Chapter 3

Towards a European Sustainable Land Management

Introduction

This chapter explains how sustainable development can be translated into principles of sustainable land management. In Chapter 5 these principles will be related to European soil protection law.

One of the conclusions of the SCAPE case studies described in Chapter 4 is that although principles are known, they are sometimes ignored. Maybe there are good reasons for ignoring principles and accepting soil and land degradation as a consequence. However, in most cases the choices or risks are not debated. This is partly because too frequently, decision makers do not have access to the correct information or influence. Knowing the principles is only half of the problem; the second half is requiring people to act upon them, which is a question of political will and prevailing norms. The anecdotes described in the next section show what can happen with soil conservation advice in practice. These examples are mainly from Spain and Norway, but they could have come from almost anywhere in Europe.

For thousands of years farmers know that they take a risk and might loose their soil if they plough on steep slopes. This is why steep areas are usually covered with grass and forest. Erosion can be a problem even when slopes are as gentle as 3 to 5 degrees. Maps of the Universal Soil Loss Equation (USLE, box 3.1) have been used in Europe to identify areas too steep for ploughing. Has this been useful?

Ten years ago the Global Change and Terrestrial Ecosystem (GCTE) soil erosion network organised a scientific excursion to the Medalus field sites in SE Spain. Medalus is the acronym for a large EU funded research project on Desertification and Land Use that existed between 1990 and 2000. An extreme rainfall event occurring once in five years in the Guadalantin Valley had left the fields full of rills and small gullies, which excited the Europeans but disturbed the African scientists, who had been trained to experience soil loss as a tragedy. What made Spanish farmers plough 25 degree slopes when this clearly contradicted the prescriptions of the Spanish National Nature Conservation Institute (ICONA, 1988) maps of the USLE? “We could not do this in Africa, so how can it happen here?” said one of the African scientists. The excursion leader explained; “erosion in Spain mainly occurs in the Plain if it rains, which is not often. Erosion mainly occurs on degraded matorral (box 3.2). Agricultural areas are not a problem, except when they are being abandoned and their agricultural terraces collapse.” Our African friends saw this as another example of unequal north-south dialogue. They had to comply with standards and norms when they spent European money in Africa. However, the same money could have been spent in Spain, but nobody cared enough about erosion then.

At our fourth SCAPE workshop in Norway, we could study the intricate and fresh rill patterns and sediment laden water, draining phosphates and adsorbed chemicals into
the once clean lakes around Oslo. During the excursion we saw, just as in Spain, farmers ploughing or harrowing steep slopes. Like the Spanish ten years earlier they also had maps of the erosion obtained using the USLE, showing areas with a high erosion risk. Recalling the Africans in Spain we asked the old question: “What compels Norwegian farmers to ignore the erosion risk maps and plough those steep slopes?” “It is no problem”, said the man from the farming advisory service. “It is quite OK. Usually it never rains strongly in the spring or after the spring-ploughing,” though at that time we sheltered form the rain. Remember, there is not much flat land in Norway so that the farmers must plough the steep slopes to get enough income.

These two experiences illustrate the value and insight of field visits. In theory there are many tools and instruments that farmers and land managers can use to combat erosion. In practice, national governments have their own (agricultural) policies influencing the choices that land users make, which may lead to disregarding consequences of land degradation. This does not happen in Africa because the farmers living in traditional systems must behave in a sustainable way or else suffer the consequences themselves. It is a different matter when countries have resources to grow what they want.

For example, wheat is a major crop both in southern Portugal and central Norway. Why is it that both countries want to be areas of wheat production? Near Faro and Oslo, it is actually quite possible to grow wheat according to the criteria of sustainability. However, managing the land is a real challenge because it requires responsible and well trained extension officers to explain and communicate to the responsible authorities what exactly the risks and long-term price are. It might be socially acceptable and economically justifiable to plough steep slopes and sacrifice the soil to a higher purpose of, for example, national self-sufficiency, but this is definitely not sustainable from the soils point of view, and those who pay the price should debate the issue. Good communication is thus very important for sustainable land management.

Some of the negative impacts of land use- and management-changes on soil conditions, are becoming increasingly evident at global, European, national and local scale. In the developing countries the need for agricultural land is increasing due to population growth, land degradation and erosion (Geist and Lambin, 2001). By 2030, the world population is estimated to be at least 8 billion (see United Nations Population Fund, 2001), which suggest that there will be only 0.08 hectares of arable land per person. In industrialized countries, soil degradation is driven by intensified agriculture. Mechanization, mono-culture agriculture, fertilization, high input of pesticides and soil sealing are impairing natural soil conditions. Intensive agricultural management systems, driven by national and international policy, are often not adapted to natural soil conditions, and therefore often lead to soil degradation.

Soil erosion is one of the most severe consequences of soil degradation with respect to restoration of soil quality and soil productivity. On agricultural land, in the long-term, soil erosion is considered to be a problem when the yearly erosion rate exceeds the rate of new soil formation. Any net soil loss larger than 1 t ha\(^{-1}\)year\(^{-1}\) can be considered as irreversible within a span of 100 years (Jones et al., 2004). In practice however, even small amounts of erosion can have serious negative impacts. According to the International Union for Soil Sciences (IUSS), consequences of soil degradation for society are equally drastic as the consequences of climate change.

Today “sustainable land management” is increasingly being seen throughout the world as a key to many problems of land degradation. For example, to help poor countries address land degradation and help them combat land

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**Box 3.3. Land Degradation Assessment in Drylands (LADA)** is a FAO project which generates up-to-date ecological, social, and economic and technical information, including a combination of traditional knowledge and modern science, to guide integrated and cross-sectoral planning and management in drylands.
degradation, both the Global Environment Facility (GEF) and the World Bank are implementing promising strategies for achieving sustainable land management (GEF, 2003). Indicators that can be used to guide and monitor this are being collected as part of a project called LADA (box 3.3). The World Bank strategies for achieving sustainable land management involve actions that emphasize capacity building and awareness raising.

The Soil Quality Principle in Sustainable Land Management

The principle of soil quality is an extremely valuable one. Today, farmers and other land users are able to assess the quality of their soil using soil quality indicators that are beautifully described and explained on the internet (http://soils.usda.gov/sqi/). Farmers are able to fill in score cards (figure 3.1) to assess their performance in achieving soil quality goals. In England, regulations now require all land users to monitor soil quality. Soil quality indicators are valuable tools and are finding increasing application throughout the world; however, they could and should be used more in Europe.

<table>
<thead>
<tr>
<th>Site Indicator Scorecard</th>
<th>USDA Natural Resources Conservation Service</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Indicator</strong></td>
<td><strong>Poor</strong></td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td></td>
</tr>
<tr>
<td>1. Walking distance to site</td>
<td>10+ minutes</td>
</tr>
<tr>
<td>2. Availability of parking</td>
<td>None</td>
</tr>
<tr>
<td>3. Visibility from street</td>
<td>Can’t see site or it is very visible</td>
</tr>
<tr>
<td>4. Hilliness of site</td>
<td>Very hilly</td>
</tr>
<tr>
<td><strong>Topography</strong></td>
<td></td>
</tr>
<tr>
<td>5. Direction the slope faces</td>
<td>North</td>
</tr>
<tr>
<td>6. Bedrock, ledge, or large boulders on site</td>
<td>Too many to work around</td>
</tr>
<tr>
<td><strong>Location/Distance to Water</strong></td>
<td></td>
</tr>
<tr>
<td>7. Water access — city water, pond, or river for irrigation</td>
<td>No water available on site, and no access to bring it to site</td>
</tr>
<tr>
<td>8. Water quality tested</td>
<td>Bad quality, can’t use</td>
</tr>
<tr>
<td>9. Runoff</td>
<td>After rainfall, a lot of soil washes from site</td>
</tr>
<tr>
<td>10. Water on surface during the growing season (spring, summer, fall)</td>
<td>After a moderate rainfall, water stays on surface for a few days</td>
</tr>
<tr>
<td>11. Sun exposure through the day</td>
<td>Shady, very little exposure</td>
</tr>
<tr>
<td>12. Amount of existing pavement on site</td>
<td>Too much pavement, will interfere with plans for the site</td>
</tr>
<tr>
<td>13. Debris (construction materials, bricks, concrete, etc.)</td>
<td>A lot on the surface</td>
</tr>
<tr>
<td>14. Shortcuts through site</td>
<td>Lots</td>
</tr>
<tr>
<td>15. Neighborhood pets</td>
<td>Site used heavily by animals</td>
</tr>
<tr>
<td>16. Human activity on site</td>
<td>Lots of evidence of people on site</td>
</tr>
<tr>
<td>17. What’s growing on the site now?</td>
<td>Lots of unwanted trees or brush</td>
</tr>
<tr>
<td><strong>History of Site</strong></td>
<td></td>
</tr>
<tr>
<td>18. History of site</td>
<td>Not known</td>
</tr>
</tbody>
</table>

Figure 3.1. Scorecard (NRCS).
Soil quality has been introduced by the Organisation for Economic Co-operation and Development (OECD) among the list of agri-environmental indicators of global relevance.

Traditionally, in agriculture, soil quality is related to the production function of soil, neglecting the other functions. Today, a new multifunctional definition of soil quality is usually applied (Karlen et al., 1997), in which soil quality is defined simply as the capacity of soil to function. A single parameter could never be used as an indicator for all of the soil functions, which are explained in the next section, although some come close. Most soil quality indicators need to be land use specific. There are some general indicators that have been used to provide an overall picture of soil quality. Soil organic matter content was used for this purpose by the recent EU programme on agri-environmental indicators (IRENA project, for more information see project website http://webpubs.eea.eu.int/content/irena/index.htm).

A high organic matter content in a soil is suggestive of fertility (a good buffering capacity, high biodiversity, good structure, effective carbon sequestration, etc). Soils with organic carbon content below 1% in the topsoils can be considered as degraded. Soils with very high organic carbon content (above 20%) can be considered as peat or peaty soils. However, it is the dynamics of organic matter and its effect on soil fertility that is important, not the actual amount of carbon present. Soils with high amounts of organic matter can sometimes be very sensitive to degradation.

There is still room for more consensus regarding definitions of soil quality that are appropriate for soil protection. While good water quality or good air quality are relatively easy to define, “good soil” or “bad soil” is still a matter of debate and the criteria used need to reflect local conditions.

Other principles for sustainable management used by soil scientist consider soil health and adaptation:

**Soil Health**

Soils function as a living ecosystem. As with all ecosystems the health status can be evaluated by asking: How is the system able to fulfil all its functions? In defining soil health we should consider the soil as a living system, address all essential functions of soil in the landscape, compare the condition of a given soil against its own unique potential within climatic, landscape, and vegetation patterns and somehow enable meaningful assessments of trends. Doran and Safley (1997) define soil health as the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health.

**Adaptive systems**

All ecosystems are able to adapt to slow changes which occur over time. Also soils have that ability. Under influence of climate, organisms and human actions, soils change gradually. For example, when changing a broadleaf forest into a coniferous forest the acid litter from the conifers can initiate a podsolisation process, where humus and iron particles are transported from the top layer of the soil and are sedimentated at a lower level. Consequently, the top-soil is getting bleached and in the lower part the soil can get a black and red colour.

These are natural processes and the systems adapt themselves to the changing conditions. However, in cases where clear thresholds are surpassed over both longer and shorter time scales, irreversible changes occur and the systems are not longer able to adapt themselves. An example is the development of gullies on a slope due to extreme rainfall. A protective vegetation cannot be established on the walls of the gullies. As a result the whole system will suffer from erosion, even in the case of much lower amounts of rainfall. Whole slopes can be eroded and large off-site damage can occur.
Soil Functions

Soil functions consider the eco-services that the soil is providing. Functions can be used to compare contrasted geographic regions, and economic values can be placed on them. Functions integrate socio-economic and physical systems. They link cultural values and perceptions with the perceived reality of the physical system. The value and benefits of a functions approach can be seen from its application in soil quality assessments. The soil quality site of the US Department of Agriculture NRCS (http://soils.usda.gov/sqi/) is recommended for this purpose. The authors at the soil quality site ask: “What does the soil do for you?”. The most important soil functions according to the European Commission (2002) and Dorren et al. (2004) are:

- **The Production Function (Food and other biomass)**
  Human survival depends on the production of food, wood, fibre, and other biomass. This is directly linked to soil quality as soil is the medium for rooting and delivers nutrients and water for growth. Soils are an important source of raw materials such as sand, gravel, clay, minerals and peat. Excavation of these materials means at the same time changes in ecosystem equilibrium, which requires changes in landscape planning and -development.

- **The regulation function of the soil**
  This includes the cycling of water and nutrients. The soil functions as a chemical factory by storing and transforming minerals, organic matter, other chemical substances and energy. Additionally, it is the main medium for storing and filtering water. Groundwater is the most important source for fresh water and in some countries soil is used as a medium to filter polluted river water to produce drinking water. But soil is also important for air quality, as it releases or stores CO₂, methane and other gases to or from the atmosphere. Within this class of function, the soil also provides a soil and water conservation function protecting people from off-site erosion damage and flooding.

- **Habitat and gene pool**
  Enormous amounts of organisms ranging from bacteria and fungi to insects and worms live in the soil. Soil performs essential ecological functions and harbours an important gene pool. Soil organisms also contribute to other soil functions, for example the breakdown of litter to humus by micro-organisms and the release of nutrients available for growing crops. Humus itself is important for the storage of water and is the living environment for many soil organisms. Destroying the habitat for soil organisms implies that the soil is not able any more to fulfil its functions in a proper way.

- **Physical and cultural environment for mankind**
  Soil is a platform for human activity and is an element of landscape and cultural heritage. At many places the first settlements were established on the best soils with regard to soil productivity; later on, the more marginal sites were taken into use. Due to the land use changes during the last half-century the degradation of soils often goes hand in hand with the degradation of the landscape and its cultural heritage.

Furthermore, the soil has a communication and an aesthetic, scientific and carrier function. It contains paleonthological and archaeological treasures, enabling mankind to better understand its history and development.

The soil functions as a soil-ecosystem. When surpassing thresholds, irreversible changes may occur. This means that the resilience of the soil ecosystem (box 1.2) is surpassed. Therefore it is important to know the resilience of the soil ecosystem to pressures or
drivers; thus it is important to have information about the soil quality and to understand the specific process of degradation and how they can be managed. Soil quality is usually measured indirectly, using indicators that are relevant and easy to measure. In this way, changes in soil quality can be detected, not only by experts but also by landowners and land managers themselves.

**Complexity and variability of soil functions**

The functions provided by the soil and land described above can be summarised as production, regulation, carrier and transport functions, all of which can be quantified. However, other types of function, including habitat, cultural and heritage functions, may have cultural and psychological dimensions that are less easy to define and measure. Although monetary values can be given to functions in order to provide a rational basis for evaluation and planning, these are often common goods. The beneficiaries of functions are not confined to a certain place. A resource may provide functions locally, directly supporting the inhabitants, but alternatively, the benefits can also be provided regionally, nationally or at a European or global level. Following from this, all areas are multifunctional, supporting a multitude of people who may live locally or far away, and be conscious or unconscious of the functions provided by soil. Different beneficiaries will rank and value subsets of functions quite differently. The complexity and variety of functions highlights the multi-sectoral nature of the values and demands that are being placed on landscapes.

It is well known that over-using or exploiting some functions (e.g. production function for crops or water) can lead to the damage of other ones. It is easy to deplete natural resources and degrade the capacity of the system to support other functions. The spatial and temporal variation in the provision of functions should be incorporated in evaluations. In other words, besides spatial complexity, there is also a temporal dimension in land use and management.

**Some functions further explained**

*Production function*

Production functions reflect the inherent quality of the land itself but also reflect fluctuations in the amount of energy and water that influence the actual productivity, and the knowledge and insight of people who manage and use the land.

*The Water and Nutrient Regulation Functions of the Soil*

The water and nutrient regulating functions can be deregulated by several processes. For a soil to be able to regulate water, it needs pores that can store and release water. This capacity is affected by the role of soil organisms in producing substances that bind the soil into water-stable aggregated particles. Water-stable soil aggregation can be an indicator of the success and failure of biological activity in creating and maintaining the water and nutrient regulation function. This biological activity depends on both a sufficient input of suitable organic matter and periods of time during which soil moisture and temperature do not limit activity. It is for these reasons that soil structural stability is seen as a key indicator of soil quality.

In more arid soils the water regulating function is greatly influenced by gypsum, water-soluble salts and the dispersion of clay minerals. Dispersive conditions are frequently found in soils that contain low amounts of salt but which have a relatively high percentage of sodium. Clay dispersion is a climate-sensitive process. A climatological threshold, above or below which the clay will be either flocculated or dispersed (box 3.4), has been proposed for southern Europe (Lavee et al., 1996). Where the

**Box 3.4. Flocculation** is the process by which soil colloids concentrate or clump together into soil aggregates, thereby coarsening soil structure. **Dispersion** is the process by which soil aggregates fall apart (disperse) into smaller soil colloids, thereby weakening soil structure.
annual precipitation is below 400 mm yr\(^{-1}\), dispersion is the key process regulating infiltration and water storage in the soil. The areas of soil affected by dispersion vary both temporally, according to the amount of rainfall, and spatially. The SAR (sodium adsorption ratio) and the ESP (exchangeable sodium percentage) are excellent indicators of how the soil is functioning.

**Soil and Water Conservation Function**

How landscapes function in regulating water is important. Human activity (e.g. farming) degrades or destroys some structures and creates others. Those that are degraded are often the ones formed over long periods of time through the interaction of plants and animals with the soil. Those that are formed could be man-made structures and terraces. Landscapes can be seen as a mosaic of hydrological or ecological response units. Positive feedbacks between vegetation, soil and water regulate the redistribution of rainfall and runoff within these units. Processes at a local scale can have profound influences on a broader scale. The degradation of water and nutrient regulation functions of soil can result in an increase of runoff and erosion, and in the reduction of landscape performance for soil and water conservation.

**Soil threats**

This section will briefly review the different threats faced by soils as discussed by the European Commission Communication (2002). Most of the threats are interlinked. The threats are often linked by similar causative factors. Actions to protect the soil implies in many cases to tackle the different threats collectively. The DG Environment working groups considered the following threats.

- **Soil Contamination**
  
  Soil contamination can be divided in point source contamination and diffuse contamination. Point source contamination is often related to waste landfills, mining and industrial activities. The number of contaminated sites in the EU-15 (before the enlargement with the Central and Eastern European Countries) is estimated to range from 300.000 to 1.5 million. Huge resources are already spent on cleaning the soil and on the prevention of leaking of polluted materials to ground and surface waters. Diffuse soil contamination is in general associated with atmospheric deposition, certain agricultural practices and inadequate waste and wastewater recycling and treatment. Atmospheric contamination can be both acidifying and poisonous. Acidifying components reduce the buffer capacity of the soil and the pH will gradually decrease. Poisonous elements like Hg, Cd, As, Pb and several organic compounds can pollute the soil gradually and damage soil- and ecosystem functioning. These contaminating elements will become part of the nutrient cycling and will consequently have an impact on human health. In addition, nuclear fallout, especially \(^{137}\)Cs, is retained in the soil, causing potential pollution hazards, as was witnessed after the Chernobyl incident.

- **Soil erosion**
  
  Severe erosion generally causes irreversible damages to soil functions; deteriorating soil quality. Erosion may threaten agriculture and the viability of rural areas. On the other hand, it also can cause landscape changes that create possibilities for new land uses, such as tourism and outdoor recreation. Today the mosaic of forest and remnants of the old sand dune landscape in the Netherlands is attractive for tourism, outdoor recreation and nature conservation. However, the effect of soil erosion is more often negative than positive. The impacts of erosion are often separated into on- and off-site impacts.

- **Decline in organic matter**
  
  Soil organic matter is composed of organic material, living organisms and humus. In general, there is equilibrium between the production of organic matter and its breakdown. However, factors such as agricultural practices and soil treatment can
disturb this equilibrium, resulting in decreased organic matter content. In the climate change debate, increased storage of carbon in soils is fundamental in plans for decreasing atmospheric carbon (Kyoto protocol article 3.3 & 3.4). Soils with a higher organic content are generally more resistant to erosion and compaction. The organic matter content in European soils however has an overall tendency to decrease due to changes in land use, particularly by intensification of agriculture.

- **Soil sealing**
  Soil sealing is the covering of soil by roads, railways, industry and housing. A sealed soil is not able to fulfil its original functions and these changes are often irreversible. The sealing of good agricultural land is considered as a major problem in many European countries. As cities are historically built around good agricultural areas, it is easy to understand that good soils are subject to soil sealing. In addition, it is cheaper to use agricultural soils for construction of roads and railways than other land types, such as forests.

  Considerations for soil sealing should contain two elements. The first is to keep the most productive agricultural areas in production, especially in regions with a low percentage of agricultural land. The second is to prevent the degradation of these areas. The latter is often not discussed at all. An active policy is needed to achieve the prevention of soil sealing, such as has already been implemented in Norway.

- **Soil compaction**
  Soil compaction occurs when soil is subjected to mechanical pressure through the use of heavy machinery or trampling of cattle. The risk on soil compaction increases as soils get wetter. Soil compaction is often a hidden problem, and it is irreversible when passing certain thresholds, which vary from soil to soil. It results in a reduced permeability of the soil and increases the risk for soil erosion, because of saturated overland flow and rill erosion in tractor wheelings. It also increases the risk on winter injury in boreal pastureland. The present increase of irrigated land increases the risk of soil compaction, because wet land is more vulnerable to compaction than dry soil.

- **Decline of soil- biodiversity**
  Increased soil biodiversity has a positive influence on soil health. Soil organisms are crucial for maintaining the physical and biochemical properties needed for soil fertility. Soil biodiversity decreases with intensification of agriculture and loss of organic matter. Reduction of soil biodiversity affects soil quality and resilience, making the soil more vulnerable to other degradation processes. Disappearance of earthworms is a good example, as restoration of soil structure that is damaged by soil compaction will be harder without the help of earthworms.

- **Salinisation**
  Salt-affected soils occur both naturally and as a result of bad irrigation and drainage practices. Salt-affected soils are divided into saline soils and alkali or sodic soils. Saline soils cover larger areas and are often caused by anthropogenic influence (Crescimanno et al, 2004). Salinisation in Southern and Eastern Europe is a big and increasing problem. In Europe, 26 countries are affected by salinisation and sodification problems and about 25% of irrigated cropland in the Mediterranean region is affected. Salinisation has major negative impacts on crop production, and restoration is very expensive or impossible. Many of the severely affected areas are abandoned without any attempts being made for rehabilitation. For example, this applies to about 300.000 ha of affected soil in the Russian Federation (EEA, 2003).

- **Floods and landslides**
  The risk of floods and landslides is often related to land use and land management. In modern agriculture surplus water is usually evacuated as fast as possible from fields to rivers and streams. Decreased organic matter content and soil compaction result in reduced water retention capacity of the soil. In other words, the capacity of the soil to
store and retain water is decreased, which results in an increased risk to flooding. Land management strategies should be implemented to keep surplus water as long as possible in the upper parts of watersheds. Landslides are often related to the geological situation, bank erosion and changes in land use.

**Soil and Land Management related to soil degradation and erosion processes**

This section provides more information about soil degradation processes and how they are related to land management. The principles will be described at different levels of scale, beginning top-down at the coarse scale.

**Global or national scales and long term considerations**

At the global scale, the causal factors that lie behind soil degradation and erosion are complex. They are often related to national and international policies. The driving forces of accelerated soil erosion are social, economic, ecological and physical, and they all act in an integrative way (Esteve et al., 2004).

**Crop choices**

Today, globalisation drives farmers to grow crops at world market prices and it is attractive to grow the most profitable products, regardless of the source of income: subsidies or retail. For some farmers this is a question of survival, for others a question of common sense. Farmers react very quickly to changes in price incentives and world prices. Local conditions and suitability are therefore often not taken into account. Growing the most profitable crops results often in a very short rotation plan, which increases the danger for soil borne diseases. This, in turn, calls for soil sterilisation (box 3.5), often with negative environmental consequences. If soil sterilisation is not allowed, the soil degrades and may be abandoned. Development of serious soil borne diseases (for example potato cyst nematode- Globodera ssp) can be considered as a form of soil degradation.

**Livestock densities and land abandonment**

The dynamics of trading and rearing livestock is an important issue that has many dimensions. Some of these are considered in the SCAPE case studies (chapter 4). Increased livestock per unit of land causes problems with soil compaction and problems with disposal of manure. In many European countries, livestock densities far exceed the ecological appropriate stocking densities. When vegetation cover is structurally damaged by overgrazing, erosion processes can start, which is widely reported not just from the Mediterranean but also from countries such as Ireland, England and Norway. Rangeland science in North America has developed systems for characterising the health of the soil and the impact overstocking has. Recently, in Alberta, thousands of cattle were relocated because the indicators of rangeland health indicated incipient desertification. The effects of land abandonment are quite varied, including amongst others, shrub and tree encroachment in Northern Europe and increasing risk to wildfires in Southern Europe.

**Tourism**

The development of tourism is an important driver of land use change causing impacts such as soil sealing, compaction and erosion. Both mountainous and coastal areas are especially susceptible to damage from tourist pressure (Esteve, 2004).
Desertification
According to the UNCCD definition, desertification comprises land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities. The Mediterranean area is identified as sensitive to desertification due to a combination of climate conditions, soil and terrain characteristics, agriculture and exploitation of water resources (Castillo et al., 2004). Desertification leads to abandonment of land and sometimes of whole communities (Rosell et al., 2005). Both natural and socio-economic factors are involved in this process. The UNCCD definition that restricts desertification to dry regions is unfortunate as the land degradation problems in Southern and Northern Europe were found to be in many ways similar. A protocol to the UNCCD convention that covers the remaining parts of Europe, including Iceland was recommended by SCAPE (SCAPE, 2005).

Climate change
Change in weather patterns results in more frequent and serious droughts or increased and more intense precipitation periods. Both result in more erosion, especially in already vulnerable ecosystems.
Today, although the water balance of the atmosphere is profoundly affected by soil properties, this is often glossed over by the general public who often see climate change as a process that stands on its own. However, there are many feedbacks between soil use or land management and the climate, for instance: Changes in the reflectance and water-holding capacity of the soil can lead indirectly to increased soil temperatures and a decrease in precipitation. As mentioned before soil conservation can be a strategy in reducing greenhouse gasses.

Principles of Land Management at the local scale
Soil degradation at a specific site or in a field is expressed in any form of reduced organic matter, soil compaction, soil contamination, reduced soil biodiversity, and damage to several other soil properties such as cation exchange, water retention and soil-structure. Often, different types of soil degradation occur at the same time. The most visible form of soil degradation is expressed in soil erosion.

Damage or impact caused by soil degradation can occur both on-site, or indirectly away from the site, which is called off-site effects. Soil erosion affects soil conditions by reducing organic matter content and rooting depth, leading to less water storing capacity and a decline in nutrients. Sedimentation areas can be polluted by nutrients, pollutants and pesticides which are transported by erosion processes. In the long run, erosion leads to substantially less productivity, as has been reported worldwide. A recent report from Czech Republic states that erosion may lead to farm abandonment (Fanta et al., 2005).

On-site damage is generally a slow process and farmers often correct it by increased input of fertilizers as long as no thresholds are passed (Wiebe, 2003). Off-site damage is often more severe. It is related to the processes of transport and sedimentation of soil particles (Dorren et al., 2004). The damage is often difficult to relate to the source of the sediment and damage can take many years to become evident. The sediments can block roads and fill up rivers and water reservoirs, such as those for the production of electricity and irrigation purposes. Subsequently, flooding hazards increase substantially, causing huge property damages and sometimes losses of human lives. Remedies are generally very expensive.

In Northern, Central and Southern Europe the main off-site damage affects infrastructure and waterways. In Northern Europe off-site damage has resulted in eutrophication (box 3.6). Several countries, such as Norway, Denmark, and Germany, have developed a national strategy to reduce erosion to prevent the pollution of both fresh and salt-water ecosystems.
Few comprehensive studies on the economical consequences of soil degradation and erosion for the farmer and society are available in Europe. Accelerated soil erosion adversely affects economical productivity on-site and environmental quality off-site (Dorren, 2004). The costs of on-site effects of erosion are to be found in decreased yields and increased costs for fertilizers and irrigation to compensate the loss of nutrients and reduced water retaining capacity. In fact, on-site damage is not a factor of concern for the farmer as long as he is still receiving profitable yields from the land.

The costs for off-site effects of erosion are more complex and much larger. It is estimated that 17% of the total European land area is affected by erosion in one or another way (EEA, 2003). Yearly estimated economic losses in agricultural areas due to on-site effects are €53 per ha. The costs for off-site effects of erosion on the surrounding civil public infrastructures are estimated at €32 per ha, but a far larger area is affected by off site erosion, which leads to higher total costs compared to on-site costs. A more thorough analysis of the costs of soil erosion is urgently needed. More accurate figures would make it possible to evaluate how cost-effective measures are to prevent and reduce erosion.

Soil degradation also has a link with land ownership. In areas marginal for agriculture, the agricultural land is often leased, due to abandonment by the actual owner. Most farmers have limited knowledge on how to reduce erosion and other types of soil degradation by improved land management. The farmer is generally more interested in the short term economic results and is less interested to invest in the long term improvement of soil quality when leasing the land. This has been reported in Norway, Finland and Estonia (Elgersma et al. 2004; Vihinen et al., 2004; Mander et al, 2004). Long term investments to improve soil quality should be made economically interesting for farmers renting out land.

**Strategies for the development of Sustainable Land Management Systems**

**Farming policy strategies**

It is clear that if subsidies make it attractive to grow specific crops everywhere, land use practices might no longer be limited by land quality considerations. Therefore, an obvious approach to reduce the risk of soil degradation and erosion is to develop land management systems that are adapted to the local soil, terrain and climate conditions. This is frequently being done by shifting from quantitative production systems to qualitative systems, which take into account the whole landscape and maintain biodiversity. The challenge is to make this change possible within a sound socio-economic framework. This could require innovative agricultural methods.

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**Box 3.6. Cases are known that lakes became unsuitable for their functions.**

The nutrients, pollutants and pesticides transported by erosion can eutrophicate and pollute ground- and surface waters. Eutrophication of drinking water has direct impact on human health. In North-western Europe eutrophication caused blue algae growth in open waters, causing pollution of shellfish which made them unsuitable for human consumption. The algae cause oxygen depletion of the water, killing other organisms in the water. The nutrient rich sediments at the bottom of lakes may even cause problems long after measures are taken to reduce soil erosion. Eutrophication has impact in both fresh and salt-water ecosystems. Erosion can affect offshore ecosystems, such as the coral reefs in the Skagerak.
In the past, “area and crop based subsidy schemes” (CAP, box 3.7, and national schemes) caused the transformation of marginal grasslands into grain producing areas and for instance, olive plantations. It is clear that as a consequence of this policy the soils and the environment of these areas have been damaged or placed at risk.

Intervention usually refers to prevention, mitigation, restoration and rehabilitation measures. Preventative measures are those that are taken in areas at risk. Evaluating risk requires expert knowledge of the local soil and terrain conditions. Mitigation strategies are those being taken in areas where soil degradation or erosion is taking place. Measures usually focus on halting degradation processes and on improving land condition or resilience. Total change in land management system, including afforestation and establishment of nature reserves, can be an option. Restoration and rehabilitation strategies might aim at restoring former or alternative land uses or functions. Sometimes it is impossible to restore former conditions so that a totally new land management strategy might be necessary, for example by afforestation or establishing nature reserves and aesthetic values.

### Technical measures

There are many hundreds of technical measures that can be used in different situations. One frequently described strategy is to keep soils covered by vegetation or crops as long as possible. A vegetation cover or mulch protects the soil from the destructive energy of rain drop impact, and at the same time leads to an improvement in the ability of the top soil to retain water. Another strategy is to reduce the amount and speed of runoff, which can be done by means of terraces or grass buffer strips. Contour ploughing is used to reduce the speed of run-off water and special systems have been devised to enhance infiltration of water by making small elevations parallel to the contours.

Soil cultivation methods can also be used to improve soil quality and reduce compaction. In some countries zero and minimum tillage techniques are applied. This was extensively experimented with in Europe, for example in Belgium and France, but it was never popular with farmers regarding problems with weeds and herbicides. In Europe, tillage regimes that avoid winter and spring ploughing and which make use of crops specifically sown in the autumn to improve soil quality, have been very effective.

Impact orientated technical measures, such as buffer strips alongside streams and sedimentation ponds, aim to prevent eroded material from reaching streams and rivers. Other options include intercepting surplus water in pipes for transportation from the fields, which requires structural maintenance of the drainage system.

Soil management practices need careful planning and timing; directed at the improvement of soil properties. Restoration of soil structure should include measures to limit the use of heavy equipment, especially during wet terrain conditions. Organic matter content can be increased in fields by adding manure or compost. The quality of organic fertilizers needs to be monitored as they may be polluted and could give problems in time.

The soil surface of olive plantations and vineyards is often kept free of vegetation, to prevent competition for water and nutrients. However, these systems increase the risk for erosion dramatically.

Extensive systems of terraces have existed on steep slopes in Southern Europe since Roman times. Under the current socio-economic situation the possibilities for increased agriculture in these areas is limited and many terraces are left abandoned or are levelled. Lack of maintenance causes the terrace walls to collapse. However, the fate of
former agricultural terraces is highly varied and in many situations they remain intact, but this depends on slope, rock type and climate. In some situations growing trees strengthen the former slopes with their roots, but in other situations they lead to collapse because they increase the normal pressure acting on the slope. They may also lead to the development of subsurface pipes that enables water to drain slopes and to concentrate this runoff at places where landslides and gullies may be triggered. When terrace walls collapse, severe and irreversible erosion processes often begin. In remote areas such erosion is not a risk and an inevitable consequence of land use change. It is only important close to villages or towns where offsite damage is possible.

**Decision support systems**

In marginal areas farmers require additional sources of income. The percentage of farmers having this can be as high as 80% (Elgersma et al., 2005). The development of multifunctional agriculture and ecological farming (box 3.8) has been shown to be helpful. In suburban areas, ecological farms, producing vegetables and fruits based on a subscription system showed interesting results (Dorren, 2004). Some of these farms have developed education programs for schools and made people interested in ecological food production. In more remote areas in Europe, the combination of agriculture with tourism and nature adventures is getting more and more common. Branding and marketing are important in increasing the added value of products, as can be seen from the Cinque Terre case study.

Knowledge about soil suitability and land capability should be available to landowners and authorities, in order to develop agriculture adapted to the local conditions. Information systems are therefore needed. These should be suited for natural resource management at the farm level, with emphasis on the risk of soil degradation and measures to reduce these risks. In both Spain and Norway such information systems are already made accessible for farmers:

- a. The Agricultural Land Evaluation Decision Support System for Mediterranean zones (MicroLEISS DSS)
- b. The Norwegian Soil Information System

**Box 3.8. Multifunctional agriculture** is a socially constructed concept that recognises agriculture beyond its primary role of producing food and fibre. It also provides other functions such as the viability of rural areas, food security, the cultural heritage and environmental benefits such as the agricultural landscape, agri-biological diversity and land conservation (Elgersma et al, 2004).

In ecological farming the farming system is as much as possible in balance with the natural resources present. The use of artificial fertilizers and pesticides is forbidden.

a. The agricultural land evaluation decision support system for Mediterranean zones (MicroLEISS DSS)

*MicroLEISS DSS* (De la Rosa et al., 2004), is developed to assist decision-makers facing specific agro-ecological problems. The land attributes that are used correspond to three main factors: soil, climate, and farming databases. For each of these main factors, a database is constructed with inter-connectivity between them. *MicroLEISS DSS* is implemented on the internet, so that users can apply the model.

The *MicroLEIS DSS* system focuses on soil protection by improving agricultural soil use and its management. Through application of the 12 land evaluation models of *MicroLEIS DSS*, site-specific measures to prevent soil degradation can be formulated with respect to two major topics: i) measures related to land use planning, and ii) those related to land use management.

In summary, *MicroLEIS DSS*, http://www.microleis.com, is an example of advisory/decision-support tool to exploit and share the scientific data and ideas across to the public. This decision tool can be especially useful in compiling detailed Guidelines of Good Agricultural Practices for the prevention of soil degradation based on; variability of soils, climate, land use, and socio-economic conditions.
b. The Norwegian Soil Information System

The development of the Norwegian Soil Information System began in the early 1980’s. In 1988/1989, an algae disaster caused the death of marine biota in the North Sea and Skagerrak. The pollution of water by nitrogen and phosphorus from agricultural land was identified as the main cause of the problem. European countries bordering the North Sea agreed on reducing this pollution. In Norway, a soil-mapping programme was initiated, with the aim to give background information on the improvement of land management systems to reduce erosion. Today around 50% of the agricultural area is mapped. Field data on soils, such as texture, organic matter content, drainage, stoniness and slope are collected at a scale of 1:15 000. By modelling field data, 16 thematic maps are developed. These maps contain information about land suitability, erosion risk associated with autumn ploughing, possibilities for different tillage systems and advised soil conservation measures in areas with high erosion risk.

The information is used in Agri-Environmental Schemes (box 3.9) to define rates of payments for different management practices to reduce erosion. Farmers use the thematic maps to plan their farm management and to write their obligatory Environmental Action Plan. Since 2004, all soil data are available via internet (http://jord.nijos.no). Farmers can also access specific farm related information by using a password.

Box 3.9. Agri-Environmental schemes: To reduce the environmental impact of agriculture, farmers can get financial support to use more environmental friendly methods. The support compensates the farmer for the reduced income he has by introducing these methods.

Sustainability Index Model

The Sustainability Index Model was developed by SCAPE (Arnalds, 2005). It aims to create easily identifiable variables and scales to allow for land use decisions in relation to subsidies and land use policy. It further allows for comparisons between land use methods, which aids the society to allocate resources to participatory approach based programs, environmental schemes and in policy making. This model does not only value soil, but also weighs the effect of any given land use on the land (e.g., soil erosion, pollution, soil functions), which is balanced against the needs and benefits of the given land use practice.

Models like this have to be simple. As complexity increases, the applicability and advantages for society decrease (Tainter, 1995). The Sustainability Index Model starts from the basis that there is a wealth of knowledge about soils, ecosystems, and methods of assessing the condition of the land. It is also known what impact various types of land uses have on the land.

1. Land use varies, but can be defined (e.g. type of production such as wine, wheat; on given landscape position, climate conditions and soil resources).
2. The current condition of the land is valued using site or land use specific methods (e.g. presence of A horizon, OM, vegetation cover on rangelands). The impact (e.g. fertilizer pollution, danger of soil erosion) is valued separately and it considers different threats. The benefits of each practice are balanced against needs: Is there surplus production? Is the food healthy vs. unhealthy? Does the land use cause fragmentation? How long are transport distances? And so on. All these elements need to be considered both on the short and long term.
3. The outcome of weighing can be used to calculate the Sustainability Index (SI). Subsidies or aid can be determined and given if the SI meets certain criteria. This can vary and does not need to be the same for all crops. A decision is made which suits the land and society best.
4. The landowner responds by continuing with same practice, which may be good for the land and society (retains payments) or bad (not supplemented by public resources, or law forbid further such land use), or by adapting his farming, in which case monitoring and revision of decision has to be made.
Each of the three factors, Condition (C), Impact (I) and Benefit (B) are weighted on a simple scale from 1 to 5; 1 being positive and 5 being a negative effect of the land use (see figure 3.2). By multiplying the factors, a simple number index is created, that can be put on a simple measuring stick reaching from sustainable to non-sustainable land use (figure 3.3).

### Use of Sustainability Index by weighting.

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<tbody>
<tr>
<td>C</td>
<td>Excellent Condition</td>
<td>Good</td>
<td>Neutral</td>
<td>Neither</td>
<td>Very Bad</td>
</tr>
<tr>
<td>I</td>
<td>Positive Impact</td>
<td>Good</td>
<td>Neutral</td>
<td>Neither</td>
<td>Very Bad</td>
</tr>
<tr>
<td>B</td>
<td>Great Benefit</td>
<td>Good</td>
<td>Neutral</td>
<td>Negative</td>
<td>Simon or Penalty</td>
</tr>
</tbody>
</table>

$$C \times I \times B = \text{Index}$$

- Sustainable: Further check or improvement
- Non sustainable: >30

Figure 3.2. Schematic overview of the Sustainability Index model.

Figure 3.3. Calculating the Sustainability Index.
It may be argued that it is problematic to decide what constitutes each value (1-5) for calculating the SI, especially when it comes to the benefits for society compartment. However, such judgment has to be made by society, regardless of this model, especially if the production is supplemented by public resources. In many cases the judgment is straightforward (e.g. when impact of community and national economics is large).

Other land management considerations

Grazing
Special attention should be given to the management of marginal and abandoned land. Marginal land is often used for grazing. Increasing the number of grazing animals beyond the capacity of the land (Schnabel, 2003) and extensification in Southern Europe has led to the initiation of erosion and landslides (Bautista et al, 2004). Stocking densities need to be adjusted to the need of the land and well constructed management goals. Since productivity of grazing lands varies considerably with climatic factors, the density should vary and never exceed the resilience of the land.

Fire risk
Fire risk increases when abandoned areas are subjected to shrub invasions in Southern Europe. Specific fire prevention measures are therefore often needed. Often, in case of fires, erosion increases dramatically and it can take years before a protective vegetation cover is regained.

Desertification
Combating desertification includes sustainable land use, prevention and/or reduction of land degradation, and restoration of degraded lands. Attention to the management consequences of the measures should be included in combating desertification strategies (Castillo et al., 2004). When reduced land use pressure does not improve the condition of the land, restoration measures need to be taken. Focus should lie on the conservation and retention of the hydrological functioning of the area.

Afforestation
Marginal and abandoned areas have often been afforested in Southern Europe. It is important that specific goals for any given location are set carefully and that afforestation is planned accordingly. Species used for re-vegetation and afforestation should suit the natural ecosystem and local landscapes. Presently, new forests have usually multifunctional objectives: production, soil conservation, tourism, leisure and aesthetic values are those often considered. Re-establishment of the soil functions discussed earlier in this chapter should also be taken into account. Soil quality should be the ruling basis for afforestation and reforestation projects. The planting process in degraded areas and construction of forest roads can increase the vulnerability for erosion. The initial species used in afforestation should be adapted to degraded situations. Species able to bind P and N to the soil and those able to develop a microclimate are preferred. This will create conditions for the establishment of other species of greater value and increased soil conservation efficiency. Usually, it is a priority to cover degraded areas with protective vegetation as fast as possible, often with grass and shrub species. After establishment of a vegetation cover it is possible to introduce taller growing trees. Young forest plantations should always be protected against grazing to protect the considerable resource investment associated with restoration and afforestation projects. In a later stage of forest development, controlled grazing activity may be allowed. The grazing activities should be adapted and controlled to the local circumstances. Advantages of limited grazing are sometimes the development of a more diverse vegetation, fire control, and more diverse agriculture for sustaining the local communities.

The occurrence of forest fires should be minimised as much as possible and measures need to be taken to prevent them and to reduce the damage in case they occur. Fire prevention needs to be part of all forest operations in dry climates. If needed, prescribed
burning is a possible management technique, however this requires ecosystem knowledge, experience and preparation, and other alternatives are often more feasible (different vegetation substrate, grazing etc).

Development of stable vegetation and the establishment of a good soil structure need to be prioritised to improve the hydrological function of the soil. When building forest roads, the hydrological aspects should be included, often by constructing obstacles to prevent runoff, e.g. in erosion gullies. Reduction of runoff and water speed contributes to less erosion and stimulates the sedimentation of soil material.

Soil organic matter content is often very low in areas to be afforested. The use of organic matter like compost or sewage sludge is a way to increase organic carbon in the soil. To avoid harmful effects to the soil, organic matter originating from bio-wastes should only be applied when it is free of soil contaminants. Attention should be given to the content of heavy metals, organic compounds, xenobiotics and antibiotics (Crescimanno et al., 2004).

Saline soils
Areas prone to salinisation can be planted with salt-capturing plant-species. Improvement of the hydrological balance is needed to reduce the surplus of salt in the soil gradually. Salt-affected soils should be covered with vegetation as soon as possible.

Education

Education of farmers and foresters in the past was not focused on soil functions and prevention of soil degradation, but on enhancing production in agriculture by the development and use of new plant varieties and the use of pesticides. During the 1980s, the negative consequences of the developments in agriculture became evident; loss of landscape mosaic and cultural heritage, biodiversity, erosion and pollution problems became frontpage news.

The lack of focus on production in balance with the natural capacity of the environment, deprived the present day landowners of an awareness of the importance of preserving soil quality. However, they are not responsible or to blame for this.

Stability in production means security for the farmer. Often, the farmer has too little knowledge on how to sustain soil quality of his soil and improve it. In addition, farmers are pressed to use non-optimal techniques for optimum cost-return benefits. For example, harvesting of the last grass crop happens in Northern Norway on wet terrain, destroying soil structure and compaction. However, the farmer feels he has no choice and is forced to accept the disadvantages to work under wet field circumstances.