.jsp.

FAO (Food and Agriculture Organization of the United Nations) (2008c): *Soil Biodiversity Portal.* Web site. Available at: http://www.fao.org/ag/AGL/agll/soilbiod/soilbtxt.stm.

Farmer, M., Swales, V., Kristensen, L., Nitsch, H., Osterburg, O. and Poux, X. (2007): *Cross compliance: practice, lessons and recommendations.* Deliverable 24 of the Cross Compliance Network Project, SSPE-CT-2005-022727. Available at: (http://www.ieep.eu/publications/pdfs/crosscompliance/cc_network_D24.pdf).

Farrar, F.P. and Crossley, D.A. (1983): Detection of soil microarthropod aggregations in soybean fields, using a modified tullgren extractor. *Environmental Entomology* 12, pp. 1303-1309.

Fenández-Aparicio, M., Sillero, J.C. and Rubiales, D. (2007): Intercropping with cereals reduces infection by Orobanche crenata in legumes. *Crop Protection* 26, pp. 1166-1172.

FFTC (Food and Fertilizer Technology Center) (2007): *Soil conservation practices for slopelands.* Available at: http://www.agnet.org/library/pt/2001024/.

Fiener, P. and Auerswald K. (2006): Rotation effects of potato, maize and winter wheat on water erosion from cultivated land. *Advances in GeoEcology* 38, pp. 273-280.

Finn, J.A., Bourke, D., Kurz, I. and Dunne, L. (2007): *Estimating the environmental performance of agri-environmental schemes via use of expert consultations.* ITAES WP5 Final Report. Available at: http://merlin.lusignan.inra.fr/ITAES/website/Publicdeliverables (retrieved: April 2008).

Fleskens, L. (2007): *Conservation scenarios for olive farming on sloping land in the Mediterranean,* doctoral Thesis at Wageningen University. Available at: http://library.wur.nl/wda/dissertations/dis4231.pdf.

Freibauer, A., Rounsevell, M.A., Smith, P. and Verhagen, A. (2002): *Background paper on carbon sequestration in agricultural soils under Article 3.4 of the Kyoto Protocol*. Report under Contract N°.2001.40.CO001, ECCP Sinks, Subgroup Soils.

Funk, R. (1995): Quantifizierung der Winderosion auf einem Sandstandort Brandenburgs unter besonderer Berücksichtigung der Vegetationswirkung. *ZALF-Berichte* 16, Zentrum für Agrarlandschafts- und Landnutzungsforschung, Müncheberg.

Funk, R. and Reuter, H.I. (2006): Wind erosion. In: Boardman, J. and Poesen, J. (eds.): *Soil erosion in Europe.* John Wiley and Sons, pp. 563-582.

Gay, S.H., Osterburg, B., Baldock, D. and Zdanowicz, A. (2005): *Recent evolution of the EU Common Agricultural Policy (CAP): state of play and environmental potential*. Deliverable of the project Impact of Environmental Agreements on the Common Agricultural Policy (MEACAP). Available at: http://www.ieep.eu/publications/pdfs/meacap/WP6/WP6D4B_CAP.pdf

Gay, S.H. and Osterburg, B. (2006): Land use implications of the 2003 reform of the Common Agricultural Policy in the European Union. In: *Schriften der Gesellschaft für*

Wirtschafts- und Sozialwissenschaften des Landbaus e.V., Band 41 Unternehmen im Agrarbereich vor neuen Herausforderungen, pp. 435-445.

Garcia, T. and Scheele, M. (2001): *Integration of environmental aspects into agricultural policy: the case of the European Union*, Paper presented at the Second World Conference on Agricultural and Environmental Statistical Application (CAESAR), Rome, 5-7 June 2001.

García-Torres, L., Martínez-Vilela, A., Holgado-Cabrera, A. and González-Sanchez, E. (2002): *Conservation agriculture, environmental and economic benefits*.

Gardi, C., Tomaselli, M., Parisi, V., Petraglia, A. and Santini, C. (2002): Soil quality indicators and biodiversity in northern Italian permanent grasslands. *European Journal of Soil Biology* 38, pp. 103-110.

Gencsoylu I. and Yalcın I. (2004): Advantages of different tillage systems and their effects on the economically important pests, Thrips tabaci Lind. and Aphis gossypii Glov. in cotton fields. *Journal of Agronomy and Crop Science* 190(6), pp. 381-388.

Giller, K.E., Beare, M.H., Lavelle, P., Izac, A.M.N. and Swift, M.J. (1997): Agricultural intensification, soil biodiversity and agroecosystem function. *Applied Soil Ecology* 6, pp. 3-16.

Gilliam, J.W., Osmond, D.L. and Evans, R.O. (1997): Selected agricultural best management practices to control nitrogen in the Neuse River Basin. *North Carolina Agricultural Research Service, Technical Bulletin* 31. North Carolina State University, Raleigh, NC. Available at: http://www.soil.ncsu.edu/publications/BMPs/glossary.html.

Giordano, A. (2002): *Pedologia forestale e conservazione del suolo*. UTET.

GLASOD (Global Assessment of Human-induced Soil Degradation) (2008): Web site. Available at: http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/GLASOD.htm.

Global Land Cover Database (2000): Web site. Available at: http://www-gem.jrc.it/glc2000/.

Gobin, A., Govers, G., Jones, R., Kirkby, M. and Kosmas, C. (2002): *Assessment and reporting on soil erosion. Background and workshop report.* EEA (European Environment Agency), Technical Report 94, 103 p. Available at: http://eusoils.jrc.it/ESDB_Archive/pesera/pesera_cd/pdf/TechRepSoilerosFIN110902.pdf.

Gomes, L., Arrué, J.L., López, M.V., Sterk, G., Richard, D., Gracia, R., Sabre, M., Gaudichet, A. and Frangi, J.P. (2003): Wind erosion in a semi-arid agricultural area of Spain: the WELSONS project, *Catena* 52, pp. 235-256.

Gómez, J.A., Giráldez, J.V., Pastor M. and M., Fereres, E. (1999): Effects of tillage method on soil physical properties, infiltration and yield in an olive orchard. *Soil and Tillage Research* 52, pp. 167-175.

Gómez, J.A., Romero, P., Giradles, J.V. and Fereres, E. (2004): Experimental assessment of run-off and soil erosion in olive grove on a Vertic soil in southern Spain as affected by soil management, *Soil Use and Management* 20, pp. 426-431.

Goossens, D. (2003): On-site and off-site effects of wind erosion. In: Warren A. (ed.): *Wind erosion on agricultural land in Europe*. European Commission, EUR 20370, pp. 29-38.

Gosling, P. and Shepherd, M. (2005): Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agriculture, Ecosystems and Environment* 105, pp. 425-432.

Goulding, K.W.T., Murphy, D.V., MacDonald, A., Stockdale, E.A., Gaunt, J.L., Blake, L., Ayaga, G. and Brookes, P. (2000): The role of soil organic matter and manures in sustainable nutrient cycling. In: Rees, R.M., Ball, B.C., Cambell, C.D. and Watson, C.A. (eds.): *Sustainable management of soil organic matter*. London: CAB, 2000, pp. 221-232.

Govers, G., Vandaele, K., Desmet, P.J.J., Poesen, J. and Bunte, K. (1994): The role of soil tillage in soil redistribution on hillslopes. *European Journal of Soil Science* 45 (4), pp. 469-478.

Govers, G., Lobb, D.A. and Quine, T.A. (1999): Tillage erosion and translocation: emergence of a new paradigm in soil erosion research. *Soil and Tillage Research* 51, pp. 167-174.

Grubinger, V. (1999): *Sustainable vegetable production from start-up to market*. NRAES, 268 p.

Guerif, J. (1994): Influence de la simplification du travail du sol sur l'état structural des horizons de surface: conséquences sur leurs propriétés physiques et leurs comportements mécaniques. In: Monnier, G., Thévenet, G. and Lesaffre, B. (eds.). *Simplification du travail du sol*, Les Colloques 65, INRA Editions, Paris, pp. 13-33.

Gyuricza, C., Liebhard, P., László, P. and Birkás, M. (1999): Effect of ridge tillage on the physical status of the soil and on the maize yield. *Novenytermeles* 48(6), pp. 631-645.

Hanley, N., Shogren, J.F. and White, B. (1997): *Environmental economics in theory and practice,* Houndmills and London, 459 p.

Hansen, B., Fjelsted Alrøe, H. and Steen Kristensen, E. (2001): Approaches to assess the environmental impact of organic farming with particular regard to Denmark. *Agriculture, Ecosystems and Environment* 83, pp. 11-26.

Hartmann, E., Schekahn, A., Luick, R. and Thomas, F. (2006): *Kurzfassung der Agrarumwelt- und Naturschutzprogramme,* Bundesamt für Naturschutz, Bonn, Germany.

Hassan, R., Scholes, R. and Ash, N. (eds.) (2005): Ecosystems and human well-being: current state and trends, findings of the Condition and Trends Working Group. *The millennium ecosystem assessment series* 1. Available at: http://www.maweb.org.

Hauggaard-Nielsen, H., Andersen, M.K., Jørnsgaard, B. and Jensen, E.S. (2001): Density and relative frequency effects on competitive interactions and resource use in pea-barley intercrops. *Field Crops Research* 95, pp. 256-267.

Heckrath, G., Halekoh, U., Djurhuus, J. and Govers, G. (2006): The effect of tillage direction on soil redistribution by mouldboard ploughing on complex slopes. *Soil and Tillage Research* 88, pp. 225-241.

Helmers, M.J., Isenhart, T., Dosskey, M., Dabney, S. and Strock, J. (2006): *Buffers and vegetative filter strips*. US Environmental Protection Agency. Available at: http://randd.defra.gov.uk/Document.aspx?Document=PE0205_6736_FRA.pdf.

Henriksen, C.B, Rasmussen, J. and Søgaard, C. (2005): Kemink subsoiling before and after planting. *Soil and Tillage Research* 80, pp. 59-68.

Henriksen, C.B., Rasmussen, J. and Søgaard, C. (2006): Ridging in autumn as an alternative to mouldboard ploughing in a humid-temperate region. *Soil and Tillage Research* 85, pp. 27-37.

Henriksen, C.B., Mølgaard, J.P. and Rasmussen, J. (2007): The effect of autumn ridging and inter-row subsoiling on potato tuber yield and quality on a sandy soil in Denmark. *Soil and Tillage Research* 93, pp. 309-315.

Heywood, V.H. (1995): *Global biodiversity assessment*. Cambridge University Press, Cambridge.

Hodgson, J.G., Montserrat-Martí, G., Tallowin, J., Thompson, K., Diaz, S., Cabido, M., Grime, J.P., Wilson, P.J., Band, S.R., Bogard, A., Cabido, R., Caceres, D., Castro-Diez, P., Ferrer, C., Maestro-Martínez, M., Perez-Rontomé, M.C., Charles, M., Cornelissen, J.H.C., Dabbert, S., Perez-Harguindeguy, N., Krimly, T., Sijtsma, F.J., Strijker, D., Vendramini, F., Guerrero-Campo, J., Hynd, A., Jones, G., Romo-Díez, A., de Torres Espuny, L., Villar-Salvador, P. and Zak, M.R. (2005): How much will it cost to save grassland diversity? *Biological Conservation* 122 (2), pp. 263-273.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V. and Evans, A.D. (2005): Does organic farming benefit biodiversity? *Biological Conservation* 122, pp. 113-130.

Holland, J.M. (2004): The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems and Environment* 103, pp. 1-25.

Hoving, I.E. (2005): Economy of grassland renovation: a model approach. Land use systems in grassland dominated regions. Proceedings of the 20th General Meeting of the European Grassland Federation, Luzern, Switzerland, 21-24 June 2004. *Grassland Science in Europe* 9, pp. 544-546.

Hudec, B., Kaufmann, C., Landgrebe-Trinkunaite, R. and Naumann, S. (2007): *Evaluation of soil protection aspects in certain programmes of measures adopted by Member States*. Final report of the Contract 07010401/2006/443994/ATA/B1, DG Environment, Eco-Logic, AHU-AG.

ICRAF (International Centre for Research in Agroforestry) (1993): *Annual report 1993*. Nairobi, Kenya, 208 p.

IEEP (Institute for European Environmental Policy) (2006): *Cross compliance: An example of better regulation?* Background Paper for the Cross Compliance Seminar held in Paris on 3 July 2006. Deliverable 15 of the Cross Compliance Network Project, SSPE-CT-2005-022727. Available at: http://www.ieep.eu/publications/pdfs/crosscompliance/D15%20Paris%20Seminar%20Background%20Paper.pdf.

IFAD (International Fund for Agricultural Development) (2008): *Combating range degradation, the experience of IFAD*. Available at: http://www.ifad.org/lrkm/theme/range.htm.

IIRR (International Institute of Rural Reconstruction) (2008): *Sustainable agriculture extension manual*. Available at: http://www.iirr.org/book.htm.

INRA (National Institute for Agricultural Research) (2005): *Grasslands worth their weight in gold*. Available at: http://www.international.inra.fr/press/grasslands_worth_their_weight_in_gold.

Intercrop (2008): *Project final report*. Available at: http://www.intercrop.dk/General.htm.

IRENA (Indicator reporting on the integration of environmental concerns into agricultural policy) (2005): *Interest group for the IRENA Project*, project web site. Available at: http://www.eea.europa.eu/projects/irena.

IRRI-CIMMYT (International Rice Research Institute – International Maize and Wheat Improvement Centre) (2007): *Crop residue management fact sheet*. Available at: http://www.knowledgebank.irri.org/wheat/factsheets/Crop%20residue%20management.doc.

ITADA (Institut Transfrontalier d'Application et de Développement Agronomique) (2005): *Etablissement et validation d'un referential regional sur le travail du sol simplifié dans le Rhin supérieur*. Programme ITADA III (2002-2005). Rapport final du projet 1.

Janssens, I.A., Freibaur, A., Schlamadinger, B., Ceulemans, R., Ciais, P., Dolman, A., Heimann, M., Nabuurs, G.J., Smith, P., Valentini, R. and Schulze, E.D. (2004): The carbon budget of terrestrial ecosystems at the country-scale – a European case study, *Biogeosciences Discussions* 1(1). Available at: www.biogeosciences.net/bgd/1/167/SRef-ID: 1810-6285/bgd/2004-1-167.

Javürek, M., Mikanova, O. and Vach, M. (2006): Changes of biological activity in soil after 10 years of minimum and no soil tillage for stand establishment. In: *Book of abstracts of the 17th Triennial Conference "Sustainability – its Impact on Soil Management and Environment"*, 28.8.-3.9.2006, Kiel, Germany, p. 62.

Javürek, M., Vach, M. and Strasil, Z. (2007): Production, economic and energetic aspect of continuous ten-year use of conservation soil tillage. *Scientia Agriculturae Bohemica* 38(4), pp.179-185.

Johnson, D.W. (1995): Role of carbon in the cycling of other nutrients in forested ecosystems. In: Kelly, J.M and McFee, W.M. (eds.): *Carbon: Forms and functions in forest soils.* Soil Science Society of America Journal, pp. 299-328.

Jones, R.J.A., Hiederer, R., Rusco, E., Loveland, P.J. and Montanarella, L. (2004): *The map of organic carbon in topsoils in Europe*, Version 1.2, September 2003: Explanation of Special Publication Ispra 2004 No.72 (S.P.I.04.72). European Soil Bureau Research Report No.17, EUR 21209 EN. Office for Official Publications of the European Communities, Luxembourg.

Jongeneel, R., Brouwer, F., Farmer, M., Müssner, R., Roest, K.D., Poux, C., Fox, G., Meister, A., Karaczun, Z., Winsten, J. and Ortéga, C. (2007): *Compliance with mandatory standards in agriculture. A comparative approach of the EU vis-à-vis the United States, Canada and New Zealand.* LEI Wageningen, The Hague.

Jönsson, P. (1992): Wind erosion on sugar beet fields in Scania, southern Sweden. *Agricultural and Forest Meteorology* 62, pp. 141-157.

JRC (Joint Research Centre of the European Commission) (2008a): *Institute for the Environment and Sustainability, Soil Action.* Web site. Available at: http://eusoils.jrc.it/events/SummerSchool_2003/presentations%5CIII_SoilFunctions%5CLT07Contam_Galbiati.ppt.

JRC (Joint Research Centre of the European Commission) (2008b): *Links to soil related bodies*, Institute for the Environment and Sustainability, Land Management and Natural Hazards Unit, web site: http://eusoils.jrc.ec.europa.eu/library/links/soil.cfm.

Kächele, H., Frielinghaus, M. and Kühn, G. (2001): Economic assessment of soil systems in Northeast Germany. *ZALF-Berichte* 47: Soil Conservation, pp. 115-120.

Kainz, M. (1989): Runoff, erosion and sugar beet yields in conventional and mulched cultivation. Results of the 1988 experiment. *Soil Technology Series* 1, pp. 103-114.

Kapadia, M., Shah, F. and Warner, G. (2002): *Sedimentation of reservoirs: prevention vs. cleanup.* American Agricultural Economics Association Annual Meeting 2002, Long Beach, CA. 27-31 July. Available at: http://ageconsearch.umn.edu/handle/19593.

Kavvadias, K. (2007): *Conservation agriculture and organic farming in Greece*. KASSA project, Mediterranean platform, deliverable 1.2, appendix A4.

Keller, T. and Arvidsson, J. (2004): Technical solutions to reduce the risk of subsoil compaction: effects of dual wheels, tandem wheels and tyre inflation pressure on stress propagation in soil. *Soil and Tillage Research* 79, pp. 191-205.

Kerselaers, E., De Cock, L., Lauwers, L. and van Huylenbroeck, G. (2007): Modelling farm-level economic potential for conversion to organic farming. *Agricultural Systems* 94 (3), pp. 671-682.

Kibblewhite, M.G., Jones, R.J.A., Baritz, R., Huber, S., Arrouays, D., Micheli, E. and Stephens, M. (2008): *ENVASSO final report*, Part I: Scientific and Technical Activities. ENVASSO Project coordinated by Cranfield University, UK, for Scientific Support to Policy, European Commission 6th Framework Research Programme.

Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., van Lynden, G.J. and Huting, J. (2004): *Pan-European soil erosion risk assessment: The PESERA map*, Version 1, October 2003. European Soil Bureau Research Report No.16, EUR 21176, Office for Official Publications of the European Communities, Luxembourg.

Kleijn, D. and Sutherland, W.J. (2003): How effective are agri-environment schemes in maintaining and conserving biodiversity? *Journal of Applied Ecology* 40, pp. 947-969.

Klikocka, H., Stöven, K. and Schnug, E. (2003): Effect of different soil treatment methods and weed control on microbiological properties of soil and potato yield. *Landbauforschung Volkenrode* 53 (4), pp. 209-215.

Klimek, K. and Latocha, A. (2007): Response of small mid-mountain rivers to human impact with particular reference to the last 200 years: Eastern Sudetes, Central Europe. *Geomorphology* 92, pp.147-165.

Kolli, R., Ellermäe, O. and Köster, T. (2007): *Soil conservation in Estonia*. KASSA project, European platform, deliverable 1.1, appendix A9.

Kumm, K.I. (2004): Does re-creation of extensive pasture-forest mosaics provide an economically sustainable way of nature conservation in Sweden's forest dominated regions? *Journal for Nature Conservation* 12 (4), pp. 213-218.

Labreuche, J., de Tourdonnet, S., Germon, J.C., Ouvry, J.F., Le Souder, C., Castillón, P., Real, B., Felix, I., Duval, R., Galienne, J. and Quere, L. (2007a.): *Synthèse des impacts environnementaux des TCSL par milieu*. Assessment of the environmental impact of non-inversion tillage methods in France.

Labreuche, J., Lellahi, A., Deseau, A., Felix, I., Ganteil, A., Galienne, J., Gabrielle, B. and Reau, R. (2007b): *Impacts des TCSL sur les gaz à effet de serre – bilans*. Assessment of the environmental impact of non-inversion tillage methods in France, pp. 41-53.

Lahmar, R. and Arrue, J.L. (2007): *KASSA: Main results, gaps in knowledge and challenges in the Mediterranean platform*.

Lahmar, R. and de Tourdonnet, S. (2007): *Knowledge assessment and sharing on sustainable agriculture: main results, gaps in knowledge and challenges in the European platform*. KASSA project, deliverable 5.3.

Lal, R. (2004): Soil carbon sequestration impacts on global climate change and food security. *Science* 304, pp. 1623-1627.

Lamers, J.G., Perdok, U. D., Lumkes, L. M. and Klooster, J. J. (1986): Controlled traffic farming systems in the Netherlands. *Soil and Tillage Research* 8, pp. 65-76.

Lampurlanés, J., Angás, P. and Cantero-Martínez, C. (2001): Root growth, soil water content and yield of barley under different tillage systems on two soils in semi-arid conditions. *Field Crops Research* 69, pp. 27-40.

Lawton, J.H. and May, R.M. (1995): *Extinction Rates*. Oxford Univ. Press, Oxford.

Le Bissonnais, Y. and Andrieux, P. (2006): *Erosion and run-off in vineyards: impact of different inter-rows management.* LISAH Mondiaviti.

Le Souder, C., Castillon, P., Genermont, S., Gillet, J.P., Laurent, F., Lebreton, J.C., Malaval, C., Nicolardot, B., Quere, L. and Reau, R. (2007): *Impacts des TCSL sur la dynamique de l'azote et les pertes de composes azotes. Assessment of the environmental impact of non-inversion tillage methods in France*, 23 p.

Lindstrom, M.J., Nelson, W.W. and Schumacher, T.E. (1992): Quantifying tillage erosion rates due to moldboard plowing. *Soil and Tillage Research* 24, pp. 243-255.

Lippert, C. (2002): How to provide for environmental attributes in rural landscape. In: Hagedorn, K. (ed.): *Environmental co-operation and institutional change: theories and policies for European agriculture,* Cheltenham Edward Elgar, pp. 185-201.

Liski, J., Perruchoud, D. and Karjalainen, T. (2002): Increasing carbon stocks in the forest soils of Western Europe. *Forest Ecology and Management* 169, pp. 159-175.

Lithuanian Agricultural Advisory Service (2001): *Grassland renovation*. Baltic Agricultural run-off Action Programme. Available at: http://www.baap.lt/education/grass_ren/grass_ren.pdf.

Llewellyn, C. (2005): *Protecting French vineyards from soil erosion – Results from 4 years of the ProTerra project 2001-2005*.

Longueval, C. (2007): *Réussir le passage au non-labour, Groupe Régional Non-Labour Midi-Pyrénées*.

López, M.V., Arrúe, J.L. and Sánchez-Girón, V. (1996): A comparison between seasonal changes in soil water storage and penetration resistance under conventional and conservation tillage systems in Aragón. *Soil and Tillage Research* 37, pp. 251-271.

López-Bellido, L., López-Bellido, R.J., Castillo, J.E., López-Bellido, F.J. (2000): Effects of tillage, crop rotation, and nitrogen fertilization on wheat under rainfed Mediterranean conditions. *Agronomy Journal* 92, pp. 1054-1063.

López-Fando, C., Dorado, J. and Pardo, M.T. (2007): Effects of zone-tillage in rotation with no-tillage on soil properties and crop yields in a semi-arid soil from central Spain. *Soil and Tillage Research* 95, pp. 266-276.

Loveland, P.J. and Thompson, T.R.E. (eds.) (2001): *Identification and development of a set of national indicators for soil quality*. Environment Agency R&D Technical Report P5-053/2/TR, Bristol.

Lyles, L. (1988): Basic wind erosion processes. *Agriculture, ecosystems and environment*, 22/23, pp. 91-101.

Maa, M., Tarmi, S. and Helenius, J. (2002): Revisiting the species-area relationship in a semi-natural habitat: floral richness in agricultural buffer zones in Finland. *Agriculture, Ecosystems and Environment* 89, pp. 137-148.

Magid, J. and Nielsen, N.E. (2007): *Organic farming in Denmark*. KASSA project, European platform, deliverable 1.1, appendix A3.

Martin, P., Joannon, A., Souchere, V. and Papy, F. (2004): Management of soil surface characteristics for soil and water conservation: the case of a silty loam region (Pays de Caux, France). *Earth Surface Processes and Landforms* 29, pp. 1105-1115.

Martin, R., Smith, D. and Voldeng, H. (1987): *Intercropping corn and soybeans, REAP Canada*. Available at: http://eap.mcgill.ca/magrack/SF/FAll%2087%20B.htm.

McCann, L. and Easter, K. W. (2004): A framework for estimating the transaction costs of alternative mechanism for water exchange and allocation. *Water Resource Research* 40(9).

McGill University, School of Environment (2002): *Soil contamination and urban agriculture, Montreal.* Available at: http://mse-research.mcgill.ca/envr401_2002/brownfields/guide.pdf

Melero, S., Ruiz Porras, J.C., Herencia, J.F. and Madejon, E. (2006): Chemical and biochemical properties in a silty loam soil under conventional and organic management. *Soil and Tillage Research* 90, pp. 162-170.

Mettepenningen, E., Verspecht, A., van Huylenbroeck, G., D'Haese, M., Aertens, J. and Vandermuelen, V. (2007): *Analysis of private transaction costs related to agri-environmental schemes.* ITAES WP6 Consolidated report, http://merlin.lusignan.inra.fr/ITAES/website/Publicdeliverables (retrieved: April 2008).

Meyer-Aurich, A., Schuler, J., Auerswald, K., Zander, P. and Kachele, H. (2001): Trade off of soil protection – assessing economic consequences of erosion control. *ZALF-Berichte*, Müncheberg.

Mitchell, C.C. (2001): *Soil acidity and liming – Part, I: Internet inservice training*. Available at: http://hubcap.clemson.edu/~blpprt/acidity2_review.html.

Monokrousos, N., Papatheodorou, E.M., and Stamou, G.P. (2008): The response of soil biochemical variables to organic and conventional cultivation of Asparagus sp. *Soil Biology and Biochemistry* 40 (1), pp. 198-206.

Montanarella, L. (2003): *The EU thematic strategy on soil protection*. Available at: http://eusoils.jrc.it/events/SummerSchool_2003/presentations%5CIII_SoilFunctions%5CPT01SoilProtStrat_LM.doc.pdf.

Mordenti, A., Pacchioli, M. T. and Della Casa, G. (2001): Riduzione del tenore in azoto, fosforo, rame, zinco con interventi sulla dieta. Liquami zootecnici. In: C.R.P.A. *Manuale per l'utilizzazione agronomica*, edizioni l'informatore agrario, pp. 99-114.

Moreno, F., Pelegrín, F., Fernández, J. E. and Murillo, J.M. (1997): Soil physical properties, water depletion and crop development under traditional and conservation tillage in southern Spain. *Soil and Tillage Research* 41 (1-2), pp. 25-42.

Moreno, F., Pelegrín, F., Fenández, J.E. and Murillo, J.M. (2007): *Influence of traditional and conservation tillage on soil physical properties in southern Spain*. Poster, Scientific registration Nº 373, Symposium Nº 20.

Moret, D., Arrúe, J.L., López, M.V., Gracia, R. (2006): Influence of fallowing practices on soil water and precipitation storage efficiency in semi-arid Aragon (NE Spain). *Agricultural Water Management* 82 (1-2), pp. 161-176.

Morgan, R.P.C. (2005): *Soil erosion and conservation*, 3rd edition. Blackwell Publishing Ltd., 303 p.

Morgan, R.P.C. and Finney, H.J. (1987): Drag coefficient of single crop rows and their implications for wind erosion control. In: Gardiner, V. (ed.): *International Geomorphology 1986*, Part II, John Wiley and Sons, Chichester, pp. 449-460.

Morschel, J., Fox, D.M. and Bruno, J.F. (2004): Limiting sediment deposition on roadways: topographic controls on vulnerable roads and cost analysis of planting grass buffer strips. *Environmental Science and Policy* 7, pp. 39-45.

Mrabet, R. (2006): Soil quality and carbon sequestration: Impacts of no-tillage systems. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 43-55.

Munkholm, L.J., Schjønning, P., and Rüegg, K. (2005): Mitigation of subsoil recompaction by light traffic and on-land ploughing I. soil response. *Soil and Tillage Research* 80, pp. 149-158.

Murdock, L. (1999): *Subsoiling of no-tilled corn*, University of Kentucky. Available at: http://www.uky.edu/Ag/Agronomy/Extension/ssnv/ssvl203.pdf

Murillo, M., Schnabel, S. and González, F. (2004): Effect of different pasture improvement techniques on soil erosion and herbaceous vegetation in a wooded rangeland, South-West Spain. In: Schnabel, S. and Ferreira, A. (eds.). *Advances in Geoecology* 37, pp. 377-389.

Muscutt, A. D., Harris, G. L., Bailey, S. W. and Davies, D. B. (1993): Buffer zones to improve water quality: a review of their potential use in UK agriculture. *Agriculture, Ecosystems and Environment* 45 (1-2), pp. 59-77.

Nägeli, W. (1943): *Untersuchungen über die Windverhältnisse im Bereich der Windschutzstreifen*. Mitteilungen der Schweizerischen Anstalt für forstliches Versuchswesen 23, 223 p.

Nakao, M. and Sohngen, B. (2000): The effect of site quality on the costs of reducing soil erosion with Riparian buffers. *Journal of Soil and Water Conservation* 55, pp. 231-237.

Nappi, P., Cenci, R. M., Barberis, R. and Dabergami, D. (2003): Suoli e muschi del Piemonte centro-nord: ditribuzione della concentrazione di elementi in tracce e flussi di deposizione. *Bollettino della Società Italiana della Scienza del Suolo* 52 (1-2), pp. 775-787.

NCCES (North Carolina Cooperative Extension Service) (2005): *Soil acidity and liming: basic information for farmers and gardeners,* AG-439-51. Available at: http://www.soil.ncsu.edu/publications/Soilfacts/AGW-439-51/basics_12-3.pdf.

Neumann, A., Schmidtke, K. and Rauber, R. (2007): Effects of crop density and tillage system on grain yield and N uptake from soil and atmosphere of sole and intercropped pea and oat. *Field Crops Research* 100, pp. 285-293.

Nevens, F. and Reheul, D. (2003): Effects of cutting or grazing grassland on herbage yield, nitrogen uptake and residual soil nitrate at different levels of N fertilization. *Grass and Forage Science*, pp. 431-449.

Nicolardot, B. and Germon, J.C. (2007): *Impacts des TCSL sur les gaz à effet de serre – Oxydes. Assessment of the environmental impact of non-inversion tillage method in France,* pp. 31-40.

North, D. and Lane, M. (2005): *Protecting French vineyards from soil erosion: results from 4 years of the ProTerra project (2001-2005).*

NRCS (Natural Resources Conservation Service) (2008): *Buffers, common-sense conservation.* Available at: http://www.nrcs.usda.gov/feature/buffers/BufrsPub.html.

Olesen, J.E. and Munkholm, L.J. (2007): Subsoil loosening in a crop rotation for organic farming eliminated plough pan with mixed effects on crop yield. *Soil and Tillage Research* 94, pp. 376-385.

Oorts, K. (2006): *Effects of tillage systems of soil organic matter stocks and C and N fluxes in cereal cropping systems on a silt loam soil in northern France*. Doctoral Thesis INAPG, 159 p.

Orlov, D.S. (1990): *Humid acids in soils and general theory of humification*. Moscow State University, 325 [in Russian].

Ortiz-Miranda, D. and Estruch-Guitart, V. (2004): The role of agri-environmental measures in the definition of property rights. In: Van Huylenbroeck, G., Verbecke, W. and Lauwers, L. (Eds.): *Role of Institutions in Rural Policies and Agricultural Markets*, Amsterdam, pp.335-348.

Otto, S., Riello, L., Düring R.A., Hummel, H.E. and Zanin, G. (1997): Herbicide dissipation and dynamics modelling in three different tillage systems. *Chemosphere* 34(1), pp. 163-178.

Pacini, C., Wossink, A., Giesen, G., Vazzana, C. and Huirne, R. (2003): Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* 95 (1), pp. 273-288.

Pacini, C., Giesen, G., Wossink, A., Omodei-Zorini, L. and Huirne, R. (2004): The EU's Agenda 2000 reform and the sustainability of organic farming in Tuscany: ecological-economic modelling at field and farm level. *Agricultural Systems* 80 (2), pp. 171-197.

Pagliai, M., Vignozzi, N. and Pellegrini, S. (2004): Soil structure and the effect of management practices. *Soil and Tillage Research* 79, pp. 131-143.

Palma J.H.N., Graves A.R., Bunce R.G.H., Burgess P.J., de Filippi R., Keesman K.J., van Keulen H., Liagre F., Mayus M., Moreno G., Reisner Y., Herzog F. (2007a): Modeling environmental benefits of silvoarable agroforestry in Europe. *Agriculture, Ecosystems and Environment* 119, pp. 320–334.

Palma, J., Graves, A.R., Burgess, P.J., van der Werf, W. and Herzog, F. (2007b): Integrating environmental and economic performance to assess modern silvoarable agroforestry in Europe. *Ecological Economics* 63, pp. 759-767.

Paoletti, M.G., Pimentel, D., Stinner, B.R. and Stinner, D. (1992): Agroecosystems biodiversity – matching production and conservation biology. *Agriculture, Ecosystem and Environment* 40, pp. 3-23.

Pastor, M. and Castro, J. (1995): Soil management systems and erosion. *Olivae* 59. International Olive Oil Council, Madrid.

Pažek, K. and Rozman, Č. (2007): The simulation model for cost-benefit analysis on organic farms. *Agronomski Glasnik* 3, pp. 209-223.

Pérez de Ciriza, J.J. (2004a): Etudes économiques comparatives en Navarre: travail profond – superficiel – semis direct. In: *Actes II Rencontres Méditerranéennes sur le Semis Direct,* 19-22 janvier 2004, Tabarka, Tunisie, 108 p.

Pérez de Ciriza, J.J. (2004b): La sembradora de chorrillo, *Navarra Agraria*, ISSN 0214. Available at: http://www.navarraagraria.com/n142/arsemba.pdf.

Pérez de Ciriza, J.J. (2004c): *Las cumas y el ahorro energetico*. Available at: http://www.navarraagraria.com/n147/arcuma.pdf.

Pérez de Ciriza, J.J. and Delgado, J. (2006): Resultados de laboreo en Navarra. *Tierras de Castilla y León* 121, pp. 62-66 (in Spanish).

Pérez de Ciriza, J.J., Pérez Zabalza, T., Delgado Pérez, J., Carro Echerría, P. (2006): El laboreo en Navarra. *Navarra Agraria* (Mayo-Junio), pp. 11-24.

Petersen, S., Axelsen, J.A., Tybirk, K., Aude, E. and Vestergaard, P. (2006): Effects of organic farming on field boundary vegetation in Denmark, *Agriculture, Ecosystems and Environment* 113, pp. 302-306.

Pietola, L., Horn, R. and Yli-Halla, M. (2005): Effects of trampling by cattle on the hydraulic and mechanical properties of soil. *Soil and Tillage Research* 82, pp. 99-108.

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T. and Cliff, B. (1997): Economic and environmental benefits of biodiversity. *Bioscience* 47, pp. 747-757.

Piovanelli, C., Gamba, C., Brandi, G., Simoncini, S. and Batistoni, E. (2006): Tillage choices affect biochemical properties in the soil profile. *Soil and Tillage Research* 90, pp. 84-92.

Plantureux, S., Peeters, A. and McCracken, D. (2005): Biodiversity in intensive grasslands, effects of management, improvement and challenges. In: Lillak, R., Viiralt, R., Linke, A. and Geherman, V. (eds.): *Integrating efficient grassland farming and biodiversity*. Estonian Grassland Society, Tartu, Estonia, pp. 417-426.

Plassart, P., Akpa Vinceslas, M., Gangneuxa, C., Merciera, A., Barrayc, S. and Lavala, K. (2008): Molecular and functional responses of soil microbial communities under grassland restoration. *Agriculture, Ecosystems and Environment,* pp. 286-293.

Poesen, J.W., van Weemael, B., Govers, G., Martinez-Fernandez, J., Desmet, P., Vandaele, K., Quine, T. and Degraer, G. (1997): Patterns of rock fragment cover generated by tillage erosion. *Geomorphology* 18, pp. 183-197.

Poesen, J.W., Verstraeten, G., Soenens, R. and Seynaeve, L. (2001): Soil losses due to harvesting of chicory roots and sugar beet: an underrated geomorphic process? *Catena* 43 (1), pp. 35-47.

Pointereau, P., Coulon, F., Girard, P., Lambotte, M., Stuczynski, T., Sanchez Ortega, V., Del Rio, A.; Anguiano, E., Bamps, C. and Terres, J-M. (eds.) (2008): *Analysis of farmland abandonment and the extent and location of agricultural areas that are actually abandoned or are in risk to be abandoned*. European Commission, Joint Research Centre, Institute for Environment and Sustainability, JRC Scientific and Technical Reports, EUR 23411EN – 2008.

Posthumus, H. and de Graaff, J. (2004): Cost-benefit analysis of bench terraces, a case study in Peru. *Land Degradation and Development* 16 (1), pp. 1-11.

Potter, K.N. and Zobeck, T.M. (1988): *Simulation of Soil Microrelief*. ASAE Paper 88-2557.

Poveda, K., Steffan-Dewenter, I., Scheu, S. and Tscharntke, T. (2006): Belowground effects of organic and conventional farming on aboveground plant-herbivore and plant-pathogen interactions. *Agriculture, Ecosystems and Environment* 113, pp. 162-167.

Prins, U. and de Wit, J. (2006): *Intercropping cereals and grain legumes: a farmer's perspective*. Joint Organic Congress, Odense, Denmark, May 30-31, 2006. Available at: http://orgprints.org/7297/01/Intercropping_paper_Odense_final.pdf.

Probst, M., Berenzen, N., Lentzen-Godding, A. and Schulz, R. (2005): Scenario-based simulation of runoff-related pesticide entries into small streams on a landscape level. *Ecotoxicology and Environmental Safety* 62, pp. 145-159.

Prokop, G. (2005): The state of EU soil policy and soil related research. *Reviews in Environmental Science and Bio/Technology* 4, pp. 81-86.

Qiu, Z.Y., (2003): A VSA-based strategy for placing conservation buffers in agricultural watersheds. *Environmental Management* 32, pp. 299-311.

Quinton, J.N. and Catt, J.A. (2004): The effects of minimal tillage and contour cultivation on surface runoff, soil loss and crop yield in the long-term Woburn erosion reference wxperiment on sandy soil at Woburn, England. *Soil Use and Management* 20(3), pp. 343-349.

Rabaud, V. (2004): Peu de pratiques alternatives en grandes cultures. *Agreste Primeur* 149, p. 4

Ramos, M.C., Cots-Folch, R. and Martínez-Casasnovas, J.A. (2007): Sustainability of modern land terracing for vineyard plantation in a Mediterranean mountain environment – The case of the Priorat region (NE Spain). *Geomorphology* 86, pp. 1-11.

Raper, R.L. (2005): Agricultural traffic impacts on soil. *Journal of Terramechanics* 42, pp. 259-280.

Real, B., Malaval, C., Bonin, L., Labreuche, J., Barriuso, E., Benoit, P., Bedos, C., Köller, R., Haddadj, D., Quere, L., Cariolle, M. and Caboulet, D. (2007): Impact de TCSL sur la pression parasitaire. *Assessment of the environmental impact of non-inversion tillage methods in France,* pp. 21-30.

Reisner, Y., de Filippi, R., Herzog, F. and Palma, J. (2007): Target regions for silvoarable agroforestry in Europe. *Ecological engineering* 29, pp. 401-418.

Renard, K.G. and Freimund, J.R. (1994): Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of Hydrology* 157, pp. 287-306.

Renard, K.G., Foster, G.R., Weessies, G.A., McCool, D.K. and Yoder, D.C. (eds.) (1997): *Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE).* U.S. Department of Agriculture, Agriculture Handbook 703.

Ribaudo, M.O., Richard, D.H. and Smith, M.E. (1999): Economics of water quality protection from nonpoint sources – theory and practice. U.S. Department of Agriculture, *Agricultural Economic Report* 782.

Rieu, C. (2004): Les enjeux économiques de la simplification du travail du sol. *Du labour au semis direct: les enjeux agronomiques,* pp. 21-22.

Ritz, K., McHugh, M. and Harris, J. (2003): *Biological diversity and function in soil: contemporary perspectives and implication in relation to the formulation of effective indicators.* Proceeding OECD Expert meeting on soil erosion and soils biodiversity indicators. Rome, March 25-28, 2003.

Rodrigues, M.A., Pereira, A., Cabanas, J.E., Dias, L., Pires, J. and Arrobas, M. (2006): Crops use-efficiency of nitrogen from manures permitted in organic farming. *European Journal of Agronomy* 25, pp. 328-335.

Rosati, A. and Aumaitre, A. (2004): Organic dairy farming in Europe. *Livestock Production Science* 90, pp. 41-51.

Rubio, J.L., Imeson, A.C., Bielek, P., Fullen, M.A., Pascual, J.A., Andreu, V. and Recatalá, L.A.C. (2006): *Directory of European organisations and persons working on soil protection*. Bratislava, Slovakia.

Rundlof, M., Nilsson, H. and Smith, H.G. (2008): Interacting effects of farming practice and landscape context on bumble bees. *Biological Conservation* 141, pp. 417-426.

Ruysschaert, G, Poesen, J, Verstraeten, G. and Govers, G. (2006): Tillage erosion. In: Boardman J. and Poesen, J. (eds.): *Soil erosion in Europe*, pp. 609-621.

Ryan, M. (1999): Is an enhanced soil biological community, relative to conventional neighbours, a consistent feature of alternative (organic and biodynamic) agricultural systems? *Biological Agriculture and Horticulture* 17 (2), pp. 131-144.

Sánchez-Giron, V., Serrano, A., Hernanz, J.L. and Navarrete, L. (2004): Economic assessment of three long-term tillage systems for rainfed cereal and legume production in semi-arid central Spain. *Soil and Tillage Research* 78, pp. 35-44.

Santalla, M., Rodino, A.P., Casquero, P.A. and de Ron, A.M. (2001): Interactions of bush bean intercropped with field and sweet maize. *European Journal of Agronomy* 15, pp. 185-196.

Santhi, C., Atwood, J.D., Lewis, J., Potter, S.R. and Srinivasan, R. (2001): *Environmental and economic impacts of reaching and doubling the USDA buffer initiative program on water quality.* ASAE Meeting Paper 01-2068.

SARE (Sustainable Agriculture Research and Education) (2008): Web site. Available at: http://64.233.183.104/search?q=cache:OlxSW0YAxq4J:www.sare.org/publications/organic/organic04.htm+bio+strips&hl=en&ct=clnk&cd=8.

Sartori, L., Basso, B., Bertocco, M. and Oliviero, G. (2005): Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy. *Biosystems Engineering* 91 (2), pp. 245-256.

Scheele, M. (2008a): *Evaluating public goods – concepts and challenges*. Presentation. European Commission, Agriculture and Rural Development Directorate General, AGRI H1. Available at: http://pmk.agri.ee/pkt/konverents_pildid/presentations/Plenary_-_Martin_Scheele.pdf.

Scheele, M. (2008b): *Integrating environmental requirements into the Common Agricultural Policy: public goods, environmental services, and meeting standards*. Presentation at the Brussels Session of the EAAE Congress on Future Challenges for Agriculture: A day of scientific dialogue, 28 August 2008, Brussels.

Schlinker, G., Sander, G., Decker, M., Kremer-Schillings, W., Burcky, K. and Koch, H.-J. (2007): Ridge cultivation of sugarbeet – Recent experiences and experimental results from Germany. *Zuckerindustrie* 132 (12), pp. 920-924.

Schmidt, O., Clements, R.O. and Donaldson, G. (2003): Why do cereal-legume intercrops support large earthworm populations? *Applied Soil Ecology* 22, pp. 181-190.

Schou, J.S., Tybirk, K., Løfstrøm, P. and Hertel, O. (2006): Economic and environmental analysis of buffer zones as an instrument to reduce ammonia loads to nature areas. *Land Use Policy* 23, pp. 533-541.

Schroeder, W.R. and Kort, J. (1989): Shelterbelts in the Soviet Union. *Journal of Soil and Water Conservation* 44(2), pp. 130-134.

Sereni, E. (1997): *History of the Italian agricultural landscape*. Giovanni Agnelli Foundation in Italian History, Princeton University Press.

Shakesby, R.A. (2001): Are the dehesa/montado agroforestery practices of Spain and Portugal low erosion risk land-use options? *ZALF-Berichte* 47: Soil Conservation, pp. 127-131.

Shao, Y. (2000): *Physics and Modelling of Wind Erosion*. Atmospheric and Oceanographic Sciences Library 23, Kluwer Academic Publishers, 393 p.

Siepel, H. and van de Bund, C. (1988): The influence of management practices on the microarthropod community of grassland. *Pedobiologia* 31, pp. 339-354.

Sleutel, S., de Neve, S. and Hofman, G. (2003): Estimates of carbon stock changes in Belgian cropland. *Soil Use and Manage* 19, pp. 166-171.

Smeeth, E. and Weterings, R. (1999): *Environmental indicators: typology and overview*. European Environmental Agency, Technical Report No. 28.

Smith J., Smith, P., Wattenbach, M., Zaehle, S., Hiederer, R., Jones, R.J.A., Montanarella, L., Rounsevell, M.D.A, Reginster, I. and Ewert, F. (2005): Projected changes in mineral soil carbon of European croplands and grasslands, 1990-2080. *Global Change Biology* 11(12), p. 2141.

Smith, P. (2004): Carbon sequestration in croplands: the potential in Europe and the global context. *European Journal of Agronomy* 20, pp. 229-236.

Smith, P., Smith, J., Wattenbach, M., Meyer, J., Lindner, M., Zaehle, S., Hiederer, R., Jones, R.J.A., Montanarella, L., Rounsevell, M., Reginster, I. and Kankaanpää, S. (2006): Projected changes in mineral soil carbon of European forests, 1990-2100. *Canadian Journal of Soil Science* 86, pp. 159-169.

Soane, B.D. and Ball, B.C. (1998): Review of management and conduct of long-term tillage studies with special reference to a 25-year experiment on barley in Scotland. *Soil Tillage Research* 45, pp. 17-38.

Soltner, D. (1999): *Les grandes cultures végétales*. Collection Sciences et Techniques Agricoles. 19e edition.

Sombrero, A., de Benito, A., Escribano, C. and García, M.A. (1996): *Water content and compaction soil evolution under three tillage systems.* National Congress of Conservation Agriculture, Córdoba (Spain), pp. 183-187.

Sombrero, A., de Benito, A. and Escribano, C. (1998): Alternative tillage systems: minimum and no tillage systems. *Boletín Informativo, Servicio Agrario Caja de Burgos* 35, pp. 12-16.

Sopena, P. (2006): Direct seeding in Aragón: Aragón's Association of Conservation Agriculture. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 101-105.

Souchère, V., King, C., Dubreuil, N., Lecomte-Morel, V., Le Bissonnais, Y. and Chalat, M. (2003): Grassland and crop trends: role of the European Union Common Agricultural Policy and consequences for runoff and soil erosion. *Environmental Science and Policy* 6(1), pp. 7-16.

Spoor, G., Tijink, F.G.J. and Weisskopf, P. (2003): Subsoil compaction: risk, avoidance, identification and alleviation. *Soil and Tillage Research* 73, pp. 175-182.

SSCMS (Saskatchewan Soil and Crop Management Subcouncil) (2005): *Deep tillage – agriculture,* Government of Saskatchewan. Available at: http://www.agriculture.gov.sk.ca/Default.aspx?DN=e0d8aef7-b0ed-4a6a-ac6b-e52bee8e50ac.

Stathakos, T.D., Gemtos, T.A., Tsatsarelis, C.A. and Galanopoulou, S. (2006): Evaluation of three cultivation practices for early cotton establishment and improving crop profitability. *Soil and Tillage Research* 87, pp. 135-145.

Sterk, G. (2000): Flattened residue effects on wind speed and sediment transport. *Soil Science Society of America Journal* 64, pp. 852-858.

Stevenson, F. J. (1994): *Humus chemistry: genesis, composition, reactions*. John Wiley and Sons, New York, USA, 281 p.

Stone, R.P. and Moore, N. (1986): *Control of soil erosion*. Ontario Ministry of Agriculture, Food and Rural Affairs Factsheet N 95-089.

Stull, R.B. (1988): *An introduction to boundary layer meteorology*. Atmospheric Science Library, Kluwer Academic Publishers, Dorbrecht Boston London.

Sullivan, P. (2003): *Overview of cover crops and green manures. National Sustainable Agriculture Information Service (ATTRA).* Available at: http://attra.ncat.org/attra-pub/PDF/covercrop.pdf.

Suri, M., Cebecauer, T., Hofierka, J. and Fulajtar, E. (2002): Soil erosion assessment of Slovakia at a regional scale using GIS. *Ekologia* 21 (4), pp. 404-422.

Swift, M.J. (1999): Towards the second paradigm: integrated biological management of soil. In: Siqueira, J.O., Moreira, F.M.S., Lopes, A.S., Guilherme, L.R.G., Faquin, V., Furtani Neto, A.E. and Carvalho, J.G. (eds.): *Interrelação Fertilidade, Biologia do Solo e Nutrição de Plantas*, Lavras, Brasil, pp. 11-24.

Syvasalo, E., Regina, K., Turtola, E., Lemola, R. and Esala, M. (2006): Fluxes of nitrous oxide and methane, and nitrogen leaching from organically and conventionally cultivated sandy soil in western Finland. *Agriculture, Ecosystems and Environment* 113, pp. 342-348.

Szabolcs, I. (1974): *Salt Affected Soils in Europe*. Martinus Nijhoff, The Hague and RISSAC, Budapest, 63 p.

Taylor, D., Younie, D., Coutts, M. and Matheson, S. (2002): Experiences with designing managing organic rotation trials. In: Powell, J., Davies, G., Fowler; S, Hovi, M., Lampkin, N., Lennartsson, M., Padel, S., Pearce, B., Philipps, L., Robertson, J. Stockdale, E., Watson, C., Weller, R., Welsh J. and Wolfe, M. (eds.). *UK Organic Research 2002: Proceedings of the COR Conference*, 26-28th March 2002, Aberystwyth, pp. 37-41.

Tebrügge, F. and Böhrnsen, A. (1997): Crop yields and economic aspects of no-tillage compared to plough tillage: results of long-term soil tillage field experiments in Germany. Experiences with the application of no-tillage crop production in the West-European countries. In: Tebrügge, F. and Böhrnsen, A. (eds.): *Proceedings of the EC-Workshop IV*, Boigneville, 12-14 May 1997, pp. 25-43.

Tebrügge, F. and Düring, R.A. (1999): Reduction tillage intensity – a review of results from a long-term study in Germany. *Soil and Tillage Research* 53, pp. 15-28.

Tenorio, J.L., Catalán, G., de Andrés, E.F., Sánchez, J. and Ayerbe, L. (2001): *Eficiencia en el uso del agua de diferentes cultivos bajo la aplicación de diferentes tratamientos de laboreo.* (Water use efficiency under different crops and tillage systems). I World Congress on Conservation Agriculture, pp. 609-613.

Tenorio, J.L., de Andrés, E.F., Sánchez, J., Estaban, E. and Catalán, G. (2002): *Effect of different tillage systems in cold semi-arid Spain.* VII Congress of the European Society for Agronomy, pp. 545-546.

Terzoudi, C.B., Gemtos, T.A., Danalatos, N.G. and Argyrokastritis, I. (2007): Applicability of an empirical runoff estimation method in central Greece. *Soil and Tillage Research* 92, pp. 198-212.

Thamsborg, S.M. (2002): Organic farming in the Nordic countries – animal health and production. *Acta Veterinaria Scandinavica* 43 (Suppl. 1), pp. 7-15. Available at: http://www.actavetscand.com/content/43/S1/S7.

Thevenet, G., Mary, B. and Wylleman, R. (2002): Carbon sequestration and soil cultivation in temperate climate: results of a 30 years' experimentation of arable crops. *Comptes rendus de l'Academie d'Agriculture de France* 88, pp. 71-78.

Thomas, F. (2006): Increase of circulating biomass in plant cover and plant cover mixtures: the experience of France. In: Arrue, J.L. and Cantero-Martínez, C. (eds.): *Options Méditerranéennes. Troisèmes rencontres Méditerranéennes du Semis Direct*, Série A, 69, pp. 37-42.

Thorsted, M.D., Olesen, J.E. and Weiner, J. (2006a): Width of clover strips and wheat rows influence grain yield in winter wheat/white clover intercropping. *Field Crops Research* 95, pp. 280-290.

Thorsted, M.D., Olesen, J.E. and Weiner, J. (2006b): Mechanical control of clover improves nitrogen supply and growth of wheat in winter wheat/white clover intercropping. *European Journal for Agronomy* 24, pp. 149-155.

Tombesi, A., Michelakis, N. and Pastor, M. (1996): Recommendations of the working group on olive farming production techniques and productivity. *Olivae* 63, pp. 38-51.

Torquebiau, E.F. (2000): A renewed perspective on agroforestry concepts and classification. *Comptes Rendus de l'Académie des Sciences, Sciences de la vie* 323, pp. 1009-1017.

Tóth, G., Stolbovoy, V. and Montanarella, L. (2007): *Soil quality and sustainability evaluation – An integrated approach to support soil-related policies of the European Union.* EUR 22721EN. 40 p. Office for Official Publications of the European Communities, Luxembourg.

Truu, M., Truu, J. and Ivask, M. (2008): Soil microbiological and biochemical properties for assessing the effect of agricultural management practices in Estonian cultivated soils. *European Journal of Soil Biology* 44, pp. 231-237.

Tsara, M., Gerontidis, S., Marathianou, M. and Kosmas, C. (2001): The long-term effect of tillage on soil displacement of hilly areas used for growing wheat in Greece. *Soil Use and Management* 17, pp. 113-120.

Tsatsarelis, C.A. (1994): *Tillage practices for crop production in Greece. Possibilities for reduced or no-tillage techniques from energy point of view*. Proceedings of the EC Workshop I, Giessen, pp. 27-28.

Tschantz, B.A., Gangaware, T.R. and Morton, R.G. (2003): *Guide to the selection and design of Stormwater Best Management Practices (BMPs).* Tennessee Water Resources Research Center, University of Tennessee, pp. 215-226.

Turin, U.V. (1965): *Soil organic matter and its role in the soil fertility*. Nauka, Moscow, 319 p. [in Russian]

UNEP/CBD/SBSTTA/13/2 (2007): *In-depth review of the implementation of the programme of work on agricultural biodiversity. Biodiversity in agricultural soils.*

United Nations (1992): *Framework Convention on climate change.* New York.

United Nations (1994): *United Nations Convention to combat desertification in countries experiencing serious drought and/or desertification, particularly in Africa*. Paris.

United Nations (1997): *Kyoto Protocol to the United Nations Framework Convention on climate change*. Kyoto.

University of Manitoba (2006): *Cultivar mixtures, cover crops, and intercropping with organic spring wheat*. Available at: http://www.umanitoba.ca/outreach/naturalagriculture/articles/wheatintercrop.html.

USDA (United States Department of Agriculture) (1996): Conservation crop rotation effects on soil quality. Natural Resources Conservation Service, *Soil Quality Institute, technical note* 2. Available at: http://soils.usda.gov/sqi/management/files/sq_atn_2.pdf.

Valdivia, R.O. (2002): *The economics of terraces in the Peruvian Andes: An application of sensitivity analysis in an integrated assessment model*. Thesis at Montana State University. Available at: http://www.tradeoffs.montana.edu/pdf/valdivia/valdivia.pdf.

Van der Werf, W., Keesman, K., Burgess, P., Gravesc, A., Pilbeam, D., Incoll, L.D., Metselaar, K., Mayus, M., Stappers, R., van Keulen, H., Palma, J. and Dupraz, C. (2007): Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. *Ecological engineering* 29, pp. 419-433.

Van Elsen, T. (2000): Species diversity as a task for organic agriculture in Europe. *Agriculture, Ecosystems and Environment* 77, pp. 101-109.

Van Huylenbroeck, G., Verbecke, W. and Lauwers, L. (eds.) (2004): *Role of institutions in rural policies and agricultural markets*, Amsterdam.

Van Lynden, G.W.J. (1995): European soil resources. Current status of soil degradation, causes impacts and need for action. *Nature and Environment* 71, Council of Europe.

Van Muysen, W., Govers, G. and van Oosta, K. (2002): Identification of important factors in the process of tillage erosion: the case of mouldboard tillage. *Soil and Tillage Research* 65 (1), pp. 77-93.

Van Oost, K. and Govers, G. (2006): Tillage erosion. In: Boardman, J. and Poesen, J. (eds.): *Soil erosion in Europe*, pp. 599-608.

Van-Camp, L., Bujarrabal, B., Gentile, A.R., Jones, R.J.A., Montanarella, L., Olazabal, C. and Selvaradjou, S.K. (2004): *Reports of the echnical Working Groups established under the thematic strategy for soil protection.* Office for Official Publications of the European Communities, Luxembourg (EUR 21319 EN/3).

Vandeputte, E. (2007): *Changes in the agricultural practices by giving up ploughing in France*. KASSA project, European platform, deliverable 1.1, appendix A2.

Veen, P.H., Kampf, H. and Liro, A. (1997): *Nature development on former state farms in Poland*. Report within the framework of the Memorandum of Understanding for Nature Conservation between the Polish Ministry of Environmental Protection, Natural Resources and Forestry and the Dutch Ministry of Agriculture, Nature Management and Fisheries, 48 p.

Vermeulen, G.D. and Klooster, J.J. (1992): The potential of a low ground pressure traffic system to reduce soil compaction on a clayey loam soil. *Soil and Tillage Research* 24, pp. 337-358.

Viaux, P. (1999): Une 3e voie en grande culture. *Editions Agridécisions*, 211 p.

Virto, I., Imaz, M.J., Enrique, A., Hoogmoed W. and Bescansa, P. (2007): Burning crop residues under no-till in semi-arid land, Northern Spain – effects on soil organic matter, aggregation, and earthworm populations. *Australian Journal of Soil Research* 45(6), pp. 414-421.

Vleeshouwers, L. M. and Verhagen, A. (2002): Carbon emissions and sequestration by agricultural land use: a model study for Europe. *Global Change Biology* 8, pp. 519-530.

Warkentin, B. P. (ed.) (2006): *Footprints in the soil: people, ideas in soil history*. Elsevier.

Warren, A. and Bärring, L. (2003): Introduction. In: Warren, A. (ed.): *Wind erosion on agricultural land in Europe*. European Commission, EUR 20370, pp. 7-12.

Washington State University (2002): *Comparing yields with Land Equivalent Ratio (LER).* Agriculture and Natural Resources fact sheet 532. Available at: http://king.wsu.edu/foodandfarms/documents/LER.pdf.

Weber, R. and Hrynczuk, B. (2002): Impact of soil cultivation methods on crop yield stability for several winter wheat cultivars. Electronic Journal of Polish Agricultural Universities, Agronomy 5 (2).

WEELS (Wind Erosion on European Light Soils) (2008): Web site. Available at: http://www2.geog.ucl.ac.uk/weels/.

Whitmore, A.P. and Schroder, J.J. (2007): Intercropping reduces nitrate leaching from under field crops without loss of yield: A modelling study. *European Journal of Agronomy* 27, pp. 81-88.

Wischmeier, W.H. (1959): A rainfall erosion index for a universal soil loss equation. *Soil Science Society of America Journal* 32, pp. 246-249.

Woods, K.B., Gregg, L.E., Hittle, J.E. and Beddoe, G.H. (1944): Pavement performance related to soil texture and compaction. *Highway Research Board Proceedings* 24, pp. 426-440.

Yildirim, E. and Guvenc, I. (2005): Intercropping based on cauliflower: more productive, profitable and highly sustainable. *European Journal of Agronomy* 22, pp. 11-18.

Yu, B. and Rosewell, C.J. (1996): A robust estimator of the R factor for the Universal Soil Loss Equation. *Transaction of the ASAE* 39 (2), pp. 559-561.

Zobler, L. (1986): *A world soil file for global climate modelling*. NASA Technical Memorandum 87802. NASA Goddard Institute for Space Studies, New York, U.S.A.

European Union: regulations, directives and communications

Council of the European Union (1975): Council Directive 75/439/EEC of 16 June 1975 on the Disposal of Waste Oils.

Council of the European Union (1975): Council Directive 75/442/EEC of 15 July 1975 on waste, OJ L 194, 25.7.1975, p. 39).

Council of the European Union (1979): Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds.

Council of the European Union (1980): Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances, OJ L 020 , 26/01/1980, pp. 43-48.

Council of the European Union (1985): Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, OJ L 175, 05/07/1985, pp. 40-48.

Council of the European Union (1986): Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture.

Council of the European Union (1987): Council Directive 87/101/EEC of 22 December 1986 amending Directive 75/439/EEC on the disposal of waste oils, Official Journal L 042 , 12/02/1987, pp. 43-47.

Council of the European Union (1991): Council Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on waste.

Council of the European Union (1991): Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment, OJ L 135, 30.5.1991.

Council of the European Union (1991): Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market OJ L 230, 19.8.1991.

Council of the European Union (1991): Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, OJ L 375, 31.12.1991.

Council of the European Union (1991): Council Directive 91/692/EEC of 23 December 1991 standardizing and rationalizing reports on the implementation of certain Directives relating to the environment.

Council of the European Union (1991): Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs, OJ L 198, 22.7.1991.

Council of the European Union (1992): Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Council of the European Union (1992): Council Regulation (EEC) No 2078/92 of 30 June 1992 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside, OJ L 215, 30.7.1992.

Council of the European Union (1996): Council Directive 96/62/EC of 27 September 1996 on ambient air quality assessment and management OJ L 296, 21/11/1996, pp. 55-63.

Council of the European Union (1997): Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment OJ L 73, 14.3.1997, pp. 5-15.

Council of the European Union (1998): Directive 98/8/EC of the European Parliament and of the Council of 16 February 1998 concerning the placing of biocidal products on the market, L 123/1, 24.4.98.

Council of the European Union (1999): Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air, OJ L 163, 29.6.1999, p. 41.

Council of the European Union (1999): Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, OJ L 182, 16.7.1999.

Council of the European Union (1999): Council Regulation (EC) No 1258/1999 of 17 May 1999 on the financing of the common agricultural policy, OJ L 160, 26.6.1999.

Council of the European Union (1999): Council Regulation (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production, OJ L 222, 24.8.1999.

Council of the European Union (1999): Council regulation No 1257/1999 of 17 May 1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) and amending and repealing certain Regulations.

Council of the European Union (2000): Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22.12.2000.

Council of the European Union (2001): Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment, OJ L 197, 21.7.2001.

Council of the European Union (2001): Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants, L 309/1, 27.11.2001.

Council of the European Union (2001): Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, L 309/22 27.11.2001.

European Commission (2001): Communication from the Commission to the Council, the European Parliament. Biodiversity Action Plan for Agriculture, III (COM (2001) 162final).

European Commission (2002): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Towards a Thematic Strategy for Soil Protection (COM (2002) 179final).

Council of the European Union (2003): Council Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No 2019/93, (EC) No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC) 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and (EC) No 2529/2001.

Council of the European Union (2003): Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC.

European Commission (2003): Report from the Commission of 5 January 2004 on the implementation of the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, COM(2003) 845 final.

Council of the European Union (2004): Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air.

Council of the European Union (2004): Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC, OJ L 229, 30.4.2004.

European Commission (2004): Commission Regulation (EC) No 796/2004 of 21 April 2004 laying down detailed rules for the implementation of cross-compliance, modulation and the integrated administration and control system provided for in of Council Regulation (EC) No 1782/2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers, OJ L 141, 30.4.2004, p. 18.

European Commission (2004): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the

Committee of the Regions. Flood Risk Management, Flood Prevention, Protection and Mitigation (COM (2004) 472final).

Council of the European Union (2005): Council Regulation (EC) No 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD), OJ L 277/1, 21.10.2005.

European Commission (2005): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions: Winning the Battle Against Global Climate Change {SEC(2005) 180}.

European Commission (2005): Proposal for a Directive of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (presented by the Commission), COM/2005/0447 final.

Council of the European Union (2006): Council Decision 2006/144/EC of 20 February 2006 on Community strategic guidelines for rural development (programming period 2007 to 2013), OJ L 55/20, 25.2.2006.

Council of the European Union (2006): Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.

European Commission (2006): Commission Regulation (EC) No 1974/2006 of 15 December 2006 laying down detailed rules for the application of Council Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD), OJ L 368, 23.12.2006.

European Commission (2006): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. A Thematic Strategy on the Sustainable Use of Pesticides, Technical Annex (SEC(2006) 895).

European Commission (2006): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Halting the loss of biodiversity by 2010 and beyond, sustaining ecosystem services for human well-being (COM (2006) 216final).

European Commission (2006): Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC, COM(2006) 232.

European Commission (2006): Report from the Commission on the Implementation of Directive 79/409/EEC on The Conservation of Wild Birds, COM (2006) 164 final.

European Commission (2006): Report from the Commission to the Council and the European Parliament on Implementation of the Community Waste Legislation for the Period 2001-2003, COM (2006) 406 final.

European Commission (2006): Thematic Strategy for Soil Protection, COM (2006) 231.

European Commission (2006): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. A Thematic Strategy on the Sustainable Use of Pesticides, COM(2006) 372 final.

European Commission (2006): Proposal for a Directive of the European Parliament and of the Council establishing a framework for Community action to achieve a sustainable use of pesticides (presented by the Commission), Brussels, 12.7.2006, COM(2006) 373 final.

European Commission (2006): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Summary of the Impact Assessment of the Thematic Strategy on Soil Protection (Sec (2006) 1165 and Sec(2006) 620).

European Commission (2006): Report from the Commission to the Council and the European Parliament on Implementation of the Community Waste Legislation for the Period 2001-2003, COM (2006) 406 final, p.5s.

Council of the European Union (2007): Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91.

European Commission (2007): Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Nitrates report on implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources for the period 2000-2003, (COM (2007) 120final).

Council of the European Union (2008): Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (Codified version), L 24/8, 29.1.2008.

European Commission (2008): Proposal for a Council Regulation establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers; Proposal for a Council Regulation on modifications to the common agricultural policy by amending Regulations (EC) No 320/2006, (EC) No 1234/2007, (EC) No 3/2008 and (EC) No […]/2008; Proposal for a Council Regulation amending Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD); Proposal for a Council Decision amending Decision 2006/144/EC on the Community strategic guidelines for rural development (programming period 2007 to 2013), (COM(2008) 360final).

Annex

The annex is provided in a separate file.

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Abstract

Agriculture occupies a substantial proportion of the European land, and consequently plays an important role in maintaining natural resources and cultural landscapes, a precondition for other human activities in rural areas. Unsustainable farming practices and land use, including mismanaged intensification as well as land abandonment, have an adverse impact on natural resources. Having recognised the environmental challenges of agricultural land use, the European Parliament requested the European Commission in 2007 to carry out a pilot project on "Sustainable Agriculture and Soil Conservation through simplified cultivation techniques" (SoCo). The project originated from a close cooperation between the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC). It was implemented by the Institute for Prospective Technological Studies (IPTS) and the Institute for Environment and Sustainability (IES).

This report presents the findings of a stock-taking of the current situation with respect to soil degradation processes, soil-friendly farming practices and relevant policy measures within an EU-wide perspective. This overview includes the results of the survey on the national/regional implementation of EU policies and national policies, a classification of the described soil degradation processes, soil conservation practices and policy measures, and finally the outcome of the Stakeholder Workshop which took place on 22 May 2008 in Brussels.

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