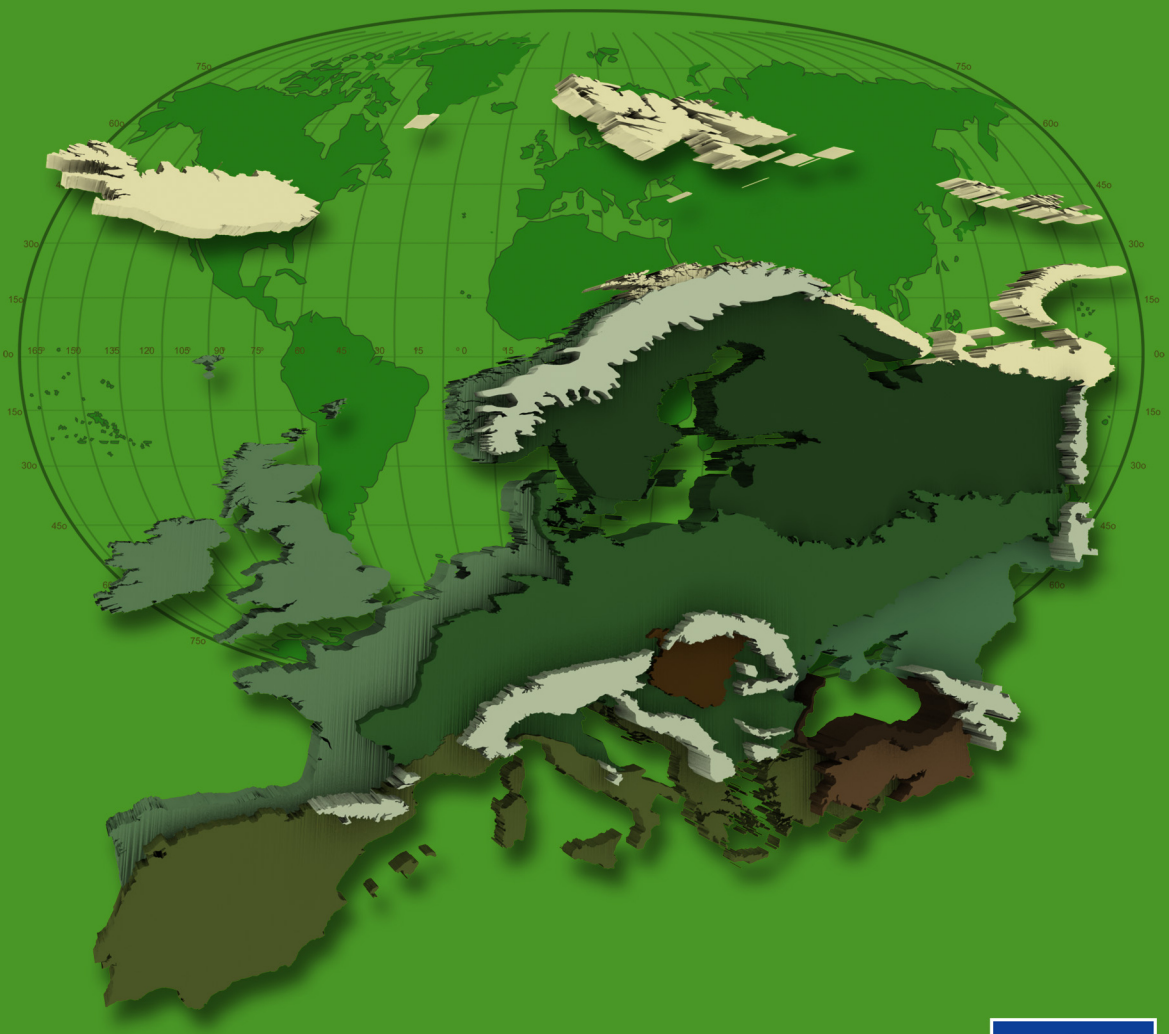
s c a p e

The way ahead



Soil Conservation and Protection in Europe

The way ahead

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So(i)l(e) facts

In Rothamsted Experimental station researchers tried to measure the surface of the particles in a single ounce of clay rich soil. They came up with a total of six acres!! (Eisenberg, 1998).

Aristotle called earthworms the intestines of the earth (Eisenberg, 1998).

Darwin's last book was not on natural selection but on worms and earth, the regeneration of life out of soil on the journey from dust to dust (Warshall, 1999).

Soils contain the largest number of biological, biochemical and biophysical phenomena of any slice of the planet (Wilson, 1984).

At dinner: All the plants on your plate were nourished by *soil*. The meat came from animals that ate plants that grew in *soil*. If your table is made of wood, it came from trees that grew in *soil*. Without soil there would be no food, no table to put it on (Silver, 1993).

When I add up the live weights, exclusive of roots, estimated by soil biologists, I find more living biomass below ground than above it, amounting to the equivalent of 12 horses per acre (Hans Jenny in Stuart, 1984).

If all the elephants in Africa were shot, we would barely notice it, but if the nitrogen-fixing bacteria in the soil were eliminated most of us would not survive for long because the soil could not longer support us (Hans Jenny in Stuart, 1984).

A single spade full of rich, garden soil contains more species of organisms than can be found above ground in the entire Amazon rain forest (Soil Biology website).

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Preface

Soil in its broadest sense is part of our human habitat; we depend ultimately on it for almost everything. Our dependence is not reflected in the way we organise or manage it. Inadvertently, it is all too easy to focus on one thing that the soil is doing and then to neglect the others, especially those things that are long term. In order to achieve a land use that is in all senses sustainable, it is necessary for people to have a better, more holistic understanding of what is going on in the soil. We hope that our book will contribute to this aim.

Currently, the EU is developing a strategy to manage European soils sustainable and protect them from the many threats soils are facing. During the last three years the SCAPE project (Soil Conservation and Protection for Europe) has given scientists the opportunity to discuss soil conservation and protection strategies in an informal way with people who are either responsible for finding solutions, or being affected by them.
Several hundreds of people have contributed to this book, either collectively or individually. They include the scientists, soil conservation and protection practitioners and stakeholders who participated in the SCAPE platforms, as well as many EU officers who are responsible for future research and environment policy. They also include people who met at the Vital Soil Conference at the Hague in November 2004 and as well the group of International experts in soil and environmental law who met at the September 2005 Conference in Iceland. We have listed the names of all workshop participants in Appendix 1. Although the names of authors are given to the different chapters, these are in fact the lead authors of the Chapters. Most of the Chapters were written collectively and contain contributions from several authors.

Foreword

This book introduces the reader to the current soil protection and conservation debate in Europe. It is written for the informed person with a background in for example environmental science, agriculture, forestry, geography or law. The focus of this book is not on the scientific analysis of the problem but rather on the actions that can be taken to improve and protect European soils. We have tried to minimise our use of technical terms. Although this book is about Europe, the issues we discuss have a global dimension. We have included many examples of successful soil conservation policies and strategies adopted in other countries, for example the USA, Brazil and South Africa, as well as examples from Eastern Europe (e.g. Hungary).

The book is based on the scientific platforms that were set up as part of the SCAPE project and contains information that was presented at free and open discussion. We were able to discuss soil conservation and protection with several hundreds of stakeholders. The scientific information that supports the interpretations we provide in this book can be located at www.scape.org.

In **Chapter 1** the reader will find an introduction and background material to the present day soil conservation and protection issues in Europe. **Chapter 2** describes soil data, monitoring and information issues. In **Chapter 3** we explore different aspects of sustainability. In **Chapter 4** we summarise the results of many case studies, most of which illustrate the lessons that can be drawn from good practises. In **Chapter 5** we discuss different approaches in policy and legislation. In **Chapter 6** we present our conclusions that largely draw from the findings of the International Conference held in September 2005 in Iceland. At this meeting soil conservation scientists and practitioners got together with members of the legal profession in order to consider amongst other things, how current science and legislation possibilities could be brought together.

This book presents the conclusions of SCAPE in a way that can be used to guide public and professionals alike in their evaluations of future soil protection policy development. Many of the readers of this book will have only a limited experience with soils. But the reader should be aware that the soil is very complex and multi-faceted so that many scientists and experts are also partially in this position. Consequently, there is a danger that the people who advise policy makers might misjudge or overlook the significance of particular data or information. For the reader to understand what the soil is (see Appendix 2), what it does and why it is important to him, he does not need to have advanced education in chemistry, biology or to be an agronomist or forester.

Chapter 1

The need for Soil Conservation and Protection in Europe

Introduction

Europe's natural landscape is changing rapidly as economies expand and cities grow. The soil is part of this changing environment and in many places it is continually being bulldozed, compacted, buried or ploughed; elsewhere it is lying quietly in relatively natural areas, slowly absorbing the elements imperceptibly raining down upon it. Although this is a book about European Soils, European soils are inextricably linked with the global climate and global economy (Jungerius and Imeson, 2005).

How great is the cause for concern? Is the increased frequency of natural disasters in some ways linked to what is happening in the soil? At the global scale, the Intergovernmental Panel on Climate Change (IPCC) recognises the role of the soil and its vegetation cover as a non-climate driver of climate change and as a sink where carbon dioxide can be accumulated from the atmosphere. Scientists are aware that half of the carbon dioxide in the atmosphere was once in the soil and that the soil is a key to reducing the concentration of greenhouse gasses. But soil is not just at the heart of the concern about climate change, it is also central to our concerns about biodiversity, land degradation, desertification and flooding.

Box 1.1. What is a soil?
There is no single definition that all soil scientists agree on. The soil is a rich world and the habitat of living matter, a chemical reactor that is constantly changing the surface of the earth to create a medium that nearly all production of food and fibre depends on. It regulates and re-distributes water and nutrients, and is the foundation for the livelihood of man on earth.

Protecting the soil is not like protecting an endangered species. There are practically no truly "natural" soils in Europe. Human actions have shaped European landscapes for thousands of years; producing the beautiful cultural landscapes of Europe of today. Maintaining existing soils and landscapes is not a practical aim of soil conservation. It is rather to facilitate the maintenance of the critical soil functions that society needs for a sustainable development and a sustainable future.

Box 1.2. What is resilience? *Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future. Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social-ecological systems (SES). "Resilience" as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:*

- *The amount of change the system can undergo and still retain the same controls on function and structure.*
- *The degree to which the system is capable of self-organization.*
- *The ability to build and increase the capacity for learning and adaptation.*

Source: Resilience Alliance

During the last decade many people expressed concern about the way land use and pollution were reducing the resilience (box 1.2) of the soil and its ability to withstand all of the threats that it is facing. There is no doubt that soil degradation (compaction, loss of biodiversity and organic matter) has resulted in soils becoming both less fertile and less able to regulate water and cycle nutrients. On the other hand it is clear that not all areas

are affected and that there are many places that serve as examples of good practice. There has become a consensus that the soil is one of the great challenges that need to be addressed, if Europe is to meet its aim of achieving sustainable development.

The aim of this book therefore is not to dwell on what has happened to European soils and to focus on what has been lost. We will look at what can be done. How can we apply all of the positive experiences and knowledge to help the development of the European Soil Strategy (explained in Chapter 5)?

A scientific platform for consultation

In some sense, what this book presents are the findings of a scientific public consultation with different actors and agents in which the following key questions were asked:

- How can sustainable soil conservation and protection be achieved?
- What are the key functions or services provided by the soil and how should these be measured and monitored?
- What is known about protecting and conserving soil functions from good practice and from case studies?
- How can strategies be identified for conserving and protecting Europe's soils, within the context of current environmental and agricultural policies?
- How can combating desertification be incorporated into soil conservation and protection strategies.

The mission was simply put, to describe how Europe might best conserve and protect its soil in the light both of its present state and the prevailing political setting.

SCAPE organised its consultations and meetings in areas where the positive accomplishments of soil conservation and protection strategies could be studied. Together with the European Society for Soil Conservation (ESSC) a directory was compiled of the many hundreds of people and organisations that were identified as being active in soil conservation (Rubio et al., 2005). It was known that in many parts of Europe, there have been considerable positive successes with soil conservation. It can be very efficient and effective to benefit not just from local knowledge but also from the principles and strategies that have been demonstrated as being effective elsewhere (Chapter 4). In many countries excellent soil protection legislation has been developed and, provided there is the political will to deal with problems, successful policies can be implemented (Chapter 5). A complete review of legal and institutional frameworks for the sustainable use of soils can be found in Hannam and Boer (2002). The final workshop of SCAPE in September 2005, brought together representatives of the legal and soil protection professions so that the recommendations being made could be embedded in both soil conservation science and law (SCAPE, 2005).

Learning from the Past

While the first large agricultural civilizations developed on alluvial materials of large river basins (Egypt, Mesopotamia, Huang-ho), much of Europe was first extensively farmed. From the late Neolithic times until the Roman Period, large areas of Europe remained forested. The phenomena of soil degradation generated by human activities is a very ancient feature of Europe. Historic soil erosion was known to occur in cycles during which periods of erosion were followed by periods of stability or soil formation. Soil loss was not only experienced as negative and in many cases it may have deliberately been induced by the local communities to produce fertile sediments. Soil erosion has been at the basis of the creation of large alluvial plains that were extensively cultivated in ancient times. Ancient societies adapted to the redistribution of resources (soil and water) and exploited the environment as how it had become.

Historic erosion had many different complex causes ranging from the destruction of forests for fuel or timber to the neglect of common lands and extremes in climate. However, large efforts had been made at the end of the nineteenth century to re-establish forests in France, Italy and Spain and there had been considerable success in reducing soil degradation.
Modern society has adapted to consequences of past soil erosion. For instance, society values the grasslands and heathlands found on areas that were formerly forested, and society wishes to preserve these heathlands. During the 1950s people were aware that upland areas of the UK (Britain's Green Deserts) were in fact created by deforestation and overgrazing in marginal areas from the Neolithic times onwards. These areas are valued today for the non-agricultural functions they provide and in many cases, efforts are made to preserve them. In the Drakensburg of Southern Africa, along the borders of Lesotho, settlers from the Southern Uplands of Scotland and elsewhere, have used fire and overgrazing as a deliberate strategy to recreate the grasslands they left behind in Scotland and to prevent the natural regeneration of forests.

Soil erosion rates over much of Europe were very low under the mixed farming that occurred before and just after the Second World War. In the 1960's and 1970's several scientists who had worked on soil conservation schemes in Africa and Asia returned to Europe where they could see that erosion rates were becoming high as well. They began to measure the longterm impacts of slow processes; not only erosion by rainwash but also those caused by ploughing, grazing and the loss of soil with root crops.

In most of Europe, soil erosion and soil contamination began to be serious issues with the advent of modern agriculture after the Second World War. At that time, agricultural policy focused on increasing agricultural production to sustain food security (Bullock, 1999). To make farming more effective and raise farm income, mechanization and intensification took place. Pesticides were developed to control plant diseases. Small fields got consolidated to enlarge fields. Furthermore, fields were levelled to make tillage, plant treatment, and harvesting operations more effective. Soil quality was gradually becoming less important as a deciding factor for the agricultural system. As a consequence organic matter and soil biodiversity decreased and soils that were susceptible became more compact and sensitive to erosion.

Figure 1.1 shows that soil erosion is mainly a consequence of land use and that climate is relatively unimportant (see case study 8, Chapter 4).

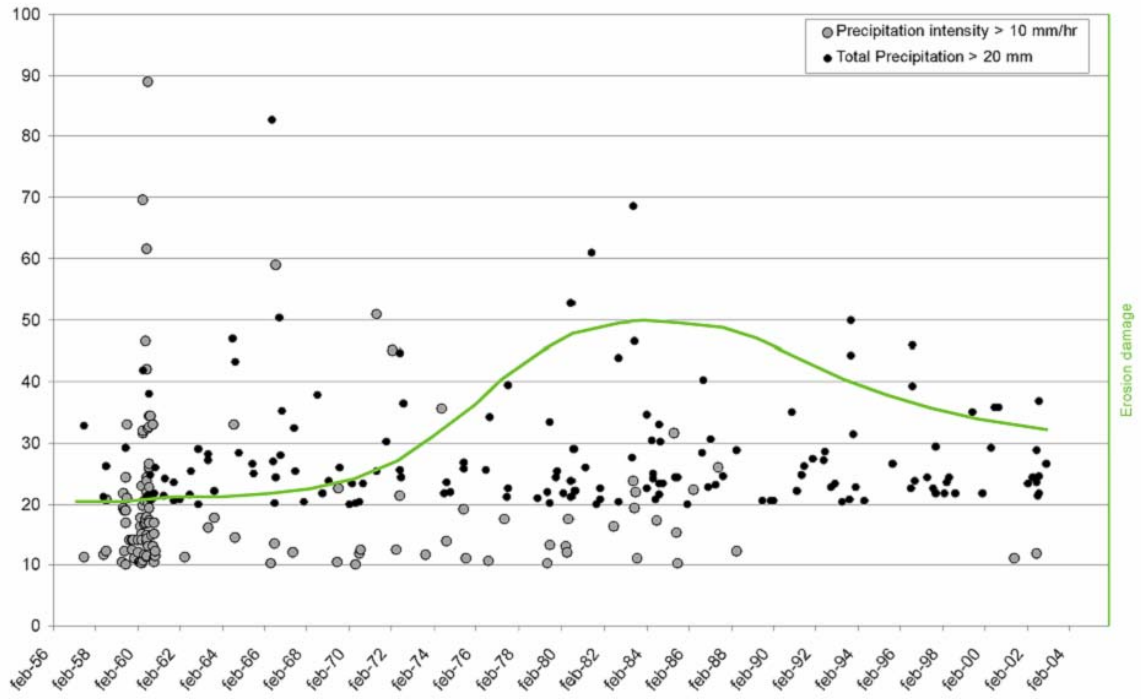


Figure 1.1. shows the relationship between soil erosion and climate in the South of the Netherlands. It can be seen that there is in fact little relationship. Erosion was at a maximum at the time of the land consolidation projects that reorganised the pre-existing farms in the 1980's. Large fields were constructed and the hedgerows and terraces ploughed away. Erosion followed land leveling.

Why Europe must act to protect its soil: Can we learn anything from the USA?

It was the "New World" that gave birth to organized soil conservation as we know it today, an achievement often attributed to Hugh Hammond Bennett said about his experience in 1905: "…..we noticed two pieces of land, side by side but sharply different in their soil quality. The slope of both areas was the same. The underlying rock was the same. There was indisputable evidence that the two pieces had been identical in soil makeup. But the soil of one piece was mellow, loamy, and moist enough even in dry weather to dig into with our bare hands. We noticed this area was wooded, well covered with forest litter, and had never been cultivated. The other area, right beside it, was clay, hard and almost like rock in dry weather. It had been cropped a long time. We figured both areas had been the same originally and that the clay of the cultivated area could have reached the surface only through the process of rainwash—that is, the gradual removal, with every heavy rain, of a thin sheet of topsoil. It was just so much muddy water running off the land after rains. And, by contrast we noticed the almost perfect protection nature provided against erosion with her dense cover of forest." (Bennett, 1930).

One hundred years ago agriculture could be seen to be having a great impact on land degradation and erosion in the United States of America. This impact resulted in the abandonment and afforestation of huge areas in New England and the Appalachians. Tens of thousands of farmers suffered hardship and left the land. Bennett and others documented the magnitude and impact of erosion and warned about the consequences if no actions were taken. They were able to set up research stations to quantify the soil loss, both in tons of soil and loss of agricultural production. When the extension of rain fed farming extended into the semi arid areas of the mid-west where rains were unreliable, the loss of the vegetation and top soil enabled wind erosion to remove vast amounts of topsoil. For weeks, dust darkened the skies in areas as far away as Washington, polluting homes and motivating the setting up and financing of the United States Soil Conservation Service.

Bennett pointed out: “It seems to take something like a disaster to awaken people who have been accustomed to great national prosperity, such as ours, to the presence of a national menace. Although we were slowly coming to realize that soil erosion was a major national problem, even before that great dust storm, it took that storm to awaken the nation as a whole to some realization of the menace of erosion."

Figure 1.2. Dust storm approaching Stratford, Texas. Dust bowl surveying in Texas. Image ID: theb1365, Historic C&GS Collection. Location: Stratford, Texas. Photo Date: April 18, 1935. Credit: NOAA George E. Marsh Album.

Soils in the picture

The majority of European citizens, except from people working on the land, are completely detached from the soil. Nevertheless, there is an enormously enthusiastic minority passionate about gardening and horticulture and there is great interest in nature and landscape. Still, preoccupations with air and water are incorporated to the daily lives of the urban population, while soils are generally considered as completely irrelevant. This makes air and water protection easy to justify to the general public, who might not understand the need for soil protection.
Raising consciousness about the importance of soil conservation and protection for the welfare of our modern societies has to be a major policy goal.

What a Living Soil Does

The soil can be thought of as a medium providing society with various benefits or services. Life on earth would (of course) be impossible without the soil and all the things that it performs for us. What ever we eat, drink or breathe, or wear to keep us warm, it almost all comes from the soil or is dependent upon it (figure 1.3). Owners of soil or land might appreciate its value in supporting the foundations of their house and in providing a garden. Less obvious are the many other benefits the soil is providing, both to them and their descendents. Soils regulate neatly all of the water and bio-geo-chemical cycles that are critical for maintaining critical elements of both the climate and biodiversity. Interference with these processes and ecological health of the soil is a major factor that underlies climate change and biodiversity loss. As already mentioned, vast amounts of carbon that were once in the soil are no longer there.

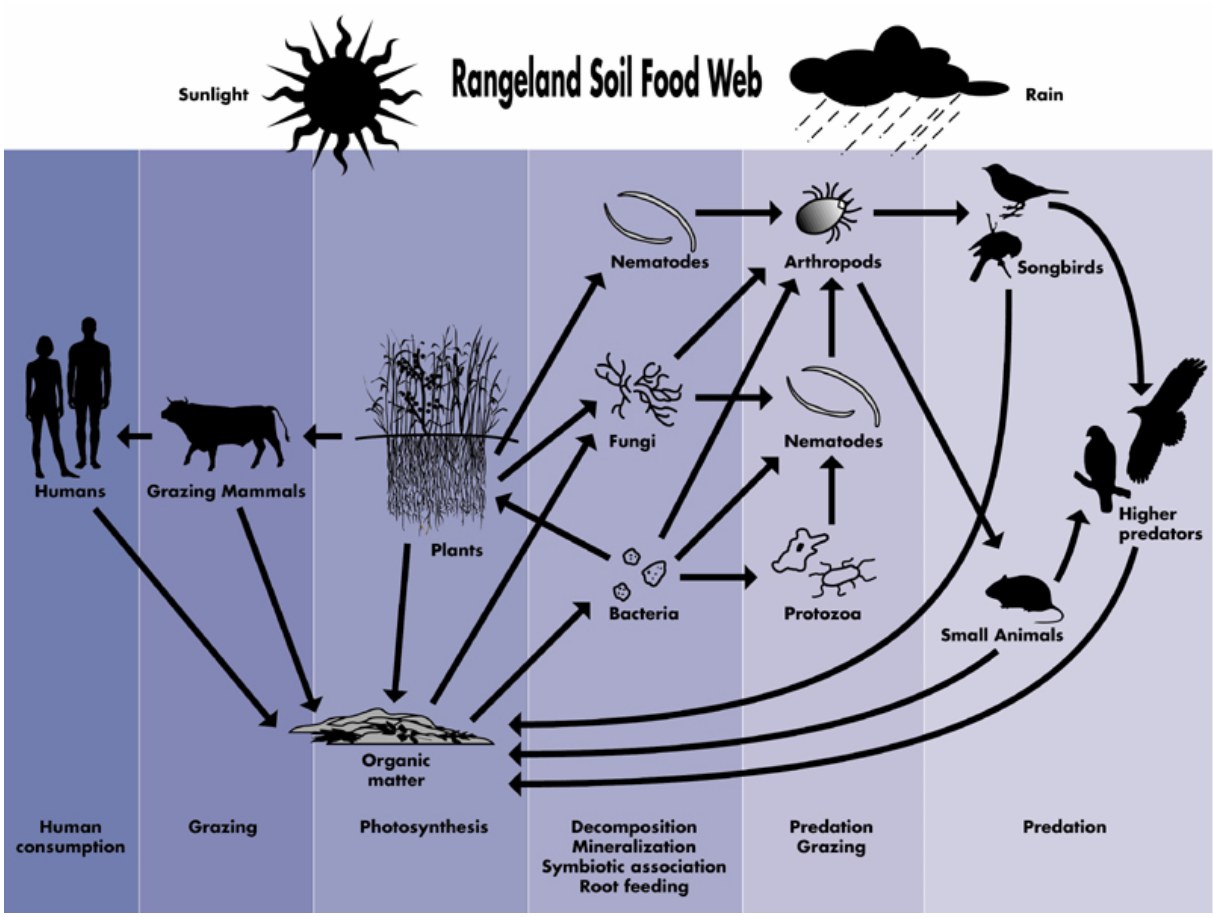


Figure 1.3. The Soil and Human Food Web (source: NRCS).

Soils are the home of one of the largest pools of *biodiversity* on earth. There is an enormous number of organisms living in soil, mostly belonging to species yet to be fully described and studied. There is more biomass inside the soil than on it. Only little is known about this ecosystem, mostly due to the lack of methods for effectively isolating the different organisms present in the soils of the world. Only few species have been fully described and isolated, often leading to the discovery of new sources of pharmacologically active natural substances, like for example penicillin. Rapidly advancing soil degradation is severely threatening soil biodiversity, eventually leading to the extinction of species yet to be discovered and fully studied. Implications for human health of the degradation of the soil ecosystem need still to be fully understood.

Private land, as well as public land, performs a number of functions that cannot be restricted to the benefit of a single landowner. Land degradation has an immediate effect on the productivity for the owner, but has also, and more importantly, substantial off-site effects with in many cases relevant economic, social and health related implications for the community. On-site impacts, the expression used to describe the consequences of changes to the soil that occur in situ, are more fully documented than the off-site impacts, some of which are only vaguely appreciated.

Soils and human health

Concern about threats to our health is often a top human preoccupation so that any aspect of air and water that is related to human health gains immediate political attention. Knowledge about health related effects of soil degradation is limited. Usually these are perceived in relation to soil pollution by chemicals and the possible role in contaminating the food chain. “Healthy food from healthy soils” is an immediately understandable slogan for anybody and there is an increasing public interest in organic

farming. The scientific links between the soil and food quality are very complex and in some cases there is no real evidence to help distinguish between real and imaginary risks. Much more evidence exists of a number of other off-site effects of soil degradation with immediate implications for our daily life.

Drinking water quality is directly linked with soils; soil is a filtering and buffering medium for contaminants. A number of physical and chemical properties of soils result in clean groundwater for all of us. Overloading a soil with contaminants, as well as limiting its permeable surface by sealing and compaction, can severely affect it's functioning as a filtering and buffering medium for water (figure 1.4). Drastic changes in soil pH can dramatically affect the retention capacity for contaminants, eventually triggering the sudden release of contaminants in the groundwater.

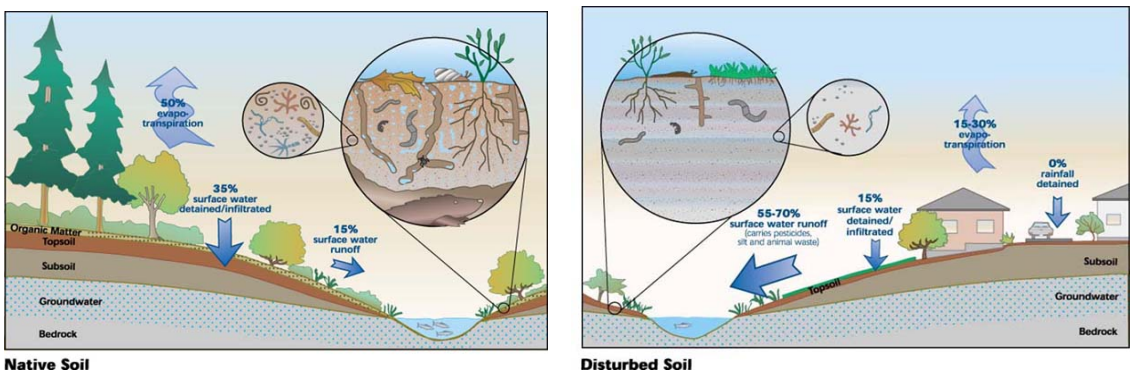


Figure 1.4. Benefits of healthy soils (source: King County Department of Natural Resources and Parks).

The off-site effects of *soil erosion* are well known and they have been frequently reviewed. The silting of artificial water reservoirs implies enormous costs to hydroelectric power plants and water authorities. Less frequently appreciated is the way that sediments from eroded soil can accumulate in river channels; reducing channel capacity, blocking culverts, increasing bank erosion, all of which cause flooding and inundation. Sediments accumulating in channels as a result of erosion have an impact that lasts for decades and centuries. Managing a river to prevent flooding through a loss of channel sediment and discharge capacity needs to be planned over many decades and centuries, as it is for example done in the tributaries of the Rhone Valley.
Sediments are often associated with a number of contaminants and nutrients that are major causes of the degradation of bathing water quality in coastal areas with severe economic implications for tourism.

Wind erosion can be a major threat to human health, particularly in densely populated urban areas. Recent examples exist of massive wind erosion problems all over the world, for instance in China, Australia (Youlin, 2001) and Iceland (see figure 1.5). For an overview of all aspects of wind erosion, the reader can visit web site of the wind erosion research unit (WERU) in the USA.

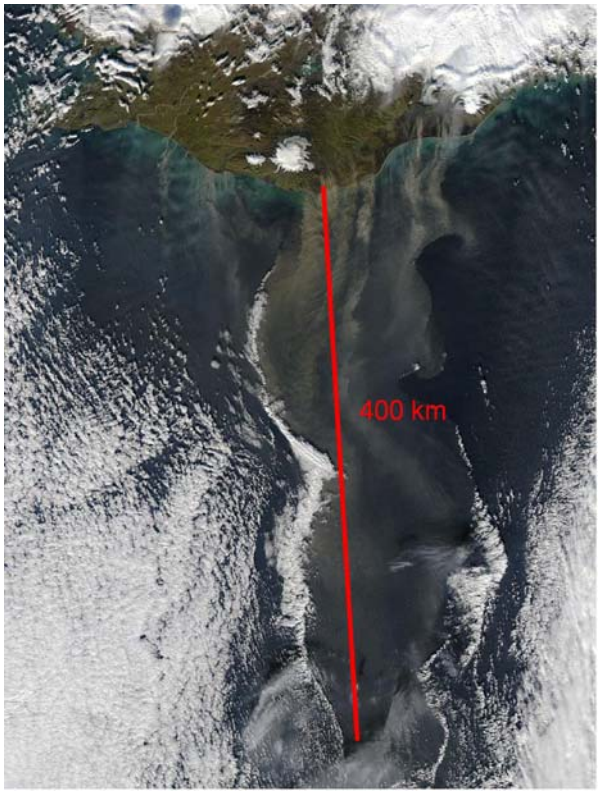


Figure 1.5. Wind erosion, Iceland.

The dramatic increase in recent years of the frequency of occurrence of *hydrogeological disasters* such as floods and landlides, often causing losses of numerous human lives, has triggered the attention of the general public to soil degradation in many parts of Europe.
Recent flooding events in Central Europe have been put in relation with poor spatial planning practices, increased soil sealing in the upper parts of the concerned catchments and a general increase of overland flow due to deforestation, soil compaction and inadvertent agricultural practices (ELSA, 2002). Changing land use can cause runoff to increase by many hundreds of percent; this is far greater than the modeled impact of climate change (figure 1.6).

1	0.2	4.0	8.0	2.5	0.5
2	20	5	2	8	80
3	0.6-1.1	0.8-1.3	0.9-1.5	0.8-1.8	0.7-1.0
4	0.15-0.8	0.12-0.4	0.2-0.5	1.0-0.2	1.5-0.4
5	30	0.9	0.8	5	10

Figure 1.6. Landuse in relation with runoff, erosion and water storage.
1 = Erosion rates [t/ha]
2 = Time to ponding [minutes] (rainfall intensity 8 cm/hr)
3 = Bulk density [g/cm^3]
4 = Storage capacity range [cm/m^2]
5 = Final infiltration capacity [mm/hr]

Landslides occurring in Mediterranean areas, often linked with degradation of the vegetation cover and poor maintenance of cultural landscapes due to land abandonment, have raised the attention of decision makers in many countries (figure 1.7).

Figure 1.7. Land degradation in the area of the Cinque Terre UNESCO world heritage site due to land abandonment. Left: Terraced landscape in 1950. Center: Actual (2000) situation with extensive area being abandoned. Right: Simulation of landscape in 2010 after extensive landslides due to the collapse of the terraced land management system. (Source: Cinque Terre National Park).

Feedbacks between the soil and the global climate and global economy

Fifteen years ago, at the Villach (1982) Conference European Governments agreed to coordinate their actions to address climate change. The Dutch Government initiated scoping studies that included investigations into the bio-climatic impacts of climate change. This included the soil. Attention was given to the role of the soil in greenhouse gas emissions and to the concern about soils being “chemical time bombs”. The findings of that time, concerning difficulties that policies have in dealing with the non-linear behaviour of the soil system, are equally valid today. Policies need to be adaptive and

make allowance for the reality of complex evolving systems, avoiding the pitfalls of a command and response strategy (Holling and Meffe, 1996).

There are invariably slow and imperceptible changes taking place in soils that can lead to sudden and unexpected consequences such as desertification and flooding. The risk of desertification on areas producing wheat near Athens (Greece) has been shown to gradually increase as erosion reduces the depth of the soil and the amount of water that it can consequently store at critical periods of the year. A good example of a potential policy surprises is the "chemical time bomb". The ability of a soil to retain a chemical or buffer a process, may suddenly be altered. A classic example is the risk of pollution from heavy metals that have accumulated on agricultural land when trees are planted. If pH is critically lowered, the heavy metals present in the former agricultural soils can enter the environment as the onetime sink is transformed into a source. Another example of an unexpected consequence is the flooding and landsliding that can occur on marls that develop badlands when they are used for agriculture. One of the properties of marls that explains the presence of badlands is the rapid weathering. One or two light showers in such areas can be all that is needed to create mudflows. European soil policy should also be able to deal with such surprises.

Box 1.3. Cultural appraisal

The American Geographer Carl Sauer stressed that "Natural Resources are a Cultural Appraisal". This adage is helpful in understanding the relationship between soil quality and land use which is not logical from the point of an imaginary intrinsic universal definition of the quality of the soil. It is logical from the perspectives and self-images of those who live there. It is quite logical for both the Portuguese in the Alentejo and the Norwegians near Oslo to want to grow wheat in spite of the fact that it is obviously at odds with the physical reality of the quality of the environments three thousand miles apart. In one case it is taiga and in the other case steppe. It is nevertheless quite possible to achieve this because it is within the imagination of what the people think is desirable and achievable, even if this comes at a price. Near Oslo the price is a 300 per cent subsidy paid for by North Sea oil; in Portugal the EU at the time of writing picks up the tab.

It's only in recent times that the full importance of soils for *global climate change* has been recognized. More research is now devoted to this in order to understand better its role in relation to the increase of greenhouse gases in the atmosphere. Actually, soils in the world contain an estimated amount of ca. 1.500 Gt of carbon (650 Gt in vegetation), and it is therefore the most important compartment of carbon in the terrestrial biosphere. Maintaining and eventually even increasing this large organic carbon pool is of crucial importance for limiting the increase of CO_2 in the atmosphere. A number of agricultural practices have been recognized as having a substantial beneficial effect on soil organic carbon content. Promoting the adoption of such practices would help reverse the current trend of soil organic matter depletion in European agricultural land.

The soil then is not just a vital resource providing us with food and water; it is also a buffer protecting us from floods, droughts and the impact of climate change. Considerable damage has been inflicted during the last decades on this water regulating function of soil, and not just in Europe. A topical issue is the degree to which the flooding and landslides in Central America and the United States last September are related to land use changes or to the greater strength of recent hurricanes. There is much evidence to suggest that the frequent flooding in Central Europe is the result of extreme climate; or is it the result of the loss of the storage capacity of soil caused by sealing and modern land use practices? This was definitely demonstrated to be the case in Austria where compaction caused by intensive grazing in areas of sensitive soil caused increased flooding.

Why are seemingly ignorant decisions often made?

If the soil is so critical to life and human well being why is it neglected? Why is it threatened? Many people may be ignorant about the long-term consequences of land use. Soil might be perceived as a limitless resource. Land is often owned by people with legal rights that entitle the owners to manage the land as they see fit. Soil degradation is often slow and complex and it is not always easy to demonstrate. Fortunately, neglect is not always a disaster and the soil does have a great capacity to survive and recover from ill treatment (soil resilience). The problem is often that if you use the soil exclusively for one thing then often it can not adequately do all of the other functions that are vital for the maintenance of fertile soils or ecological processes such as regulating the water cycle. The problem then is an organisational and institutional one as will be discussed in Chapter 5.

Managing the soil and land in a sustainable way is a complex undertaking not only because of the organisations and people involved, but also because the underlying processes themselves are complex and dynamic. Power over decisions affecting land use is diffuse and subject to subsidiarity.

> ***Box 1.4. Changes in soils are difficult to measure.***
> *As an example, it takes hundreds or even thousands of years for clay particles to form in the soil or vital organic compounds to accumulate in surface layers. Such changes are difficult to measure or monitor, and it makes interpretation of soil information a difficult task.*

At any one location the properties of the soil and land are constantly changing. This creates not only a challenge in soil monitoring and data collection. The problem is also in how data is interpreted into relevant information for policy. Land use and management policies need to account for the changes that are taking place in the soil and its landscape and may take guidance from the golden rules of natural resource management that have been formulated (Holling and Meffe, 1996).

Long term soil monitoring experiments, (like the famous ones at Rothamstead, UK), demonstrate that only with a long term commitment to regular monitoring and archiving of soil samples (figure 1.8), changes can be detected. Samples from Rothamstead enabled for example the effects of radio-active fallout from atmospheric atomic tests and Chernobyl to be established.

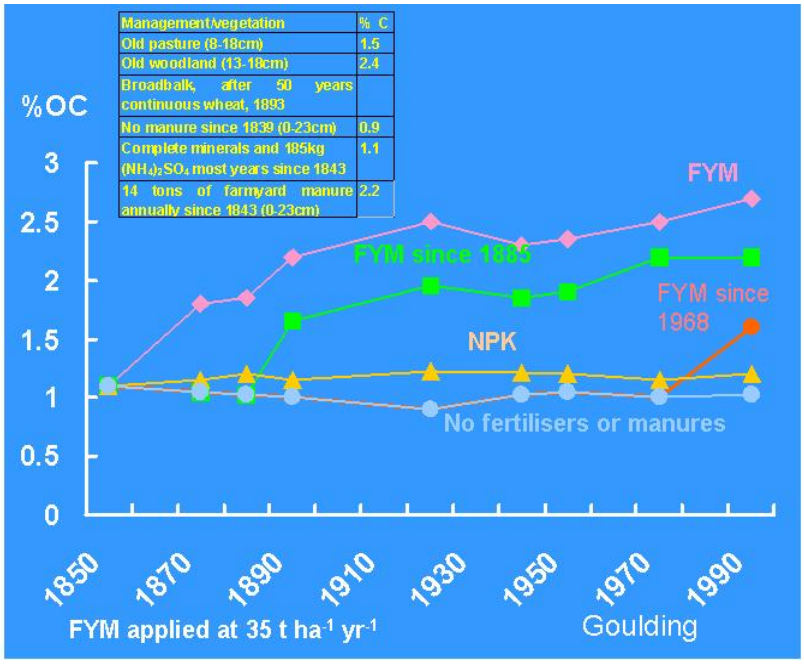


Figure 1.8. Organic carbon in topsoil under different land management practices over a time period of more then 100 years (source: Goulding and Poulton, 2003).

Evidence for changes and losses in soil functions: a global concern

During the last decades, experts have gradually become concerned that so many of the things that the soil does are being lost or impaired so that sustainable development itself is being threatened. The way these functions are being provided is indicative of "soil quality" (box 1.5) or of the "ecosystem health" (box 1.6). Long-term monitoring of ecosystem health and soil quality is being performed in many countries of the world so that environment agencies have in many cases a good idea of what is happening. The Environmental Protection Agency (EPA) and the US Soil Conservation Service in the USA were pioneers in this respect and have for several decades recorded indicators to measure the condition and vulnerability of ecosystems and their soils. This data is available on the internet so that citizens can "surf their own watersheds" and see what is happening to the soil quality and health in their own city or village. Trends from monitoring such as this, as well as concerns about soil contamination and food safety, showed sometimes alarming conditions and public health problems.

Box 1.5. Soil quality. *Soil quality is the capacity of a soil to function for specific land uses or within ecosystem boundaries. This capacity is an inherent characteristic of a soil and varies from soil to soil. Such indicators as organic-matter content, salinity, compaction, available nutrients, and rooting depth help measure the health or condition of the soil-its quality-in any given place.*
For example, organic-matter content, biological activity, acidity, and salinity are related to the ability of a soil to store and cycle nutrients for plant growth. Soil tilth, compaction, and available water capacity reflect the ability of a soil to regulate and partition the flow of water. Texture, such as loam or clay, is an important soil property in the support of buildings and roads. An enhancement of soil health or quality could be measured by an increase in organic matter content in cultivated soils over the years, which would reflect the soil's ability to cycle nutrients (source: NRCS).

In Europe, the picture is at first sight less well documented than in the USA because each European Country has its own equivalent of the US EPA, with its own traditions and legal responsibilities. European knowledge about the environment is therefore often less well integrated. The European Environment Agency (EEA) is establishing a European database of indicators.
The United States has for long had the tradition of seeing soil and water conservation as a single issue. In Europe, water is seen as the main issue, addressed in the Water Framework Directive. On the one hand, this was a very positive step, but with respect to the processes and cause and effect, it would perhaps have been better to have a more conceptual basis including soils, than a directive just addressing hydrology. The soil and its functions were half left out.

Box 1.6. Ecosystem health *is an emerging trans-disciplinary concept useful in bridging the natural, social, and health sciences and to integrate the human values and perceptions that are part of management. In this view, a healthy ecosystem is a socio-ecological unit that is "stable and sustainable", maintaining its organization and autonomy over time and its resilience to stress, while capable of remaining economically viable and able to sustain human communities (Rapport, 1995).*

Concern in Europe: What the EU is doing

Worrying trends emerged from research findings and monitoring programmes about the status of European soils. This made the EU decide to analyse and describe the threats being faced by the soils of Europe and suggest a foundation for their protection. These threats were published in 2002 in a fundamental discussion paper known as "Towards a Thematic Strategy of Soil Protection" or more simply the "Soil Communication". In the same year, public consultation and stakeholder meetings were organised to set up a comprehensive analysis of the threats and to recommend strategies and policies that could deal with them. More than 600 end users, with the support of the European

Directorate General for the Environment, established the European Soil Forum as an arena for analysing how these threats should be addressed to develop a European Soils Policy.

The threats considered in the “Soil Communication” were erosion, organic matter, contamination, sealing (covering the soil with building materials), compaction, biodiversity, salinisation, flooding and landslides (explained in more detail in chapter 3). What the European policy makers needed to know was; how to deal with these threats. What actions and policies would work in the light of both scientific knowledge and past experience?

Finding answers to these questions is challenging for several different reasons. Firstly, the threats themselves are complex and sometimes involve slow processes that are hard to demonstrate. Another problem is that the claims made about the soil are often political where it is hard to draw a line between concerns that are reasonable or speculative. There is in general surprisingly little information or data about some of the threats to support far reaching actions.

Much of the published data and information about the nature of European soils is based on surveys that were made more than half a century ago. Those who were responsible for this work have mostly retired. Much of what is known about soils is biased towards the needs of agriculture and crop production. Emphasis was given in old soil surveys to recording information that could be reliably recorded and which enabled the agricultural quality of the soil to be assessed. The soil threats often involve dynamic soil properties that show seasonal variations or demonstrate gradual trends. Thus, the challenges of establishing a coherent framework for soil protection in Europe are big.

Chapter 2

Soil data and monitoring

Introduction

Fundamental knowledge of soils is needed for developing sound soil conservation strategies. Knowledge based legislation for soil protection is at the core of the development of the EU Thematic Strategy for Soil Protection, which is discussed in more detail in Chapter 5. However, the soil is a complex medium that changes from place to place and it is often difficult to describe in easily understandable terms. This variability is three-dimensional, with soils developing different properties in the vertical dimension by layers (horizons) that are the expression of specific soil forming factors (figure 2.1) and with a high variability of soils in the horizontal dimension, with different soil types distributed under different local conditions. In addition, soils change over time under the influence of an ever changing environment and human activity.

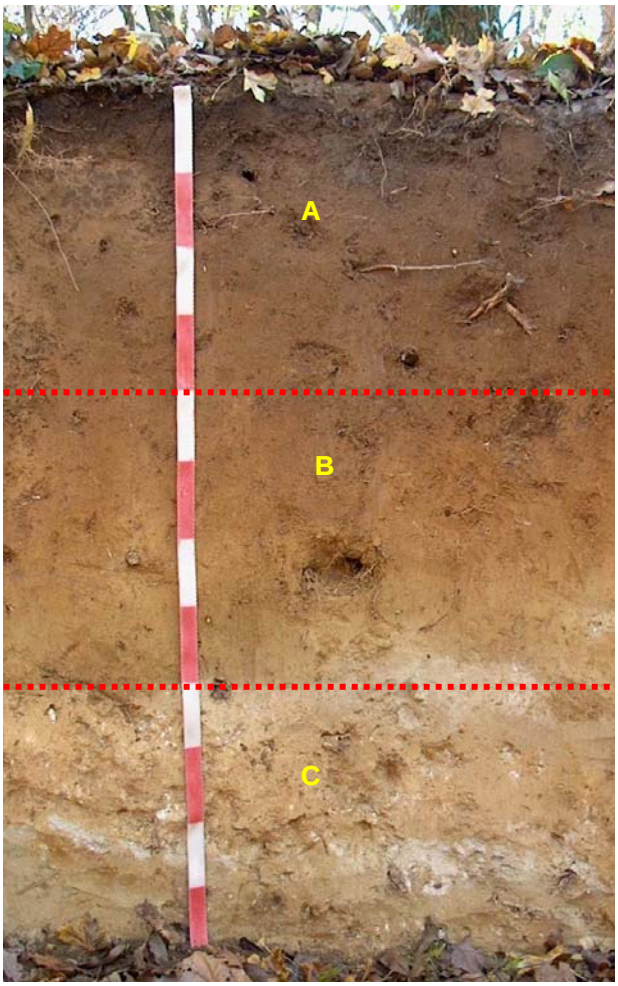
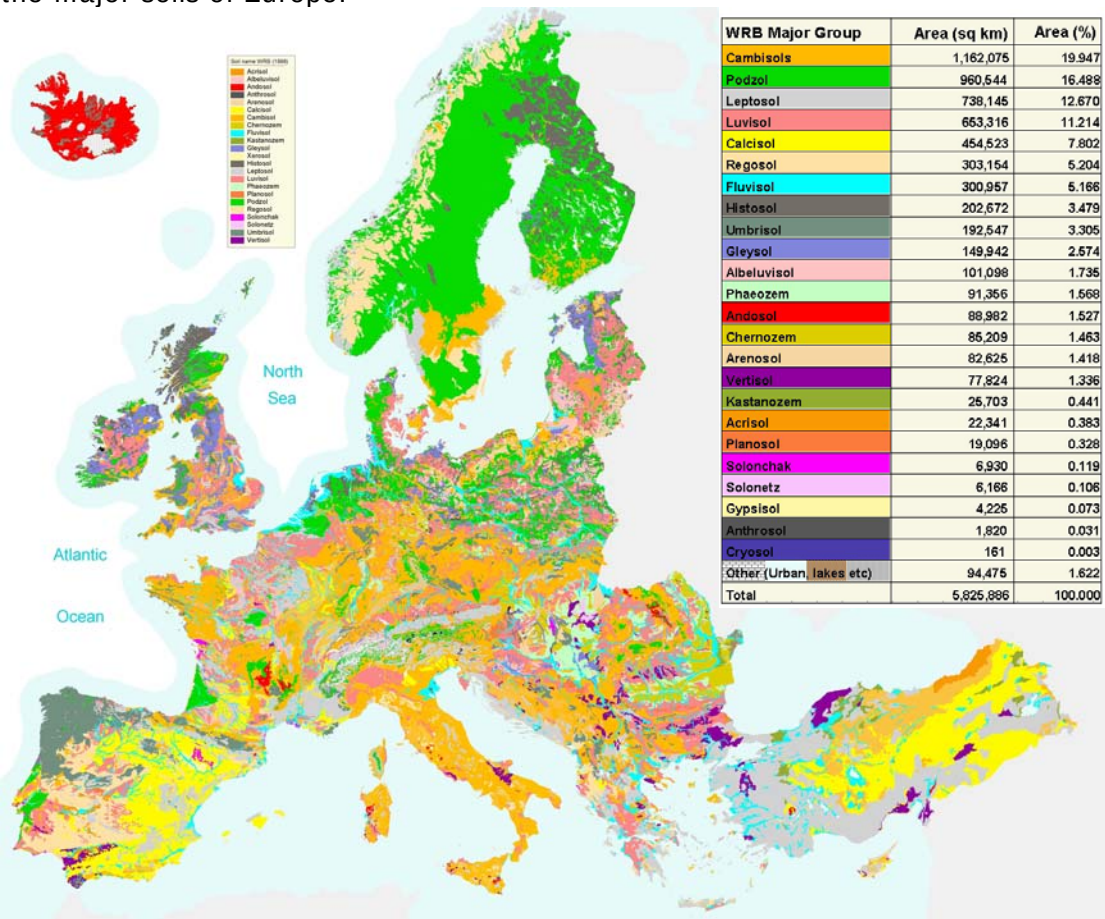


Figure 2.1. The profile above, a Cambisol under a forest, shows a classic A-B-C sequence of soil horizons, with colour differences reflecting the relative distributions of organic matter and weathered iron oxide minerals (source: Soil Atlas of Europe, 2005).

The distribution of the major soil types over Europe is well represented within the European Soil Information System (EUSIS). In particular the Soil Geographical Database of Europe at scale 1:1,000,000 (figure 2.2) can be used to summarize the distribution of the major soils of Europe.



WRB Major Group	Area (sq km)	Area (%)
Cambisols	1,162,075	19.947
Podzol	960,544	16.488
Leptosol	738,145	12.670
Luvisol	653,316	11.214
Calcisol	454,523	7.802
Regosol	303,154	5.204
Fluvisol	300,957	5.166
Histosol	202,672	3.479
Umbrisol	192,547	3.305
Gleysol	149,942	2.574
Albeluvisol	101,098	1.735
Phaeozem	91,356	1.568
Andosol	88,982	1.527
Chernozem	85,209	1.463
Arenosol	82,625	1.418
Vertisol	77,824	1.336
Kastanozem	25,703	0.441
Acrisol	22,341	0.383
Planosol	19,096	0.328
Solonchak	6,930	0.119
Solonetz	6,166	0.106
Gypsisol	4,225	0.073
Anthrosol	1,820	0.031
Cryosol	161	0.003
Other (Urban, lakes etc)	94,475	1.622
Total	5,825,886	100.000

Figure 2.2. The European Soil Database ver. 1.0. Distribution of major soils groups is shown in inset (source: European Soil Bureau, 2004).

Table 2.1 is listing the twelve most frequent soils that account for more than 50% of the total land area. The rest is covered by more than 300 other soil types occurring often only on very limited land areas (<2% of total land area covered by the Soil Geographical Database of Europe (SGDE)).

Table 2.1. Most frequent soils in Europe (more than 1,6% of total land area covered by the SGDE ver.3.28).

Soil Name (WRB)	**Area in km^2**	**Percentage area**
Cambisol	1 162100	19,9
Podzol	960500	16,5
Leptosol	738100	12,7
Luvisol	653300	11,2
Calcisol	454500	7,8
Regosol	303200	5,2
Fluvisol	301000	5,2
Histosol	202700	3,5
Umbrisol	192500	3,3
Gleysol	149900	2,6
Albeluvisol	101000	1,7
Phaeozem	91400	1,6
Total	**4148100**	**91,20**

Source: SGDE ver. 3.28

This large number of soil types with relatively little aerial distribution needs to be taken into account in designing a soil protection strategy. Uncommon soil types may deserve special attention as unique habitats for a number of organisms, making them potentially eligible for specific protection measures. The European Union has made a Directive to investigate and conserve European ecological habitats, a directive called HABITAT. It is of great interest to analyze the distribution of soil types in relation to bio-geographical regions as defined within the HABITAT Directive (see figure 4.1). We conclude that it is important to include some soil habitats in the list of habitats to be protected within the Natura 2000 network (box 2.1).

Box 2.1. HABITAT and Natura 2000. *In May 1992 European Union governments adopted legislation designed to protect the most seriously threatened habitats and species across Europe. This legislation is called the Habitats Directive and complements the Birds Directive adopted in 1979. At the heart of both these Directives is the creation of Natura 2000, which is a network of areas designated to conserve natural habitats and species of wildlife which are rare, endangered or vulnerable in the European Community. The Birds Directive requires the establishment of Special Protection Areas (SPAs) for birds. The Habitats Directive similarly requires Special Areas of Conservation (SAC) to be designated for other species, and for habitats. Together, SPAs and SACs make up the Natura 2000 series. All EU Member States contribute to the network of sites in a Europe-wide partnership from the Canaries to Crete and from Sicily to Finnish Lapland.*

As mentioned in chapter 1, biodiversity is greater belowground than above, but unfortunately, the knowledge about soil organisms is still very limited. Many species have not yet been studied or classified, and the role of many of the soil organisms is still being discovered. A renewed effort in soil biology research is needed, in order to obtain the necessary knowledge of these rare habitats before they are lost because of the activity of man. Soil types are also related to landscapes and rare soil types may represent unique landscape types which need special attention and protection.

Soil information in Europe

There are a variety of initiatives in Europe to collect soil information. These initiatives were developed over several decades and were coordinated by actors at different levels: Global (FAO, UNEP, etc.), European (European Community, ECE/ICP Forest, FOREGS), national, regional and local level.

Collection of soil information in Europe can be broadly classified into three categories:

a) *Soil Mapping*, enabling to identify areas of land for management purposes.
b) *Soil Inventories*, providing a one-off assessment of soil conditions and/or properties at a point in time.
c) *Soil Monitoring*, providing a series of assessments showing how soil conditions and/or properties change over time because of land use.

Soil Mapping

Soil mapping has historically been the main activity of national soil survey organizations in Europe. Many of these were initiated after World War II in response to demand for increased agricultural production and food security. Early on, Land Capability Classification (Klingebiel and Montgomery, 1961) was developed. In the UK, Germany and other countries, land classification maps for land use planning were produced in recognition of the need to protect the best agricultural land for the future.

The period 1950-90 was the most productive period for soil surveys. This period also experienced development of an understanding of the main soil processes, information that is now proving to be important in helping to solve environmental problems of today.

In the mid- to late 1980s, a number of EU countries became self-sufficient in agricultural products. Large surpluses of cereals, milk, wine, olive oil and certain fruit crops were accumulated. At the same time environmental problems linked with the development of a production orientated agriculture became more evident. There was a sharp decline in support for soil science because the discipline was inextricably linked to productive agriculture and further research was perceived to lead to even larger surpluses in the future. The importance of soil in the broader environmental context was not yet recognized. Funding for soil surveys declined and many soil survey programmes were curtailed or halted completely. The result was that only one country in the European Union, Belgium, had completed its detailed national soil-mapping programme by the end of the 1980s.

The Concept of Soil Mapping

The general aim of soil mapping is to provide representation of soils of continents, countries, regions, farms, or in fact any area of land of interest. It involves identifying the different types of soils that occur, collecting data about their nature, properties and potential use, and recording this information in databases and supporting documents, to visualize all this information by maps and tables, and to analyze soils, landscapes, and societal factors by linking soil information with other types of information.

Soils can be mapped at a *range of scales* from very detailed, scale 1:1,250 to 1:5,000, showing soil patterns within individual fields or parcels of land, to broad exploratory surveys at 1:500,000 to 1:5,000,000, providing only a much generalized picture of the soils of a country or continent (table 2.2).

Table 2.2. Scales of soil survey and their objectives. After Dent and Young (1981) and Avery (1987).

Description	**Scale**	**Ideal inspection density**	**Kind of map unit**	**Typical objectives**
Large scale	1:2,500	64 per ha.	Simple	Special purpose and
(Detailed)	1:10,000	4 per ha.	Simple	Detailed general purpose
	1:25,000	64 per km^2	Mainly simple	Surveys. Project planning
Medium scale	1:50,000	16 per km^2	Mainly	Regional land use
(Semi-detailed)	1:100,000	4 per km^2	simple	Planning. Project
				Feasibility studies
Small scale	1:200,000	1 per km^2	Compound	Regional or national
(Reconnaissance				Resource inventories.
	1:250,000	<1 per km^2	Compound	National land use
	1:500,000	<1 per km^2		Planning
Exploratory	1:1,000,000 or smaller	<< 1 per km^2	Compound	Display. National Atlases, Continental assessments

In establishing a soil-mapping programme, decisions need to be made on whether surveys are to be general purpose or special purpose. *General-purpose surveys* are expected to provide the basis for interpretations for many different uses, some of which may not yet be known. By contrast, *special purpose maps* are prepared for specific uses and the relevant soil characteristics are emphasized in the separation of the different map units. Examples of special purpose maps include those for planning irrigation or sewage sludge disposal. The drawback of special purpose mapping is that the information may be unsuitable for other purposes or applications that develop later.
Most national surveys of soils involving detailed mapping have been general purpose in nature with the expectation that they will provide a broad information base from which

to respond to a wide range of demands, varying from agricultural and environmental to planning purposes.

In order to identify and map different soil types, it is necessary to classify the soils. A number of classification schemes have evolved; many European countries have developed their own systems suited for local conditions. There are two main international systems of classification: the IUSS termed the World Reference Base for Soil Resources, abbreviated as *WRB* (FAO, 1998) and the *US Soil Taxonomy*. Most soil classification systems are hierarchical in structure with a number of divisions representing different degrees of refinement and definition.

The *soil series*, defined as collections of soil profiles showing the same or similar succession of layers in lithologically similar parent materials (Hollis and Avery, 1997) is often the lowest order in a classification and is the one chiefly used to identify map units at scales of 1:65,000 or larger. It is conceived as a grouping of soils that are alike in their characteristics and behavior in the landscape.

The basic unit of soil sampling and classification is a *soil type*. A soil type is characterized by making a soil profile description. A soil profile is a column excavated from the surface through the soil layers or horizons to the undisturbed underground, which may be hard rock or other parent material (figure 2.1). Selected *profile characteristics* are described for each profile and their properties determined for each layer, such as particle size distribution, amount of organic matter, colors representing aerobic or anaerobic conditions, and many more. Biological properties are commonly limited to intensity of worm activity and rooting intensity.

Soil mapping involves the use of an auger at intervals throughout the landscape to examine the nature of the soil at a point. The intervals between inspections can be organized according to a pre-determined grid (grid survey) or more commonly an irregularly spaced grid, chosen based on past geological and geomorphological developments and place in the landscape. Auger boreholes are supplemented by excavated profile pits chosen as representative of a particular soil type, and sampled for analysis to provide more details about the nature of the different soil horizons.

Soil Mapping in Europe

Soil maps in Europe have been prepared at a range of scales and because of the differences in national approaches there is little consistency between countries in the scale used or in whether the emphasis is on small or large-scale mapping. It is generally accepted that as an absolute minimum each country should have a national map at a scale of 1:250,000. Any scale smaller than this is regarded of little value for in-country management of soil resources.

An overview of available soil maps in Europe is given in table 2.3 and figure 2.3.

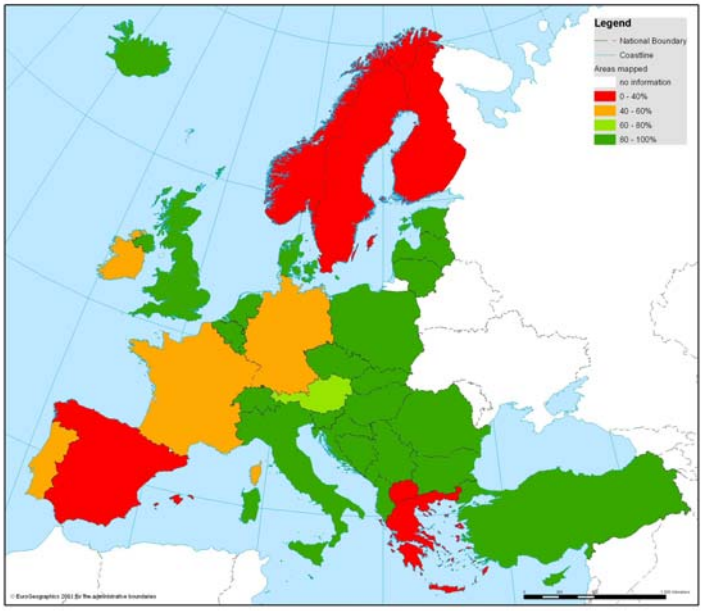


Figure 2.3. Availability of detailed soil surveys at 1:50,000 or 1:25,000 scale in the EU and bordering countries (Jones et al., 2005).

Table 2.3. Details of national soil mapping programmes and inventory or monitoring systems.

Country	1:250,000	1:50,000 to 1:25,000	1:10,000	Number of Sampling (Inventory or Monitoring) sites
Albania	100%		28% (farms) at 1:5K	
Austria		63-98%	10% F, 63% A 20% 1:5K	514 F plots (grid 8.7 x 8.7km), 5,000 F soil profiles, 26,000 analyses BORIS; 432 agri monitoring points; soil assessments data – 32% Environ. Soil survey 5,000 F + 2,500 A
Belgium	100%	100%	100%	15,000 soil profiles =+ analyses
Bosnia Herz		100%		
Bulgaria	100%	100%	90%	50,000 main soil profiles
Croatia		100%		6,000 soil profiles
Cyprus	100%	100%		Nitrate monitoring (1:250,000)
Czech Republic	100%	100%	100% 100%, at 1:5K,	30,000 soil profiles 200 permanent monitoring plots, 500 forest monitoring
Denmark	100%	A	In prep	8,000 soil profiles, 7km x 7km grid survey; 393 HM monitoring
Estonia	100%	100%	100%	10,000 soil profiles; various monitoring programmes
Finland	In prep.	30%		28,000 texture, 80,000-100,000 samples (for farmers) 2,000 monitoring sites (pH, C, Ca, Mg, K, HM)
France	30%	Incomplete	case studies	ICP Ft (16x16 km, 540 plots); some monitoring
Germany	30% (1:200K)	Incomplete	case studies	
Greece			case studies	3,000 sites for fertiliser monitoring
Hungary	100%	100%	70%	1,200 points (800A + 200F + 200 hot spots)
Iceland				75% vegetation maps at 1:40,000 & 1:25,000, soil erosion databases for 1:100,000, >100 profiles, >500 sampling points
Ireland	100%	44% at 1:126K		295 soil points (22% of country)
Italy	100%		case studies	
Latvia	100%		100% of farms	2,547 points (5km x 5km); various monitoring projects
Lithuania	100%		farm level	7,000 profiles (analytical data A + F); various monitoring projects
Luxembourg	100%	100%		
Macedonia				
Malta		100%		MALSIS: 280 points (1kmx1km) 1st stage; 240 Malta+60 Gozo 2nd stage 350 profile data, 800 soil samples data
Netherlands	100%	100%	55% groundwater table	various monitoring projects
Norway				9km x 9km grid F
Poland		district level		2,000F, 5,700A, 1,000 mineral soil samples 216 arable soil profiles
Portugal	100%	35%	case studies (irrigation)	800 soil profiles described 100 soil profiles analysed 80 soil profiles for hydraulic properties; soil erosion monitoring
Romania	100%	80% A	20% A	soil survey (A) at scales 1:10,000 & 1:5,000) forest survey at 1:50,000; database of land units soil quality A & F – grid 16x16km (942 profiles=670A + 272F) PROFISOL 4,200 soil profiles (16kmx16km) 1,200 profiles for pedo-geochemical database,
Serbia	100%		Case studies	Agriculture and water research-42,000 sq km; some monitoring
Slovakia	100%		100% 100% at 1:5K,	18,000 soil profiles + analyses 330 monitoring points (A) 280 monitoring points ((F)
Slovenia	100%	100%	1:5K for urban soils & on GIS	1,700 soil profiles+analyses; pollution monitoring (2kmx2km A.; 4kmx4km F), 1kmx1km in polluted areas
Spain	50%	15%		453 soil profiles; 2,000 data (critical loads studies) erosion studies 20,000 points; contamination: 1,200 samples from pastures; +2,600 samples from arable land
Sweden		1% A		ICP Forest soil monitoring (no. of sites not known)
Switzerland		7%		Some monitoring
Turkey		A (for irrigation)		
United Kingdom	100%	30%	case studies	6000 soil profiles + analyses; 9,000 national soil inventory points (5km x 5km); 6,500 analyses; 2200 monitoring sites

A – agricultural; F – forest ; HM – Heavy Metals; 1:5K – 1:5,000

The development of a Soil Map of Europe

European soil scientists made an effort in 1952 to harmonise methodologies and classification systems. As a result of this meeting, a request was submitted to the Director-General of the Food and Agriculture Organization of the United Nations (FAO) to sponsor the harmonisation within the framework of the FAO European Working Party on Land Utilisation and Conservation. In response to this request, FAO established a Working Group on Soil Classification and Survey, later affiliated with the Sub-Commission on Land and Water Use of the European Commission (Jones et al., 2005).

This work resulted in a first draft of the soil map of Europe at a 1:2.5 million scale presented in September 1959. From 1959 to 1964 several drafts of the map and text were produced and discussed at successive meetings of the Working Group and at the Seventh and Eighth International Congresses of Soil Science. The map and its explanatory text were published by FAO in 1966.

A further step towards a common European map was the preparation of the 1:5 million Soil Map of the World, jointly undertaken by FAO and UNESCO. The project was initiated in 1961 and publication started in 1971. The two map sheets covering Europe were issued in 1981. The FAO/UNESCO Soil Map of the World incorporated the European systems of soil classification into an internationally recognized legend that enhanced cooperation and overview of the characteristics of Earth's soils (FAO, 1995).

The broad composition of the soil associations at scales 1:2.5 million and 1:5 million was considered as a basis for more detailed land resource management and planning. Conscious of its responsibilities with regard to the practical application of soil data, the Working Party on Soil Classification included the preparation of a map at 1:1 million scale in its programme in 1965. This map was published as the EC Soil Map by the Directorate General (DG) of Agriculture in 1985, and was later digitized under the CORINE (Co-ordination of Information on the Environment) project (see Soil inventories).

Soil inventories

Recently, there has been an increasing need to organize the existing soil resource information of each country into a digital Soil/Land Information System. Digital soil information is needed for most of the current computerized models, for example in order to derive both environmentally and agriculturally relevant information from basic soil data. Most countries have accepted this need but, as with soil maps, there is a large contrast in terms of development of such systems across Europe.

As can be observed from *Soil Resources of Europe: second edition* (Jones et al., 2005), soil and land information systems vary across the countries of Europe. They range from essentially simple databases containing soil profile and analytical data to well developed integrated computerized systems containing climatic, land use and cadastral information as well as soil data. The capabilities of these systems range from purely storage and retrieval of data to integrated dynamic modeling using GIS technology for evaluating current and future policy requirements at national and regional scale.

Computerized information systems are now capable of producing sophisticated graphical outputs. However, it is important to consider that the outputs are only as good as the input data, and for at least half of the European countries, this is inadequate for decision making because less than 50 per cent of the area has sufficiently detailed soil maps. Furthermore, some of the information can be up to 50 years old.

European Soil Inventories

There are essentially three major European scale initiatives aiming at creating coherent inventories of soil properties across country borders: 1) *The European Soil Information System (EUSIS)* of the JRC, covering Europe at 1:1,000,000 scale and incorporating more detailed inventories at 1:250,000 and 1:50,000 scales in a nested GIS system, 2) the *EC/ICP Forest 16 km x 16 km grid inventory* on forest soils and 3) the *FOREGS Geochemical baseline mapping project*.

The European Soil Information System (EUSIS)
This system is based on the 1:1,000,000 scale "Soil Geographical Database of Europe (Jamagne et al., 2001). The database has been recently extended to cover the Mediterranean basin countries and the former Soviet Union (Montanarella, 2001; Stolbovoi et al., 2001). This map has been integrated with Canadian and US incentives to create a Circumpolar Soil Database (figure 2.4).

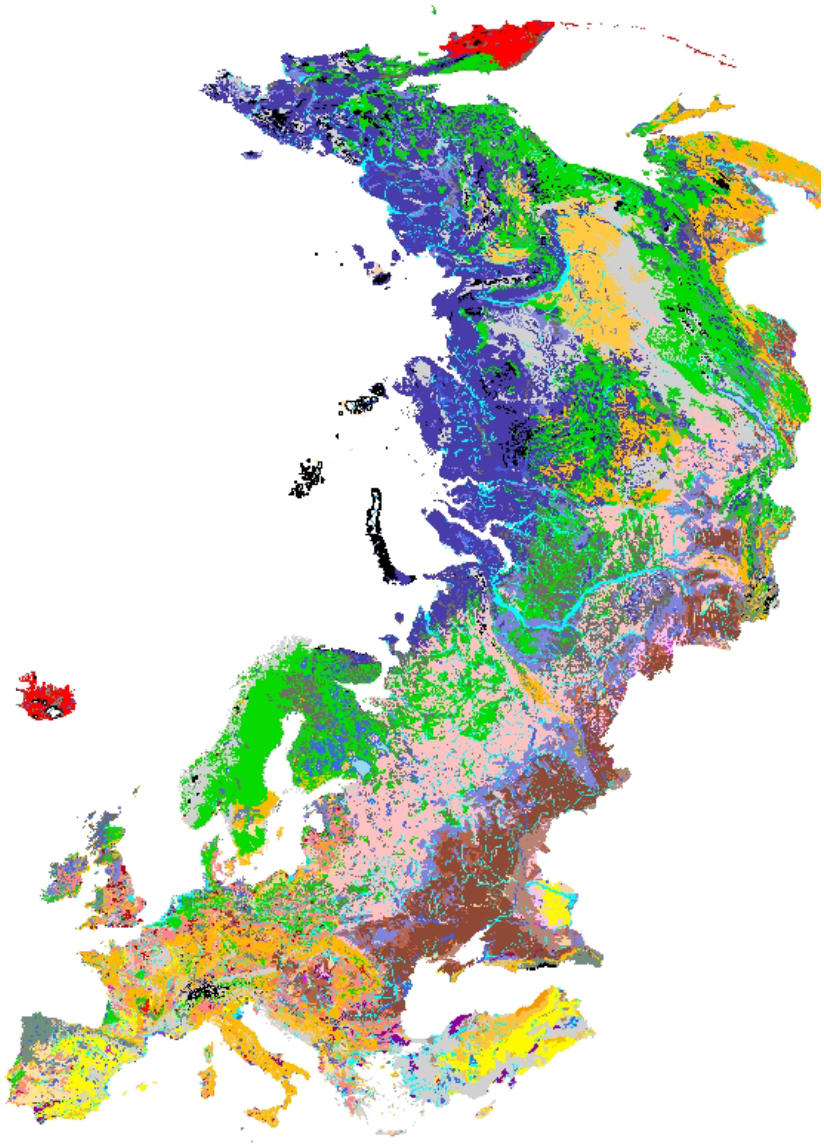


Figure 2.4. Provisional soil map extracted from the Eurasian Geographical Soil Databases.

This database will serve as a tool for the more accurate estimation of soil organic carbon pools in the boreal areas and for estimates of potential changes in greenhouse gas emissions in relation to changes of soil temperature regimes in these areas.

EUSIS is a multi-scale system integrating data of different level of detail into one single Geographic Information System (GIS) (King et al., 1998; Montanarella and Jones, 1999). It links to global scale systems as the World Soil and Terrain database (SOTER) (1:5,000,000 scales, FAO-ISRIC, 1995) at one end, while assuring compatibility with the European 1:1,000,000 scale soil database at the other hand. Using GIS technology, the database is also linked to more detailed databases on national, regional or local level (1:250,000 to 1:5,000). This allows for a coherent approach expanding scales from the local to the global scale according to needs and available data (figure 2.5).

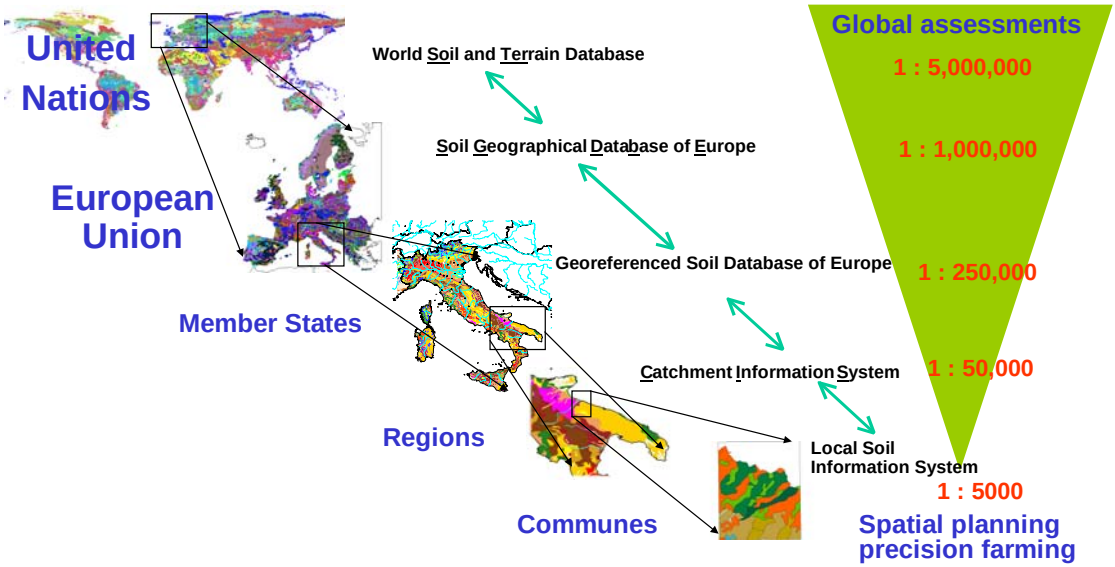


Figure 2.5. The European Soil Information System, responding to users (in blue) needs at different scales (in red).

The system also allows for the preparation of derived information such as soil erosion risk maps, soil organic carbon estimates, and many others (see Van Ranst et al., 1995). More complex models use the EUSIS for the early forecast of for example crop production, desertification risk assessments, groundwater vulnerability to agrochemicals. Still the system is far from being ideal for all applications required; nevertheless it currently forms the only soil information system covering the entire European continent.

The main elements of the European Soil Information System are described below:

Soil Geographical Data Base of Europe at scale 1:1,000,000

This database forms the core of EUSIS. In 1985, the Commission of the European Communities published a soil map at a 1:1,000,000 scale (see above). The aim was to provide a harmonized set of soil parameters covering Europe and the Mediterranean countries to be used in agro-meteorological and environmental modeling at regional, national, or continental levels. In 1986, this map was digitised to build a soil database to be included in the CORINE project. The database was enriched in 1990-1991 from the archive documents of the original EC Soil Map which led to version 2. Subsequently, a soil and GIS expert group recommended that new information should be added and each participating country should make updates, which led to the current version 3 of the database.

Originally covering only European Union countries, the database has recently been extended to Central European and Scandinavian countries. Work is going on to further extend it to other Mediterranean countries: Algeria, Cyprus, Egypt, Jordan, Lebanon, Malta, Morocco, Palestine, Syria, Tunisia and Turkey.

Beside these geographical extensions, the database has also experienced important structural changes. The latest change introduced a new list for parent materials and the use of the World Reference Base (WRB).

The database contains a list of Soil Typological Units (STU), characterizing distinct soil types that have been identified and described. The STUs are described by attributes (variables) specifying the nature and properties of the soils, for example texture, moisture regime and stoniness. At the used scale 1:1,000,000, it is technically not feasible to delineate each STU. Therefore, STUs are grouped into Soil Mapping Units (SMU) to form soil associations. The criteria for soil groupings and SMU delineation have taken into account the functioning of pedological systems within the landscape.

Georeferenced Soil Database for Europe at scale 1:250,000
The scale and the precision of the 1:1,000,000 databases do not ensure harmonization between the various soil survey organizations and the need for more specific soil information. The feasibility of the creation of a soil inventory of Europe at scale 1:250,000 was therefore carried out (Dudal et al., 1993). Meetings of leaders of national soil surveys of the European Union, in 1989 (Hodgson, 1991) and 1994 (Le Bas and Jamagne, 1996), recommended the preparation of a georeferenced soil database for Europe at scale 1:250,000. The implementation of these recommendations was carried out by a Soil Information System Development Working Group (SISD) and subsequently entrusted to the European Soil Bureau, which was created within the JRC in 1996 (Montanarella, 1996). A Manual of Procedures was published, outlining the basic structure and procedures for establishing this new database (European Soil Bureau, 1998). Most of the database is based on existing soil data combined with newly collected additional soil data.

EC/ICP Forest Soil Inventory
Public concern for the European forest ecosystems called for an extensive forest soil condition monitoring. This programme was implemented by the European Commission (EC) and the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). The inventory aims to provide basic information on the chemistry and on other soil properties which determine its sensitivity to air pollution. Forest soils were sampled at the intersection points of a transnational 16 x 16 km grid. Sampling and analysis were carried out by the national focal centres (NFCs). The results are stored in a common geographical database at the Forest Soil Co-ordinating Centre (FSCC) in Belgium. Of the 31 countries participating in the European forest soil condition inventory, 23 have completed their national survey activities.

A new EU regulation, the Focus regulation (European Commission, 2003), establishes a new forest monitoring scheme and allows a new demonstration study (BioSoil) that aims at a repetition of the first soil monitoring survey on the regular 16 x 16 km grid. Starting in 2005 this will be the single most important study implemented at EU level for the verification of the feasibility of systematic soil monitoring in Europe. It is an exercise in designing the soil monitoring system of the future, and therefore should be considered as a demonstration study and not as an operational system. It will answer such important questions as:

- Will a second survey detect any changes in selected soil parameters?
- Are changes explicable by cause-effect relationships within the DPSIR framework?
- Is the adopted manual of procedures applicable at EU scale?
- Can results be compared across EU Member States?
- Are results relevant in the EU context?
- Can results be integrated into a wider European Soil Information System?

FOREGS Geochemical baseline mapping project
The FOREGS Project, mapping large parts of Europe, is the result of more than 15 years of discussions among governmental geochemists from Geological Surveys all around the world. In Europe these discussions are reflected in a series of WEGS (Western European Geological Surveys) reports (e.g. Bølviken et al., 1990; Bølviken et al., 1993). As the main outcome of the discussions, Darnley et al. (1995) published a handbook for a worldwide geochemical mapping project. Financing for a worldwide project was never accomplished and in the end the Forum of European Geological Surveys (FOREGS, the successor of WEGS) decided to carry out a European Geochemical Mapping Project. For this project samples were taken in 26 European countries. The size of the survey area is 4,250,000 km^2 and up to 925 sample sites were visited throughout the area. This gives an average sample density of *1 site per 5,000* km^2. The sampled materials include: stream water, topsoil (0-25 cm), O- (where available) and C-horizon soil samples, stream sediments and floodplain sediments.

Soil monitoring

Monitoring is vital in the quest for understanding soils and their responses to land use, alongside soil maps and databases. Monitoring can provide information about how soils change and if the quality of a soil is improving, deteriorating or is stable under given land use and management practice. Furthermore, monitoring is essential for identifying the nature of contaminated land, effects of trans-boundary migration of pollutants and the extent and form of land degradation.

In most cases, soil survey organizations are involved in helping to establish monitoring programmes, for example by relating monitored components to soil types. This is particularly important for distinguishing between natural and man-made changes of soils. It is also essential that monitoring programmes are linked to the national land/soil information systems for enhancing the use of such information. This allows for interactive use of monitoring programmes with other databases, such as ecological, land use, climatic, cadastral and demographic databases. It is particularly important that information collected is not isolated from all other information about soils, their use and management.

National reports confirm that most countries in the EU have established monitoring programmes for soil. An inventory of existing national monitoring systems is represented in table 2.4 (Jones et al., 2005). However, regional schemes are often carried out without linkage to others within the same country. Unfortunately most of these programmes are not real monitoring programmes, since only in very few cases more than one observation in time is made. The European Environment Agency (EEA, 1998) has called for harmonized soil monitoring programmes. For the moment, the present efforts can be considered as inventories that could in the future develop into monitoring systems. The uncertainties of these systems are mostly due to the lack of permanent funding for the responsible institutions.

Table 2.4. Reported soil monitoring programmes in Europe (source: Jones et al., 2005).

Country	Nr. of sites	Sampling scheme (regular grid or stratified location)	Periodicity (depending on parameters observed)	Starting year (depending on sites)
Austria	790	grid	3 years/10 years	1987-1995
Belgium	940	stratified	40 years	1947
Bulgaria	300	not reported	3/10 years	1986/1992
Czech Republic	700	stratified	3/6 years	1992
Finland	860	stratified	5/12 years	1974/1992
France	2300	grid	5/10 years	1993/2001
Germany	800/1800	stratified/grid-EU/ICP	5/10 years	1980/1997
Hungary	1236	stratified	1/3/6 years	1993
Netherlands	240	stratified	6/10 years	1983/1993
Norway	13	stratified	1 year	1992
Slovakia	400	grid/stratified	5 years	1992
Spain	41	stratified	1 year	1995
Sweden	26800	grid/stratified	4 month/10 year	1983/1993
United Kingdom	1200	grid	1/5/15 years	1969/1992

European Soil Monitoring Initiatives

Land Use Land Cover Annual Survey (LUCAS)
LUCAS is a pilot project launched by Eurostat in co-operation with the Directorate General of Agriculture that aims at obtaining harmonized data at EU level on *land use, land cover and additional environmental features*. The survey consists of about 100,000 observation points that are sampled regularly on an 18 x 18 km grid distributed over the entire surface of the European Union (box 2.2). Surveyors visit the observation points and make a number of visual observations, including soil erosion features.

Box 2.2. LUCAS Key points:

- *Harmonized nomenclature and methods of observation throughout the EU*
- *Identification of agricultural covers at species level*
- *Clear separation between Land Cover and Land Use*
- *Grid of 18 km x 18 km enables many integer divisions for enlargement of the sample for national purposes (2 km, 3km, 6km and 9km)*
- *The systematic sampling approach is designed to cover with the same probability of observation all the territory and to collect multi-purpose information*
- *Precise and well documented location of points (orthophotos), geo-referenced system*
- *Regular observations in time (each survey with a precision of one to two meters)*
- *Clear specifications to manage and organize the survey (follow-up and training of surveyors)*
- *Harmonized quality control of data (common data entry software)*
- *Project managed by the Commission ensuring coherence of the system*
- *Full comparability with similar monitoring systems in other OECD countries, like the Natural Resources Inventory (NRI) of the United States.*

The LUCAS survey adopts a two-stage sampling design: the first level, Primary Sampling Units (PSUs) are cells on an 18 × 18 km grid, and the second level, the Secondary Sampling Units (SSUs), are 10 points geo-statistically distributed at each PSU. LUCAS is still at a pilot phase, but has proved its reliability in providing for the first time harmonised and comparable data at EU level. Threats such as erosion, decline in soil organic matter, soil sealing, and possibly floods and landslides can be assessed indirectly.

LUCAS could provide yearly updated information on land cover, which is the most important factor in soil erosion processes, using about 20.000 observation points in 15 European countries, with more data from additional countries becoming available over the next years. It is strongly believed that using LUCAS and other existing EU data would complement the planned soil monitoring system, particularly considering the need of harmonized data and common methodology at EU level. Understanding threats to soils, from local to continental scales, needs information from quite a variety of sources. The most obvious example is the assessment of soil erosion by water, where data on soils, slopes (digital elevation models), land cover/land use and rainfall are combined by applying models. The results are usually soil erosion risk maps (figure 2.6) that represent a rough estimate of the actual soil erosion risk at continental scale.

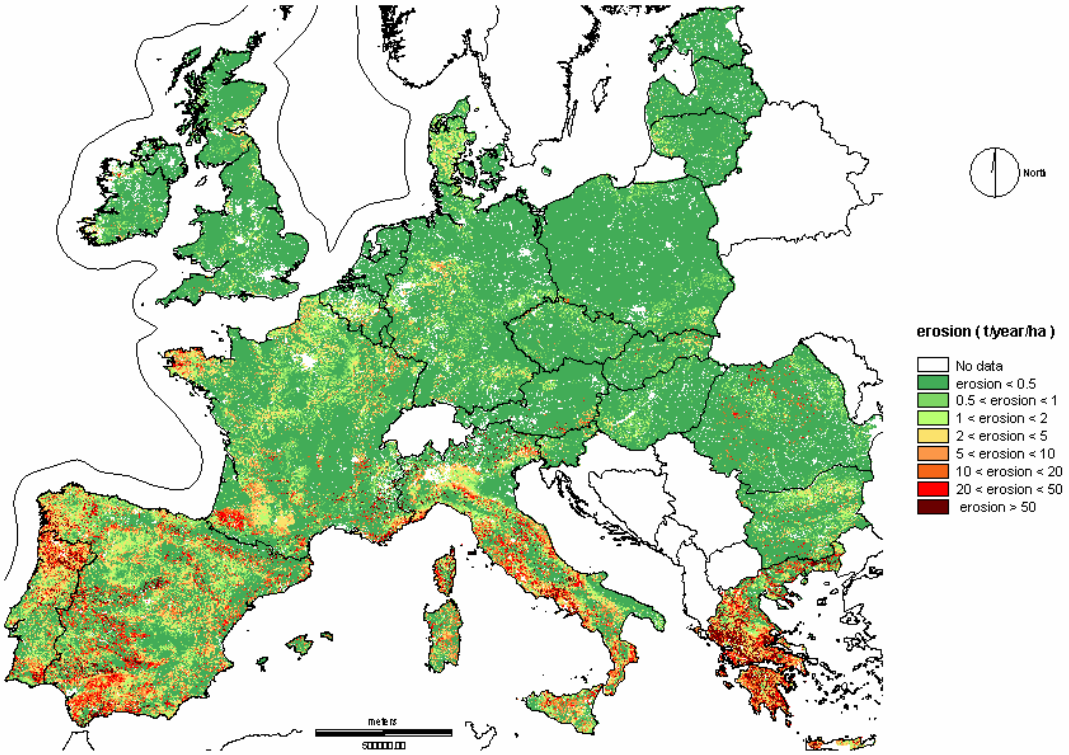


Figure 2.6. Soil erosion risk map derived from the Pan-European Soil Erosion Risk Assessment (PESERA) project.

Digital Elevation Models

Digital Elevation Models (DEM) provide important information on landscape elements such as elevation, slope and slope length. Such information, combined with other data, is important for soil erosion risk assessment and many other applications. A high-resolution digital topographic database has recently been obtained by the Shuttle Radar Topography Mission (SRTM). This has a promising applicability for small and medium scale soil-landscape modeling and applications. One example is the modeling of soil organic matter content in topsoil, which is strongly related to the landuse, vegetation,

climate and terrain features, which can be modelled with DEM and satellite data. An example of is shown for Hungary in figure 2.7.

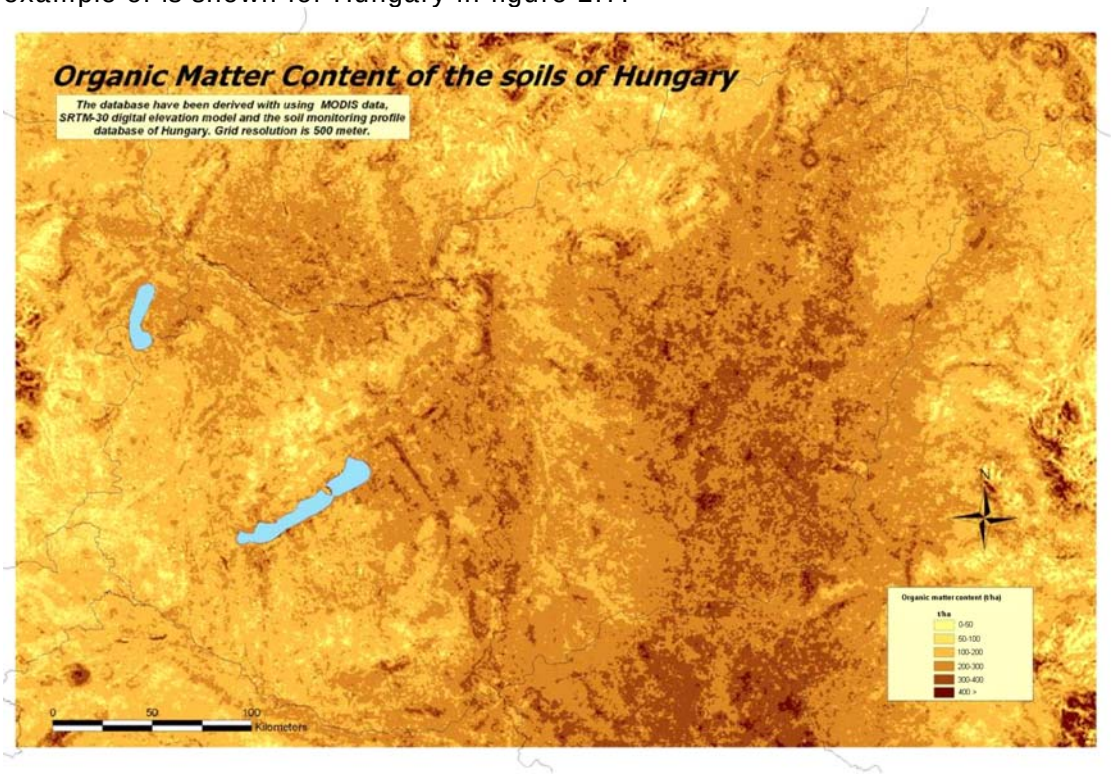


Figure 2.7. Organic matter content of the soils of Hungary derived from MODIS and SRTM30 data through regression kriging (source: Dobos et al., 2005).

Land cover

The major source for land cover information in Europe is the remote sensing based CORINE land cover programme (EEA, 2002). The CORINE land cover was produced in 1990 but a new CORINE land cover for 2000 has just been completed and provides a very valuable tool for the assessment of changes in soil properties in relation with land cover changes, including soil erosion and organic matter.

Analysis of land cover changes in relation to soil type distribution, using these databases, are of great interest. They clearly demonstrate that little attention is given to soil properties in the planning processes, and their influence on optimisation of land uses. High value agricultural soils are often extensively sealed by housing and infrastructure, causing permanent losses of non-renewable soil resources in many areas of Europe.

Land use

Data about alternative land management practices on agricultural lands, such as reduced tillage and no tillage, allows taking into account positive practices that are otherwise not captured by simple land cover information. Unfortunately only very fragmented information is available in Europe on land management practices applied in the field. Some pilot studies have been launched by some EU Member States at national level.

The only pilot study at EU scale is the LUCAS project (see above) that is collecting actual land use information through regular surveys in the field. This information can potentially dramatically improve pan European assessments, such as the soil erosion assessment, by incorporating data on land management practices that are beneficial to soil protection.

Meteorological data

Access to meteorological information in Europe is still not at an acceptable level. Access is often restricted for several reasons and data are often fragmented and of little use.

The most commonly used dataset is the MARS meteorological database generated by the Joint Research Centre (JRC) of the European Commission. This database contains daily

meteorological data spatially interpolated on 50x50 km grid-cell. The original weather observations data set originates from several hundred meteorological stations across the European continent, Maghreb countries and Turkey. The MARS climatic database was originally designed for crop yield forecasts purposes and stored in a database for JRC/MARS research purposes. A technical description of the processing and interpolation of the MARS meteorological data can be found on
http://mars.jrc.it/documents/stats/cgms/GridWeather.pdf.

Geological data
The geology in which soils develop is an important attribute of soil environments and therefore, geological data is necessary for sound soil information systems. Nevertheless, traditional soil surveys are often carried out independent from geological surveys. Bringing together these two areas of earth science is therefore very desirable in order to have a multidisciplinary approach to soil protection.
A first possible point of collaboration is the development of a joint database on soil parent materials for Europe. Starting from the existing parent material data in the European Soil Information System (covering the same area as figure 2.4) a further development of a common dataset for surface materials should be developed, bringing together surface lithological data with soil data in a coherent system.

Conclusions and recommendations

Soil data and monitoring are both crucial elements of any soil protection strategy. Currently available soil information in Europe is scarce and often of little use in a soil policy development process. Still it is not yet possible to answer such important questions as “is soil erosion increasing or decreasing in Europe?”, due to lack of reliable data. In this sense the EU is certainly lacking behind some other OECD countries, like USA or Australia.
This brief survey of existing systems in Europe has demonstrated the need for a common approach to soil monitoring, in order to capitalize on the numerous existing initiatives and to increase the efficiency of the resources already allocated to the various initiatives. To achieve a common EU approach to soil monitoring there seems to be the lack of an EU body, such as an EU Soil Conservation Service, that could act as a European focal point for soil protection and monitoring.

Establishing a common approach to soil monitoring requires first of all the establishment of a common baseline. Without a basic soil inventory, there will be no possibility to detect changes over time in the selected soil properties for monitoring. If this base line inventory is planned to be the “first measurement” in a long-term monitoring, site selection, criteria for harmonization, agreements on soil classification system, sampling and analysis have to be standardized. A number of initiatives exist at national and European level aiming at the collection of basic soil data in the form of inventories accessible in electronic formats (soil databases). The possible gains in efficiency and the consequent cost savings of harmonized data collection have been already documented in many related initiatives (e.g. INSPIRE initiative, http://www.ec-gis.org/inspire/).
The common baseline should have an information density corresponding to at least the 1:250,000 scale. Baseline information at this scale is currently collected through National programmes in France, Germany and Italy. Once these standardized baseline data are available, a reliable and comparable delineation of the areas at risk for the major soil threats can be achieved. Main threats stressed for delineation of risk areas are: soil erosion (water and wind erosion), loss of soil organic matter, soil compaction, soil salinisation and areas at risk of landslides.
Once risk areas have been determined, soil monitoring could effectively be implemented in the delineated areas for each of the threats, allowing monitoring the impact of soil protection measures implemented by Member States.

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?

Box 3.1. The Universal Soil Loss Equation *predicts the long term average annual rate of (sheet or rill) erosion on a field slope:*

$$A = R \times K \times LS \times C \times P$$

A = the potential long term average annual soil loss (tons/acre/year), R = rainfall pattern, K= soil erodibility factor (tons/acre/unit area), LS = slope length-gradient factor, C = crop/vegetation and management factor, P = support practice factor.

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 mattoral (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.

Box 3.2. Mattoral *is a plant community of drought tolerant plants dominated by shrubs, characteristic of regions with a Meditarranean climate.*

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 practise 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

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.

SITE INDICATOR SCORECARD

for Connecticut Community Gardeners

NRCS
USDA, Natural Resources Conservation Service

Date: _____
Site Name: _____
Form Completed By: _____

☒ *applicable box*

Site Indicator	Poor	Tolerable	Best
Accessibility			
1. Walking distance to site.	10+ minutes.	5-10 minutes.	0-5 minutes.
2. Availability of parking.	None.	Difficult.	No problem.
3. Visibility from street.	Can't see site, or it is very visible.		Somewhat visible.
4. Hilliness of site.	Very hilly.	Some slope.	Level or nearly level.
Topography			
5. Direction the slope faces.	North.	East, West.	South.
6. Bedrock, ledge, or large boulders on site.	Too many to work around.	Some, but can work around them.	None.
Location/Distance to Water			
7. Water access -- city water, pond, or river for irrigation.	No water available on the site, and no access to bring it to site.	Have to connect to city water or bring water to site.	Water available easily.
8. Water quality tested.	Bad quality, can't use.	Fair quality.	Good quality.
9. Runoff.	After rainfall, a lot of soil washes from site.	After rainfall, a little soil soil washes from site.	After rainfall, no soil is seen to wash from site.
10. Water on surface during the growing season (spring, summer, fall).	After a moderate rain-fall, water stays on surface for a few days.	After heavy rainfall, water stays on surface for a short time.	After rainfall, no soil is seen to wash from site.
11. Sun exposure through the day.	Shady, very little exposure.	Sun is blocked some of the time.	Mostly sunny.
12. Amount of existing pavement on site.	Too much pavement, will interfere with plans for the site.	Some, but can work around.	None.
13. Debris (construction materials, bricks, concrete, etc.)	A lot on the surface.	Occasional.	None.
14. Shortcuts through site.	Lots.	Some.	None.
15. Neighborhood pets.	Site used heavily by animals.	Some use.	No pet evidence observed.
16. Human activity on site.	Lots of evidence of people on site.	Some people use site.	Very little or no evidence of people on site.
17. What's growing on the site now?	Lots of unwanted trees or brush.	Some unwanted trees and brush.	Plants will not interfere with site plans.
History of Site			
18. History of site.	Not known.	Some stories may be true.	Definitely known.

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 CO_2, 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 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 gets 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.

> ***Box 3.5. Soil sterilisation**: the use of certain pesticides with the purpose to sterilize the soil. This method is often used in the case of an infection with persistent soil borne diseases like nematodes.*

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.

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.

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.

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.

***Box 3.7. CAP**. The Common Agricultural Policy of the European Union deals with the development and support to the European agriculture. It was restructurized in 2003. Under the umbrella of the CAP EU member states are able to develop national rules for support to agriculture. After 2003 an impact assessment is needed to evaluate the environmental consequences of the CAP.*

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.

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.*

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

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.

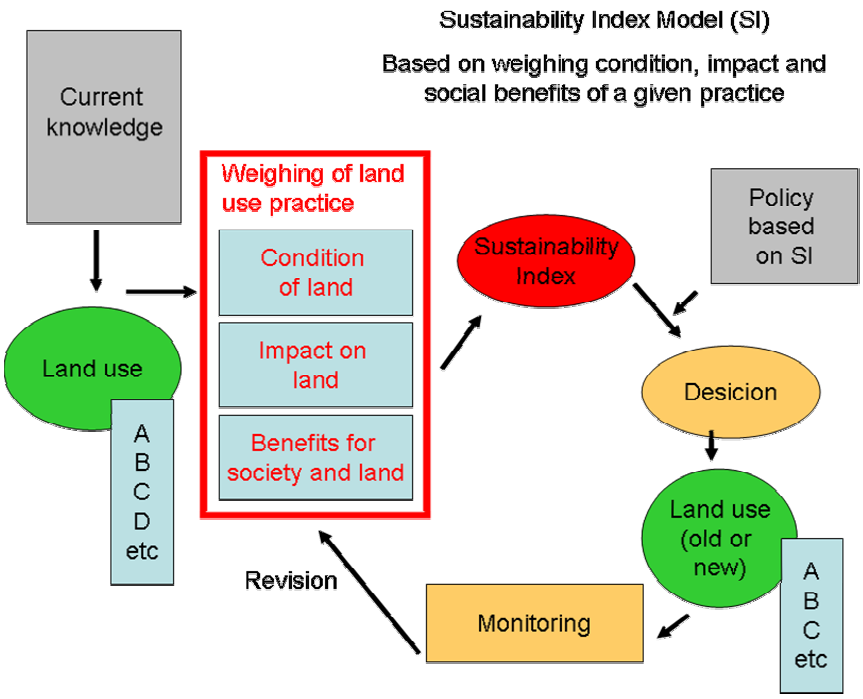


Figure 3.2. Schematic overview of the Sustainability Index model.

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).

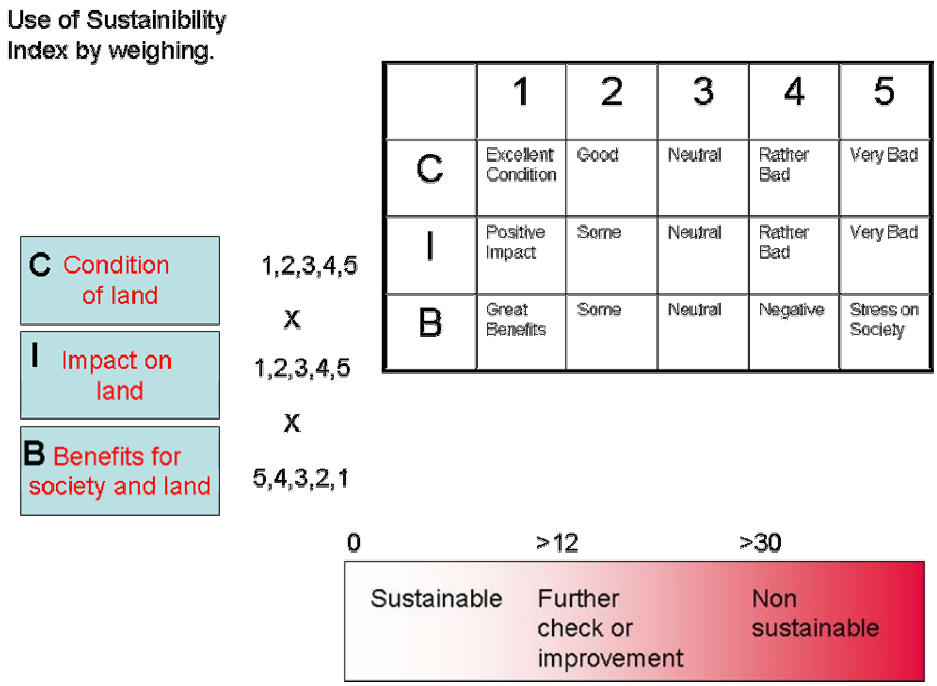


Figure 3.3. Calculating the Sustainability Index.

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 afforestated. 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.

Chapter 4

Case Studies and Good Practices

Introduction

SCAPE made use of three different types of case studies. All of these had the aim of learning from successful actions or 'good practices' in soil conservation and protection. Firstly there were the case studies that concerned specific regions or problems that were presented and discussed by scientists working in these areas. They included case studies from different biogeographic regions, such as the Mediterranean, the European Alps, the continental, boreal and the Atlantic Europe (see figure 4.1) or, thematic case studies such as those on urban soils, sealing and economic aspects of soil conservation.
Secondly there were case studies that looked at experiences from countries outside of the EU, which had successful soil conservation services (Israel, the USA and Iceland). The third type of case study concerned the excursions that were organized to see first hand soil conservation and protection work that is realized in practice. An up-to-date view of a particular area is achieved. Case studies reveal the 'real life' status or 'reality' of what is happening in the field. A case study dealing with soil conservation and protection has to be specific about scale and timeframe. Attention was given to understand which actions had been successful in these case study areas and which had failed. The aspects discussed, ranged from policy and economic instruments to technical and ecological measures of soil conservation. The following case study areas were visited:

- Alicante (ES) which is representative for the Mediterranean biogeographic region located in the dry Mediterranean zone
- Cinque Terre (IT), representative for the Mediterranean / continental biogeographic region, located in the humid Mediterranean zone
- The Montafon region (AT) , representative for the Alpine biogeographic region
- Southern Norway, representative for the Boreal biogeographic region
- Southwest of Iceland, representative for the arctic biogeographic region.

All of these areas are environmentally sensitive areas. The different threats to soils in these areas originate from climate, slope or rock type, as well as socio economic factors.
The Alicante and Murcia case study (Spain) was interesting because the region is undergoing many rapid changes in land use. A lot of data is available on the different threats facing the soil, stemming from many past or ongoing EU or national research projects. The region also contains badlands. The region is within the Target Area of the Spanish National Action Plan of the UNCCD. Tourism and irrigated Agriculture are the main economic activities. Formerly, dry land farming was an important activity. Large areas have been abandoned and are now covered with matoral or forest. The SCAPE excursion visited a large restoration project. The climate is semi-arid but there is a large inter-annual variability in precipitation, so there are often periods with droughts or relatively high intensity rainfall.
The Cinque Terre case study (Italy) was focused on the management of terraces. In Southern Europe large areas are covered with terraces, which are, in many cases, several hundreds of years old. The abandonment of terraced land is nowadays very common in many Mediterranean areas. On steep slopes the abandoned terraces can be lost to erosion and landslides. During the SCAPE seminar in Cinque Terre existing terrace systems from different areas were compared including Malta, Turkey and North Africa. The Cinque Terre region was made into a National Park and has the status of a UNESCO world heritage. How the park status helped the region to protect its landscape and how it prevents the degradation of the terraces is an important example for other regions.

In the Montafon region (Austria) the specific problems of mountain areas were studied. Mountain soils can be very vulnerable to erosion, compaction and mass movements. Forests with a direct protective function against rockfall, snow avalanches and landslides play a key role in landscape management in the Alpine region. Such forests are managed in a way that they also protect their own sites against erosion and shallow landslides. In that sense, forest management, which mainly consists of selective 'close to nature' interventions, contributes to soil conservation. Tourism and hydro-electric power generation are major sources of income for the region. In the Stand Montafon, a regional land management and political body that deals with forest, land and water management as well as with tourism, good practice and community action is demonstrated.
The Southern Norway case study focused primarily on the boreal zone where transforming marginal grasslands into arable farming land has increased erosion much. Land leveling was one of the main factors increasing erosion. The erosion processes lead to the pollution of drinking- and fishing water resources (blue algae). Legislation and a set of technical measures (e.g. legislation on land leveling) was developed to decrease the amount of soil erosion and to improve water quality. Case studies were presented from most Scandinavian countries.
The Iceland case study showed unusually vivid examples of both the severity of land degradation, and the success in mitigating these problems. Field excursions demonstrated that Iceland has faced tremendous land degradation and desertification (see www.rala.is/desert) but has also gained long experience in many types of remedies, including law, subsidy related solutions, and wide ranging of successful participatory approaches. Icelanders are proud of having the oldest operating soil conservation service of the world, *Landgræðsla ríkisins* (the Icelandic SCS; direct translation is "healing the land institute"), which was established in 1907.
A list of papers representing the many SCAPE case studies can be found in Appendix 3. These papers can be downloaded from www.scape.org.

The general consensus of the SCAPE case studies is that soil conservation and protection requires a holistic interdisciplinary approach and that integrated actions are required. Although SCAPE is concerned about soils, this means that it is concerned about soils in their environmental setting. It is concerned with all of their functions. The soil cannot merely be treated as an object or issue on its own without looking to its interactions. The case studies have shown and proven that many aspects are relevant to soil, and vice versa, soil is relevant to many aspects outside the field of soil science. Many speakers who presented a case study during SCAPE workshops were not soil scientist, but amongst others were farmers, sociologists, economists, policy makers, environmental lawyers etc. All these speakers showed a different perspective of our common good; soil. Elaborations about, decisions in land use planning, economic decisions, social structures, cultural aspects and traditions proved to have a close relation with soils. This means that soil can only be protected if we approach the problems from an interdisciplinary approach.

Ten case studies in different biogeographic regions in Europe will illustrate the above mentioned. Each study deals with some of the 8 main threats to soils in Europe as identified by the European Commission (CEC, 2002, see also chapter 3). These threats are:

1. Erosion
2. Decline in organic matter
3. Soil contamination
4. Soil sealing
5. Soil compaction
6. Decline in soil biodiversity
7. Salinisation
8. Floods and landslides

The following case studies will be presented by moving up from southern to northern Europe.

	Biogeographic region	Main threats to biodiversity
	Arctic region	Climate change may change conditions for plant and animal communities Ozone depletion
	Boreal region	Intensive forestry practices Exploitation for hydroelectric power Freshwater acidification
	Atlantic region	High degree of habitat fragmentation by transport and urban infrastructures Intensive agriculture Eutrophication with massive algal blooms Invasive alien species
	Continental	High degree of habitat fragmentation by transport and urban infrastructures Industry and mining Atmospheric pollution Intensive agriculture Intensive use of rivers
	Alpine (Alps, Pyrenees, Carpathians, Dinaric Alps, Balkans and Rhodopes, Scandes, Urals and Caucasia).	Climate change may change conditions for plant and animal communities Transport infrastructures Tourism Dams
	Pannonian	Intensification of agriculture Drainage of wetlands Irrigation combined with evaporation leads to salinisation and alkalisation Eutrophication of large lakes Mining industry with heavy metals pollution of some rivers
	Mediterranean	The world's most important tourism destination High pressures from urbanisation in coastal areas Intensification of agriculture in plains, land-abandonment in mid-mountains Desertification in some areas Invasive alien species
	Macaronesian (Includes Azores, Madeira, Canaries islands)	Invasive alien species Tourism Forest fires and uncontrolled tree-felling Intensification of agriculture with large greenhouses
	Steppic	Intensification of agriculture, e.g. abandonment of nomadic pastoral activities Desertification Large mining and industrial settlements, with pollution problems
	Black Sea	Intensification of agriculture: irrigation, salinisation Waterlogging Tourism
	Anatolian	Intensification of agriculture : conversion of steppes into arable lands, irrigation, drainage of wetlands, overgrazing Building of dams

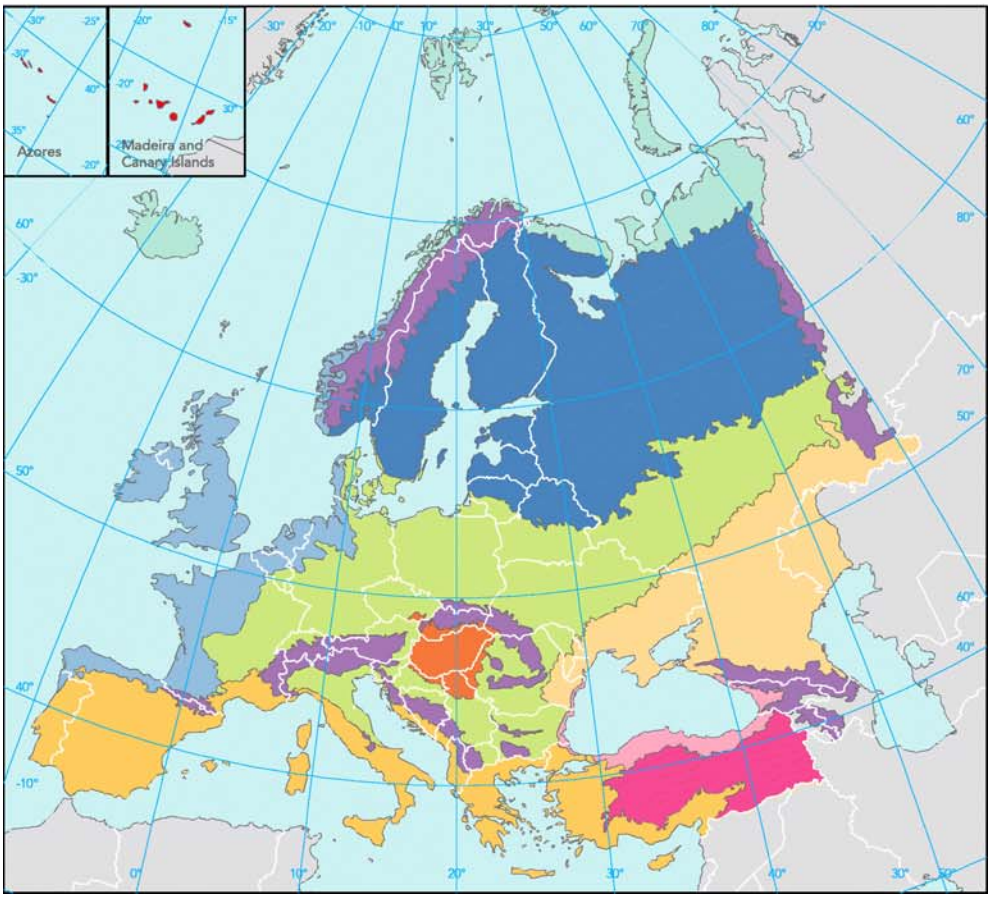


Figure 4.1. The different biogeographic regions in Europe and the main threats to biodiversity occurring in those regions, which are relevant for the soils as well (Source: EEA, 2000).

Case study 1

Land degradation, soil conservation and rural livelihoods

A case study of the influence of financial subsidies and access to water in semi-arid Spain

Carolina Boix, Joris de Vente, Juan Albaladejo and Michael Stocking

Semi-arid South-east Spain presents probably the most visible problems of land degradation in Europe, including sheet erosion, rills and gullies, piping and tunnelling, salinity and sodicity, as well as collapse of conservation structures and damage to infrastructure such as roads and dams. Within the Mula basin, Province of Murcia, a field, participatory assessment was undertaken to identify the drivers of land degradation and possible entry points for soil conservation through the Sustainable Rural Livelihood (SRL) framework. Two neighbouring municipalities were chosen with similar biophysical characteristics but differential economic opportunities, arising especially through availability of financial subsidies and access to irrigation water. The transformations of capital assets in the SRL framework have major implications for land use and environmental sustainability. Major findings of this study include the perverse effect of financial subsidies in (1) when available, enabling land users to benefit from non-productive land while causing soil erosion; and (2) when not available, leading to abandonment of land and extremely high rates of soil erosion and damage to the landscape. When water is available, large-scale commercial farmers buy the land from small part-time farmers. They use land levelling techniques which lead to much hidden soil erosion with possibly irreversible effects on the landscape. Subsidies and access to irrigation water are the major drivers influencing both land degradation and rural livelihoods in this semi-arid part of Europe.

Introduction

The province of Murcia in South-east Spain presents major contrasts in soil erosion, land degradation, agricultural use and rural livelihoods. Closely juxtaposed, areas with access to irrigation are vastly different to dryland farming areas. Irrigated agriculture is intensive and highly commercialised. Where there are access rights to irrigation water, the landscape is subject to major modification through land levelling. Drip-irrigated tree crops are especially important and give an apparent image of greenery and high productivity. Intervening dryland sites, often with older systems of bench terraces, are being progressively abandoned and show extremely evident soil degradation. Large gullies, areas of badlands with intense sheet erosion, piping and tunnelling, as well as salinity and chemical degradation, are all commonplace.

As land use changes, communities are also changing, with many of the poorer land users working part-time in agriculture, while commercial companies are buying up areas with irrigation access. This case study was undertaken to understand the drivers of land degradation and the opportunities to promote soil conservation and ensure sustainable rural livelihoods. Its objective is to show how an understanding of aspects of rural livelihoods is essential in the analysis of land degradation processes and designing remedial measures that may benefit both land users and society.

The Mula Basin

Within the Mula Basin a preliminary integrated land degradation assessment using the Sustainable Rural Livelihood (SRL) framework (Stocking and Murnaghan, 2001) was undertaken in two neighbouring municipalities: Yéchar and Campos del Río. Both municipalities are similar in physical environment. Both traditionally had an economy

based on dryland agriculture. Dryland terraces were used for widely-spaced olive trees and some cereal crops. In the 1970s construction of water transfer canals from the Tajo basin in Spain's central highlands to the Segura basin in Murcia offered an important opportunity to expand irrigated agriculture in the area. The National Hydrological Plan of the 1970s determined which field would have access to water and which could be irrigated. Since then, traditional dryland farming has been progressively abandoned while attention has been focussed on irrigated fields, progressively introducing more commercial fruit species (largely for export) that need many hours of irrigation during dry periods.

Rates of soil erosion in those agricultural areas had previously been estimated using the USLE at 3-10 t h^{-1} y^{-1} (Ortiz Silla et al., 1999). However, in this study on abandoned agricultural fields with old terrace systems and on recently land-levelled areas, erosion rates of 150 and 86 t h^{-1} y^{-1} respectively were measured, following the participatory field methodology of Stocking and Murnaghan (2001). In the first situation, the degradation is very apparent and has given rise to great concern within the community. In the second situation, intensive agricultural practices largely 'hide' the field evidence for erosion by obliterating rills after every intense storm and using drainage ditches to carry runoff and eroded sediments. Nevertheless, careful field examination indicates existing high rates of soil loss even under intensive management.
The results of the SRL assessment in the Mula Basin showed that the factors that affect land use decisions are closely related to the resources available to the land user, and these decisions in turn determine the degree and extent of land degradation. The SRL framework divides resources into a number of capital assets: social, financial, natural, human and physical capital. Communities such as those at Yéchar and Campos del Río have different access to each type of capital. Lack of one category of capital may be compensated for by another, and one form of capital can be converted – or substituted - to another (Stocking and Murnaghan, 2001). The process of transformation from one type of capital to another may have unintended effects on land degradation. Further, farmers' perceptions of soil erosion and their ability to seek subsidies influence the transformations they make, as the next section describes.

Farmers' perceptions and the influence of subsidies on soil erosion

The participatory field assessment of land degradation is especially concerned with understanding farmers' perceptions of their own situation, since that largely controls the decisions they make. The two municipalities are strongly contrasted, making their land degradation situation quite different. The SRL framework is useful in depicting the contrasting assets available to land users (figure 1).
The following analysis of the relative strength of the different capital asset categories is based upon a preliminary and semi-quantitative database compiled during participatory field exercises by participants of two international training courses in April 2004 and 2005, which will need to be verified in a more intensive study. Nevertheless, the differences are clear.

Farmers at Yéchar have enthusiastically organized themselves into an agricultural cooperative (high S) that commercialises agricultural products and provides access to agricultural subsidies at financial cost - but low risk - to members (low F). This organization provides important social support and access to information networks (high P). Physical assets (P) are also high because the agricultural plots are easily accessible and farms are mechanized, often thanks to the social network for access to expensive equipment. Farmers do not perceive on-site or off-site effects of soil erosion as a big problem affecting their activities or their lives. Their main worry is about water availability. The farmers are generally well-informed with respect to productivity in the short term, but not with respect to sustainability. Most farmers consider soils in the valley bottoms, derived from soft marl rocks and with few stones, as good soils for agricultural production (high N), provided that water is available (figure 1). Rapid

formation of gullies is not considered a problem since the farmers of Yéchar have the facilities and social networks to eradicate gullies as soon as they start to form. The cost is relatively small compared to the financial income from the land use. Hence, in terms of the SRL framework, farmers are substituting financial, social and physical capital at the expense of the natural capital in the quality of their soil.

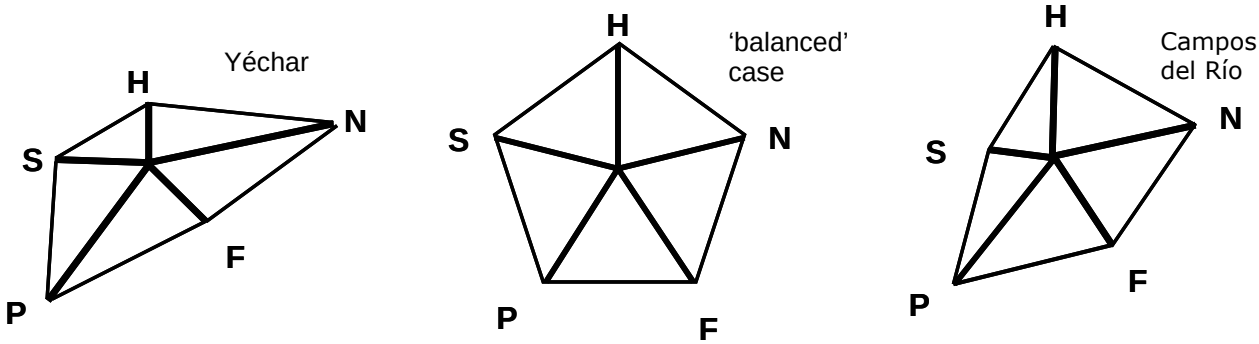


Figure 1. Capital assets polygons representing farmers' perspectives of their agricultural resources – relative strength/abundance of human capital (H): natural capital (N); financial capital (F); physical capital (P); social capital (S).

Further, in Yéchar, the intervening areas of dryland agriculture have very low agricultural production. Young farmers especially look for opportunities in other areas or in other economic sectors and much land is abandoned and unused, leaving erosion processes to accelerate over time causing progressively more land degradation, especially on old dryland terraces. The current lack of human capital – H, mostly in labour but also knowledge of dryland farming techniques – explains why few efforts are devoted to rehabilitating these extremely degraded areas. In these abandoned plots soil erosion was measured in the range 100-150 t h^{-1} y^{-1}. There are no penalties for abandoning land use, and no sanctions on downstream effects of large sediment flows, although there is much discussion locally that prevention will need to be enforced. In some cases, dryland plots do attract some environmental subsidies. For example, some unseeded fallow areas are used for grazing sheep while attracting subsidies, but later are abandoned. Erosion rates were measured at 40-70 t h^{-1} y^{-1}, agreeing with results from central Spain where subsidised unseeded fallow was shown to have high susceptibility to soil erosion (Boellstorff and Benito, 2005).

Farmers at Campos del Río have similar perceptions of soil erosion as in Yéchar. However, the economic situation is different. A canning-food factory was established in this village more than 20 years ago and absorbs a large number of the farmers as labour. Therefore, many have become part-time farmers. A few large-scale commercial farmers are buying the fields of the part-timers. They have introduced drip irrigation with new land-levelling techniques by bulldozer in the last 5 years. Therefore, financial capital in these systems is relatively high (higher F; moderate H). Levelled land is perceived as positive for erosion control due to the easy access and movement within a plot with heavy machinery, gullies can be filled up relatively easy and land is again levelled after heavy storms. However, field estimations of erosion rates were between 80-90 t h^{-1} y^{-1}, demonstrating that farmers' perceptions about erosion are not necessarily substantiated by field measurements.

The presence of the canning factory guarantees a secure income at low risk. In Campos del Río there is no agricultural cooperative (low S), although a local development agent facilitates access to subsidies and to extension courses. However, the demand on these issues is low due to a lack of interest and an inhibition of initiatives related to farming. The access to subsidies is further complicated for part-time farmers since their main income comes from their work at the factory and not from farming, which invalidates their access to agricultural subsidies (figure 1).

In both municipalities, water scarcity is perceived as the main problem rather than soil erosion. Erosion is seen as a process that can be controlled and the on-site and off-site

consequences are generally underestimated. In the cases of Yéchar and Campos del Río the cost of soil erosion on a land levelled for apricot trees on marly lithology was in the order of €70-90 h^{-1} y^{-1}. This is higher than estimates for other areas: e.g. according to Hein (2004) erosion costs €1.1 to 32.4 h^{-1} y^{-1} on dry herb crops and €3.3 to 48.5 for dryland almond trees depending on the slope of the plot.
Overall, the policy of crop and environmental subsidies are counter-productive for prevention of land degradation and the promotion of soil conservation in semi-arid South-east Spain. Depending on the local economic situation and the water availability, farmers will either use the subsidies to bring marginal fields into production that will be abandoned shortly after, or subsidies cannot be accessed because the main income of the farmer does not come from farming. In this case farmers will sell the land to large mechanized farms that use land levelling operations, creating more erosion that is effectively hidden from view. Both abandonment and land levelling have high erosion rates as a consequence.

Influence of access to water on soil erosion

As illustrated above, access to cheap (and subsidised) water in Southeast Spain strongly determines farmers' decisions on land use and agricultural practice. Agriculture in the area is dominated by high productivity irrigated crops, such as apricots, peaches, plums, and irrigated almond trees. Not only does access to water open up choice of crop, it also vastly increases production and therefore the price of the land. All these land use changes also affect erosion processes. In the area access to water was found to determine soil erosion in two ways:

- When irrigation water is unavailable because the fields were not included in the irrigation schemes of the National Hydrological Plan, the fields, which in most cases correspond to bench terrace systems, are abandoned, leading to high erosion rates. In other cases, plots are farmed with subsidies (seeded and unseeded fallow land mainly) but because of low production these fields are finally also abandoned. Both unseeded fallow and abandonment of terraced systems lead to high erosion rates measured in the field at 40 t h^{-1} y^{-1} and between 70-150 t h^{-1} y^{-1} , respectively.
- When there is access to water in sloping areas, land is transformed with land-levelling techniques by young farmers who want to maximize short-term benefits in fully mechanized farms. Furthermore, rich farmers and large agricultural companies benefit from their ability to buy large areas of land, transforming the land with land levelling systems and installing drip irrigation. Field estimates of soil erosion ranged from 70-90 t h^{-1} y^{-1} on levelled land, although as noted above this erosion is not as visible as that on dry abandoned terraces.

Discussion and conclusions

The complex and contrasting situations in Yéchar and Campos del Río show that land degradation is a product of many variables that affect the resources for farming available to land users. The SRL framework organises these resources into 'capital assets', and an examination of these assets and how they are transformed assists an understanding of how and why farmers 'cause' degrading or conserving farming practices.

Farmers' perceptions of the value of access to subsidised irrigation water in South-east Spain is the single most important factor determining the occurrence of land degradation and soil erosion. Such access is an immediate addition to natural capital (N) and to financial capital (F) through subsidy. Soil erosion, even though it degrades natural capital, is perceived a relatively minor problem in relation to water, because its impacts on production may be 'hidden' by irrigation water in compensating for lost water-holding capacity of the soil and by fertilisers in replacing lost nutrients in the sediment. The on-site costs of soil erosion, although substantial in terms of requiring technical inputs to correct for them, are relatively insignificant compared to the transformation in land use and production afforded by irrigation water. Off-site costs of soil erosion are inflicted on

society, not on the land user generating the sediments, although this may change if policies of subsidies for protecting water courses pass into law and the financial amounts are sufficient to compensate farmers for the lost income ('opportunity costs') in production foregone.

The implications of the use of subsidies in agriculture are very much dependent on the local economic opportunities in each municipality. Transformations taking place within the capital assets polygons (figure 1) have positive and negative effects on soil erosion. Transformation from natural to financial capital through activities such as leasing the land for grazing and using inadequate subsidies (unseeded fallow) increases soil erosion. On the other hand activities such as urbanisation of land and leasing for cropping reduce soil erosion. Transformation from human to financial capital tends to increase soil erosion. The primary example of this is the selling of the land of older farmers to big commercial farms that introduce land-levelling. Transformations from financial to natural capital through an inadequate policy of subsidies causes increased soil erosion through processes such as the abandonment of plots. Transformations from social to financial capital are causing negative effects on land due to the absence of an understanding of the concept of sustainability in the education of farmers. However, the transformation of social to financial capital through the membership of cooperatives and their role in facilitating access to subsidies and education has a reducing effect on soil erosion.

Acknowledgements

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References

Boellstorff, D., Benito, G., 2005. Impacts of set-aside policy on the risk of soil erosion in central Spain. Agriculture, Ecosystems and Environment 107, 231-243.

Hein, L., 2004. Final report on the costs of land degradation and the benefits of mitigating desertification. Medaction Work Package 1.3; Deliverable 14. ECEA,FSD (Wageningen), ICIS (Maastricht University) 35 pp.

Ortiz Silla, R., Albaladejo Montoro, J., Martínez-Mena García, M., Guillén Mondéjar, F., Alvarez Rogel, J. 1999. Mapa de riesgos de erosión hídrica en zonas agrícolas. In: Atlas del medio natural de la región de Murcia. Instituto Tecnológico Geominero de España and Región de Murcia, Consejería de Política Territorial y Obras Públicas.

Stocking M.A., Murnaghan, N., 2001. Handbook for the field assessment of land degradation. Earthscan, London, 169 pp.

Case study 2

Forest fires are not so bad

A case study in Spain

Artemi Cerdà

The traditional rural socio-economic systems, which once characterised the Mediterranean region, have collapsed during the last few decades. As a consequence, rural abandonment spread in parallel with rapid land-use changes implying urbanisation, coastal tourism development and infrastructure construction near the coast and the cities. Most of the rural abandoned land returned to grassland, scrubland and forestland, and this vegetation recovery induced an increase in the flammability, which resulted in the spread of forest fire. Around 1.5% of the Mediterranean rangelands are burnt yearly due to the 50.000 fires that affect 700.000 hectares. Since the 60's the fire-affected land has been quadrupled. This is due to fast changes in land-uses, the socioeconomics conflicts and the natural conditions of the Mediterranean.

Some of the effects of wild-land fires cross borders such as smoke pollution and its impacts on human health and safety, and the loss of biodiversity. The depletion of carbon in the soil due to fires is one of the driving forces of disturbance in global biogeochemical cycles, notably the global carbon cycle. Within them, soil erosion is seen as one of the most dangerous post-fire effects, ultimately leading to desertification.

Soil erosion implies the loss of the upper part of soils, where most organic matter is available. Erosion that is triggered by fire, also enhances the depletion of nutrients and the seed bank. Under Mediterranean climatic conditions fires takes place mainly during summer, when the weather is dry and hot. During the following autumn rainfall reaches its highest values, in volume and especially in intensity. Some examples from Eastern Spain demonstrate how the combination of fire in summer and intense rainfall can result in high erosion rates.

Figure 1. Wildfire at the Calderona Range, August 2004. Eastern Spain. After the fires the old abandoned terraces are found everywhere.

Figure 2. Sediment depostion in bottom valley terraces after a thunderstorm (98 mm 5 hours). Eastern Spain.

Table 1. Daily precipitation for selected intense rainfall events at the Mediterranean.

Location	Month/year	Precipitation (mm)
Xàbia (Alicante)	10/1957	878
Oliva (València)	11/1987	817
Zurgena (Almería)	10/1973	600
Albuñol (Granada)	10/1973	598
Sumacàrcer (València)	11/1987	520

However, Mediterranean ecosystems are adapted to fire, such as the sprouting of trees (Quercus ilex), shrubs (Pistacea lentiscus) and even herbs (Brachypodium retusum) show. Moreover, other species are encouraged to seed germination and growing by fire (Pinus halepensis, Ulex parviflorus, Cistus albidus).

Forest fire implies the removal of vegetation, the disturbance of soil and the increase in surface runoff. Those conditions result in an increase in the erosion rates which sometimes are three orders of magnitude greater than directly before the fire.

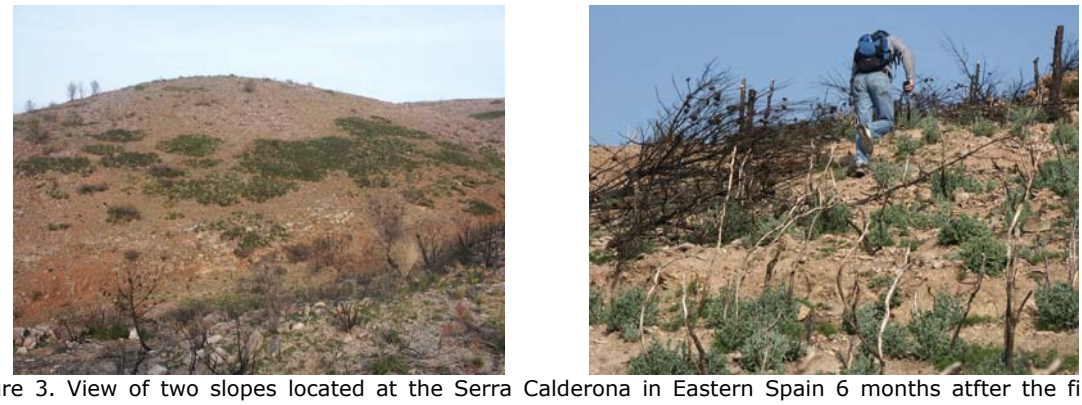

Figure 3. View of two slopes located at the Serra Calderona in Eastern Spain 6 months atfter the fire. The sprouting of Quercus coccifera and Anthyllis Cystisoides recover the soil with a patchy distribution of plants.

Forest fires were found in the geological records of the Mediterranean region along the Quaternary and most of the species of the Mediterranean ecosystems are adapted to fire. Both facts demonstrate that for the Mediterranean ecosystems fire is not a rare phenomenon. However, erosion rates are high after fire due to soil degradation. The main question for the post-fire ecosystem dynamics is: Is the soil recovering after the fire? Or, will a degradation process take place inducing less vegetation after burning, less rainfall infiltration, more runoff and as a consequence more soil loss? More soil loss also means less nutrients and less vegetation, which results in even more erosion. Will such a degradation cycle take place on fire affected land?

Table 2. Soil erosion rates before and after fire measured by means of different methods in Spain.

Author, year	Method	Soil erosion rate (Mg ha-1 y-1)	
		Before fire	After fire
Rubio (1987)	USLE	0-2	17-76
Ubeda & Sala, 1996	Gerlach	0.03	32.5
Soler et alk., 1994	Gerlach	2.7	34.9
Rodríguez et al., 1999	Gerlach	0	2-11
Soto et al,,1994	Plots (4 x 20 m)	1,5	24.8
Gimeno et al,, 2000	Plots (4 x 20 m)	0.05	2.89

Measurements after forest fire are usually taken for some months or years. The data collected under different Mediterranean locations showed a sudden increase in soil loss after the fire, although for some weeks the soil has a protective cover of ash. Few

researches monitored erosion after fire over long periods. The researches that did, demonstrate that soil erosion is reduced after some years to values similar to erosion rates previous to the fire. This leads to the conclusion that fire does not establish a permanent degrading system, and that recovery is faster than expected, ranging from 2 to 10 years. In fact, fire encourages the redistribution of soil on a slope and induces the connectivity between slopes and streams. However, this is only the case during a short period of time.

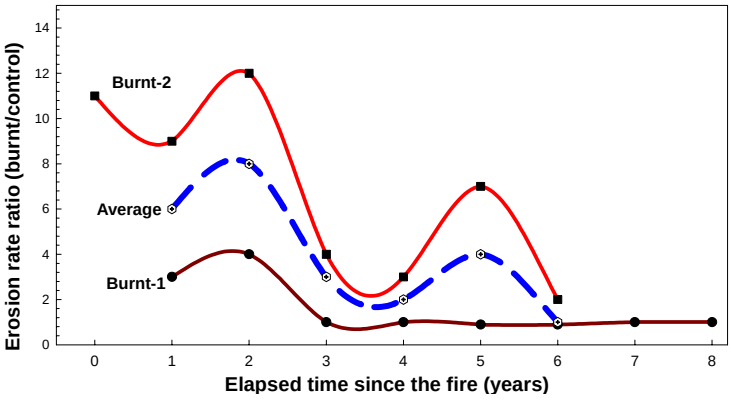

Figure 4. Erosion rate ratio (Burnt/Control) at the Aísa valley soil erosion experimental station, Central Spanish Pyrenees.

These results show that fire is part of the natural Mediterranean ecosystems and that soil is not damaged in the case of a natural forest fire return-period. However the recurrent fires found during the last 40 years in the Mediterranean, due to the fast recovery of pirophytic vegetation, and the land abandonment, induced increased soil erosion caused by both an increased magnitude and frequency of fires. The combination of more forest fires and the increase of very intense rainfall episodes in Spain results in an increase of the risk on soil erosion in forest fire affected areas.

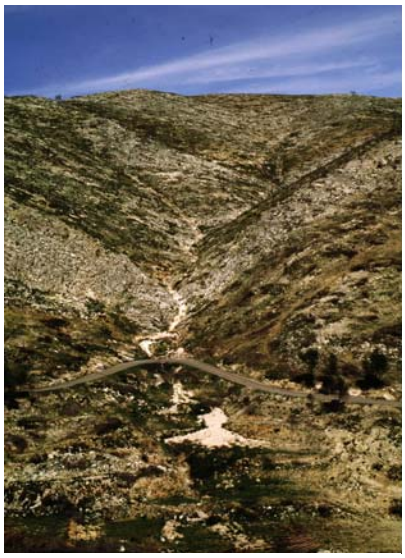

Figure 5. Alluvial fan developed after a summer thunderstorm in September 1993 after the July forest fire.

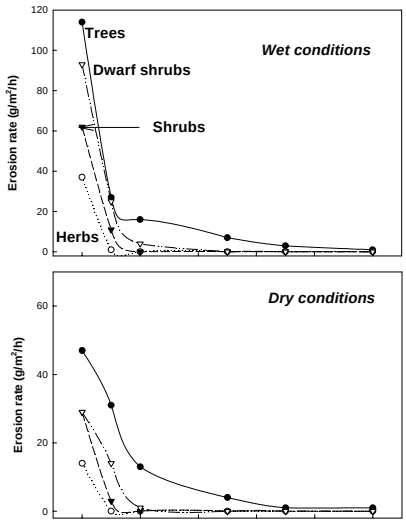

Figure 6. Soil erosion rates changes after forest fire during the recovery of vegetation by different plant types in La Costera district, Eastern Spain.

References

Andreu, V., Imeson, A.C., Rubio, J.L. 2001. Temporal changes in soil aggregates and water erosion after a wildfire in a Mediterranean pine forest. Catena 44, 69-79.

Bautista, S. 1999. Regeneración post-incendio de un pinar (Pinus halepensis, Miller): en ambiente semiárido. Erosión del suelo y medidas de conservación a corto plazo. Ph. Doctoral Thesis, Universidad de Alicante, 238 pp.

Cerdà, A. 1998. Postfire dynamics of erosional processes under mediterranean climatic conditions. Z. Geom. 42, 373-398.

Cerdà, A. and Lasanta, A. 2005. Long-term erosional responses after fire in the Central Spanish Pyrenees: 1. Water and sediment yield. Catena, 60, 59-80

Doerr, S.H., Shakesby, R.A. and Walsh, R.P.D. 2000. Soil water repellency: its causes, characteristics and hydro-geomorphological significance. Earth Science Review, 51, 33-65.

Ferreira, A.J.D., Coelho, C.O.A., Shakesby, R.A. & Walsh, R.P.D. 1997. Sediment and solute yield in forest ecosystems affected by forest fire and rip-ploughing techniques, central Portugal: a plot and catchment analysis approach. *Physics and Chemistry of the Earth*, **22**, 309-314.

Imeson, A.C., Verstraten, J.M., van Mulligen, E.J., Sevink, J. 1992. The Effect of Fire and Water Repellency on Infiltration and Runoff under Mediterranean Type Forest. Catena 19, 345-361.

Case study 3

Dam(n) the river!

a case study on the border river between Portugal and Spain

Michiel Curfs

In the last five years rapid changes in the natural regime of the lower-Guadiana basin occurred. These last years have seen a rapid expansion of citrus plantations, an increase in human population and accompanying construction of urbanizations, and the finalization of the biggest reservoir of Europe, the Alqueva dam. The quality of the water in the Guadiana is deteriorating because of the 'new' inputs that contribute to contamination. During the last years, algae bloom occurred in several reservoirs in the watershed and in the Guadiana river itself. This year at the estuary of the Guadiana, the water and the beach were filled with algae's. The recent agricultural and urbanization developments are mainly invented to lift up the economic status of the area, but now it seems that due to the contamination effects, the main economic pillar already in place, tourism, is threatened.

Some trends in contamination

Pollution has a long history. Pollution has an ability to contaminate the surroundings it passes or the place where it is dumped. Consequently, contamination has a long history. The creation of waste is a typical aspect of human societies. Humans have a tendency to first create waste, then dump it and only in a (often much) later state realize the consequences (Ponting, 1995). Rivers have always played a major role in the human waste stream. Their currents carry away our waste - residential, municipal and industrial - "out of sight, out of mind". Contamination started predominantly locally; for instance near cities or mines. Nowadays however, contamination acts at a much bigger scale; affecting oceans and soils on all continents. It even affects mechanisms that control the natural balance on earth (i.e. Greenhouse gasses, climate change).

In the history of contamination, the industrial revolution brought about an explosive growth in size, intensity and diversity of contaminants. One could say it lead to a 'contamination revolution'. Rivers, oceans and soils were treated as endless pits where waste could be disposed of. The contamination that accompanied the industrialization in the 19th century in Western Europe, the United States and later Eastern Europe and the Soviet Union, had a big impact on the lives of people that were working in the industries. Since World War II many aspects have changed in the process-industry and consequently in the types of contaminants. Contamination grew faster than the population or even the consumption of goods by the population. The accent of the modern industry has changed from more natural and less polluting products to more polluting products such as chemical fertilizers and synthetic goods. For example, the change in production from natural soap to synthetic soap has resulted in a 20-fold increase of Phosphorus-production (Ponting, 1995).

Nowadays the EU considers contamination as one of the eight main threats affecting soils. Contamination is mainly related to two different sources, point source contamination and diffuse source contamination.

The Guadiana area

The lower Guadiana basin forms the natural border between Southern Portugal and Southern Spain. Recently, in 2002, the biggest reservoir of Europe (Alveirinho Dias et al. 2004), the Alqueva dam, has closed its gates. This dam is situated in the Guadiana river, some 200 km from the estuary. The influence of this dam does not only affect the

natural flow of the amount of water flowing through, but furthermore has big influences on the natural sediment regime in the river. The Guadiana river is a river where, when looking to other big rivers in Europe, relatively little industries are situated on its banks or within its drainage area, making it an interesting research object to study particular influences (Ferreira et al., 2003). The main form of industry in the lower basin drainage area is agriculture. Some important pollution sources can be distributed as 35 per cent urban discharges, 39 per cent animal feedlots sector and 18 per cent food production. Many of these discharges do not have any treatment, which causes a large amount of nutrients exportation to the water and soil. On the other hand, agricultural activities and animal production have a great impact in this basin (Gomes & Quadrado, 2001). The land occupation is predominantly rural and part of the water quality problems come from agricultural practices where nitrates, phosphates and phytopharmaceutical products from pesticides abound. Diffuse pollution from agriculture and point source pollution from industries, mining, sewage treatment plants, landfills, and others, are identified as major pollution sources. (http://www.transcatproject.net/engguadiana.htm).

River and ecosystem dynamics

All the streams in a river basin/drainage area are connected, like the branches of a tree to the trunk. Throughout its life, a river and the nearby land change. Natural forces (like wind, water, and gravity) can alter a river's channel, direction, flow rate, and vegetation (www.riverwebmuseums.org). Human intervention can make similar changes, but often on a larger scale and at accelerated speed. The Guadiana can be seen as the 'aorta' of the Guadiana drainage area/river basin. It is the main river, all smaller rivers within its drainage area flow into the Guadiana. The Guadiana will transport everything that comes into its water ultimately out to sea, the Gulf of Cadiz.

Soil has many functions and one of its functions is buffering and filtering. Water that flows through the soil is filtered by the soil, leaving relatively clean water. The contaminants or salts filtered from the water however do not simply disappear. They are bound to the soil and, depending how toxic a contaminant is, it can be transformed or broken down by the soil community in time. The soil community can be explained as the chemical and physical properties of the soil and all the animals in the soil such as bacteria, fungi, insects and worms.

Contaminants can enter the Guadiana in different ways and forms. Contaminants can be dumped directly into the river, but they can also end up in the river after a long journey. How soil is treated and managed within the drainage area is therefore of great influence to the quality of any river.

River & Dam: Sediments
The Alqueva dam influences the natural flow regime of water and sediment. The sediment is trapped at the dam. This results in less sediment in the water downwards of the dam. Sediment in water has a cleansing ability, binding minerals and contaminants. The water quality of the Guadiana river is thus under threat, for its cleansing ability is reduced.

The intensification of mainly citrus agriculture affects the quality of the Guadiana. At citrus plantations, pesticides are used frequently, which amongst others contaminate the soil. The management of citrus plantations in this area is not concerned in taking erosion control measures. The soil is left vulnerable to erosion. The contaminants used at orange plantations can thus quite freely find their way into the Guadiana due to erosion. The eroded soil is transported via little creeks to finally end up in the Guadiana. The contaminated soil of the citrus plantations (point source pollution) affects the entire drainage basin and ultimately, contaminants enter the Guadiana from various sources (diffuse source pollution).

River & Dam: Natural vs. Regulated flow
The dam changes the water flow regime: In wintertime the reservoir is filled, so less fresh water from rainfall flows down the river in comparison to the natural flow regime. In summer time, more fresh water is let through to create energy. These flow fluctuations can severely impact habitat, and thus wildlife, downstream. In the Guadiana case it also changes the natural regime in salt and fresh water balance. With a reduced water flow salt water is able to penetrate longer and further upstream and causes problems for the water quality. Another aspect in relation to the flow of water is called *Thermal Pollution:* Cool reservoir water released from the base of a dam can alter a river's normal water temperature regime downstream and influence which species of wildlife can exist there. Shifts in temperature can also influence the amount of dissolved oxygen in the water - again affecting species composition. Many dead fishes have been observed in the Guadiana and fishermen on the river don't know anymore when to fish what fish. In total, less fresh water flows through the Guadiana as much water is used for irrigation from the reservoirs.

Urbanization & Human Population
On the Spanish side of the Guadiana a big urbanization is being built. This results in sealed soil, which reduces the water infiltration capacity and increases run off. The urbanization will be surrounded by 2 golf courses and the inhabitants need to be secured of water, putting more pressure on the already pressurized fresh water system.
The villages in the lower part of the Guadiana don't have a proper sewage system, and now still in 2005, the sewage of these villages is discharged directly in the Guadiana. Even some bigger cities don't have proper sewage system resulting in the deterioration of the water quality of the Guadiana.

Double edged knife

The increase in agriculture and the expansion of urbanizations are developed to increase the economic status of this rural area. These aspects pressurize the ecosystem through an increase in contamination. The Alqueva dam generates hydro-power but also increases pressure on the quality of the Guadiana river. The last years have seen an increase in negative aspects in relation to contamination of the Guadiana, whereas no actions seem to have been taken to reduce contamination. The contamination that is brought about by these new aspects creates a controversy. The loads stemming from this agricultural activity combined with the summer high temperatures periodically ignite algae blooms. Eutrophication of several man-made lakes is already occurring (PRB 2000). The beaches are filled with algae and the river water deteriorates where also algae blooms have been observed. This affects the main economic pillar, the tourism industry, that is mainly concentrated along the beaches (littoralization) and in which the Guadiana river is an integrated aspect. A link to Scandinavian countries could be made here. In the Baltic Sea toxic blue algae blooms affected human health and the sea's ecosystem. It was discovered that the algae bloom could be related to the input of nitrogen (N) and phosphorus (P) that derived from agricultural processes. Many erosion control measures are now taken in order to reduce this contamination aspect with great success.
The lessons learned in Northern Europe could be used to prevent damage in the Guadiana river. Prevention is always less costly than solving the problems when they go out of hand. Sharing knowledge over boundaries is necessary!

References

J.M. Alveirinho Dias, R Gonzalez, O Ferreira, 2004 .Natural versus Anthropic causes in variations of sand export from river basins: An example from the Guadiana river mouth (Southwestern Iberia) In Polish Geological Institute Special papers, 11, pp 95-102

A.M Ferreira, M. Martins, C. Vale, 2003. Influence of Diffuse sources on levels and distribution of polychlorinated biphenyls (PCB) in the Guadiana river estuary, portugal

F. Gomes, F. Quadrado 2001. Pressures and impacts on water quality, a case study of the Guadiana riverwatershed

Ponting, C., 1995, A green history of earth.

Case study 4

Land for Bread

A case study in Portugal

Maria José Roxo

During decades, particularly during the 1920's and 1930's, vast areas of inland Portugal have gone through major changes in land use, as a result of incentive policies for cereal production, implemented during the dictatorial Government period. This lead to a decisive transformation in the landscape and to accelerated soil erosion. Agriculture mechanization and the use of chemicals, especially from the 1950's onwards, have dramatically increased land degradation and the risk of desertification in large extensions of farmland. Because the Alentejo was the major wheat production region, it was here that greatest landscape transformations have occurred, being nowadays the most affected area. In the light of this degradation scenario, it is urgent to effectively implement measures to halt land degradation and act towards the preservation and conservation of the natural resources and farming ecosystems, thus combating desertification.

Historical and political background of desertification in Alentejo

In Portugal, after the fall of the Republicans on May 28th 1926, a deep and long social and economic crisis took over and lasted up to 1933, during which a military dictatorship set in under the command of Salazar (as Prime Minister and supreme chief of the military forces) that from 1930 onwards, lead the definition of the ideological and political grounds of the regime. On an international scale, World War II had inevitably affected the country, though indirectly but with serious consequences for the population and the economy (mainly lack of food and fuel supplies).

The Wheat Campaign

In this historical and political context the first "Wheat Campaign" was put forward, being considered, in the agriculture sector, as one of the steadiest workmanships resulting from the economic policy of the Government. Soon in the first year of Salazar's administration, 4 million escudos (approximately €20.000) were invested in the promotion of the wheat production. The Campaign was instituted by the Decree nº 17 252, dated August 16th 1929. The objectives were very clear: Directly - promote the increase in wheat production until it meets the national needs, preventing the outflow of important gold reserves; Indirectly - to dignify the agricultural industry as the noblest and most important of all industries, and as the top key factor of economic prosperity of the Nation.

To attain the enunciated objectives, the Ministry of Agriculture trusted special organisms (Central Offices, district commissions, municipal and sub-local bodies) for the following: propaganda, technical assistance (agricultural extension and experimental fields), financial assistance, direct exploration of non cultivated land (division of non cultivated communal land and delivery to farmers), aid in agricultural material and machinery, subsidies for the acquisition of fertilizers and seeds, subsidies and attribution of yield prizes.

The Wheat Campaign had yet two other underlying objectives: (1) to attach the agricultural population to rural land and (2) to reduce unemployment. The first objective aimed at counteracting the attraction exerted by main cities and urban regions, responsible for population migrations and urban demographic growth. Several studies were developed by the so called "Junta de Colonização Interna (JCI)" (Internal

Colonization Office) that led to the planning and settling of small population nuclei (new villages), such as “Vales Mortos” in the southeastern Alentejo.

The goal was to settle people in the wheat agriculture explorations and put forward the cultivation of communal shrub and forest land. The JCI, was "… in charge of the acquisition of drylands, that were put on sale to develop them as farm explorations to be acquired by new settlers …"(Cabral 1974). Also the objective was, to avoid rural-urban migrations and urban unemployment and attach rural population to their land through wheat production.

In reality the Wheat Campaign has resulted in an increase in the national cereal production. Between 1912-1921, annual average production was 218.000 tons whilst between 1930-1939 it was 471.724 tons, as a direct result of improvement in farming practices and methods, namely the use of fertilizers (higher production per unit area), and of the great increase in the overall cultivated area, with some fluctuations along the years. In the period of 1915-20 the total area sown with wheat corresponded to approximately 416.000 hectares; in 1929, 440.000 hectares, and in 1935, 557.000 hectares (Estatísticas Agrícolas).

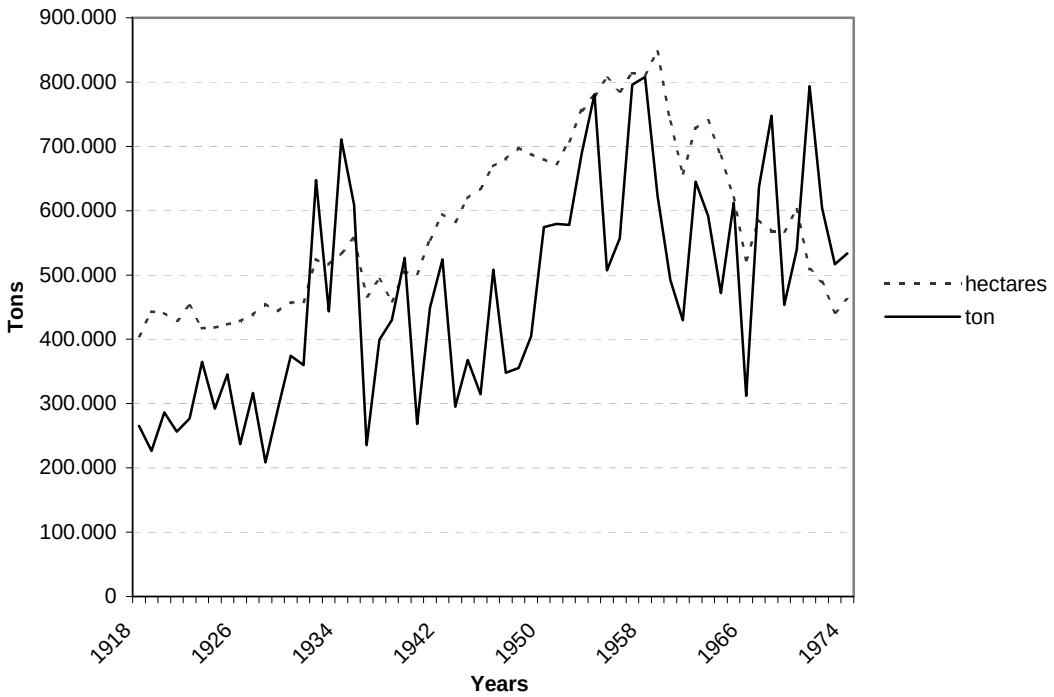

Figure 1. Wheat production in Portugal (sown areas and production yield).

Figure 1 shows some annual fluctuations in the sown areas, which in part can be explained by the way farmers themselves face each agricultural year. Usually, sown areas increases subsequently to bad agricultural years, as it happened, for example, after 1940 (502.000 hectares), 555.000 hectares were sown in 1941. It should also be noted that after 1939, the sown areas increase until reaching a maximum of 847.000 hectares in 1959, diminishing later up to 1974 (25 April), when the revolution allowed a change in the political regime.

In fact, the set of actions and measures that constituted the programmatic base of the Wheat Campaign, during its implementation, had great adhesion by farmers and rural population as a whole. It is very interesting to note that there was an appeal to the

"battle of cereal production", and to the "return back to the land", which was "ruled" by a series of "Commandments". Two of these commandments can be emphasized, such as "1º - Plough your land with good machines. The State puts them at your disposal in conditions for you to be able to evaluate your results' improvement with minimum expense for you"; and "10º - never forget that the wheat of our land is the border that best protects us" (Rosa 1990)

Alentejo – landscape changes and soil erosion

One of the regions of Portugal, that knew greatest transformations in the landscape, was the Alentejo, considered as having a great potential for wheat culture, due to its characteristics of morphology (extensive flat fields, with some residual relief and areas of rolling topography) and climate. However the reality has proved much different. The predominant shallow soils, based on schist and other metamorphic rocks, with very low organic matter content and very weak stability, were easily degraded by water erosion. Data collected at the Vale Formoso Experimental Erosion Center (Southeast Alentejo), (Roxo, 1994) reveal that wheat as a crop was responsible for very high soil losses, as shown by the figures in Table 1;

Table 1 - Soil loss under different land uses – Vale Formoso Erosion Centre – WICHMEIER Experimental plots.

Soil cover/Land use	Soil loss (sediment yield in Kg/ha/year)
Natural vegetation	186
Shrub (*Cistus ladanifer*)	1.700
Cereal / Wheat	4.000
Bare soil / "up and down" ploughing (most common technique)	12.000
Bare soil / contour line ploughing	5.000

Most authors refer that the Wheat Campaign had the following consequences: (a) a substantial increase in the demand for land; (b) the clearing and ploughing of many hectares, even in hilly areas with poor and shallow soils with very low or no agricultural capability at all; (c) unorganized and widespread wheat cropping; (d) reduction in the production of other crops; (e) destruction of large portion of forest and shrub land (especially the "Montado", an open forest formation of *Quercus suber, Quercus rotundifolia* or *Quercus ilex*); (f) reduction of crop rotation and land resting periods; and (g) reduction in cattle breeding.

In conclusion, the so yearned cereal (wheat) self-sufficiency did not happen, because even though there were some years of exceptionally high wheat productions, such as 1931-32, 1933-34, 1934-35), the number of bad agricultural years was greater. The 1940's were one of the most rainy decades all over the Country, considering a series of sixty years of meteorological data, which contributed for the high number of bad production years (excess water), and to an increase in soil degradation by water erosion (Roxo, 1994).

Assessing and combating desertification

As result of the Wheat Campaign, and other agricultural policies, the high desertification level of vast areas of Portugal is a reality and a serious environmental and socio-economic problem. About 36 per cent of the country is classified as having great susceptibility to desertification (Rosário 2004), with Alentejo as one of the most affected regions.

The application in the region of the ESA's (Environmental Sensitive Areas) methodology, developed in aftermath of the project MEDALUS – Mediterranean Desertification and

Land Use (Kosmas, 1999), demonstrated that about 64 per cent of Alentejo is considered to be in an advanced state of land degradation and desertification.

In the light of this situation, it is urgent to implement measures and actions to combat desertification. The political decision makers should be responsible to develop sets of measures in an integrated way, with the active participation and involvement of all stakeholders. Given this urgent need, five pilot areas were established in Portugal, for the field implementation of the Portuguese National Action Plan of Combating Desertification and Mitigate the Effects of Drought under the supervision of the Portuguese National Focal Point of UNCCD – United Nations Convention to Combat Desertification (http://www.unccd.int).

References

Cabral, M. V. 1974. Materiais para a questão agrária em Portugal, séculos XIX e XX. Porto, INOVA, 572 p.

Kosmas, C., Kirkby, M Geesson, N. 1999 .The MEDALUS Project, Mediterranean Desertification and Land Use.,Manual of Key Indicators on Desertification and Mapping Environmentally Sensitive Areas to Desertification", D.G. Project Report, EUR 18882, 87 p.

Mira Galvão, J.M. 1949. O Seareiro-Sua Função Económica e Social na Cultura do Trigo e a Crise Agrícola, in Folhas de Divulgação Agrícola, Série VI, Nº 3, folha Nº 44, Beja, Min.Economia, DGS Agrícolas, Brigada Técnica da XIV Região Agrícola.

Rosário,L. 2004. Indicadores de Desertificação para Portugal Continental, DGF; MADRP, Lisboa,48p

Rosas, F. J. 1990. Portugal entre a Paz e a Guerra - Estudo do Impacto da II Guerra Mundial na Economia e na Sociedade Portuguesa (1939-45), Dissertação de Doutouramento, Lisboa, FCSH - UNL, 805 p.

Roxo,M.J. 1994 «A Acção Antrópica no Processo de Degradação de Solos — A Serra de Serpa e Mértola», Dissertação de Douroramento, Lisboa,FSCH,1994

Case study 5

Building a cross-border soil information system in an Alpine region

a case study in Italy and Slovenia

Sara Zanolla, Borut Vrščaj and Stefano Barbieri

In order to provide information about the main characteristics of alpine soils and the major threats that affect them (decline of organic matter and soil erosion), the Italian Ministry of Environment promoted the project ECALP: Eco-pedological Map for the Alpine Territory. The objective was to develop a common exchange format to be tested in some pilot areas. This new way of representing the main characteristics of soils to a non-specialised public has been tested in a cross-border pilot area between Italy and Slovenia.

Soil information in Slovenia and Italy.

In the late 1980's the activities to set up the digital soil map of Slovenia had started at the Centre for Soil and Environmental Science (CSES). The soil mapping continued with several interruptions until the end of January 1999, when all the territory of Slovenia was included in a digital soil map at a scale of 1:25.000 (DSM25). In the mid-nineties the Soil Information System of Slovenia (SIS) was designed to unite the majority of available Slovenian geo-referenced soil data. The basic goal of the SIS is to bring together geographically defined soil data into a user-friendly system. At present, the SIS is used mostly at CSES and at the Agricultural Institute of Slovenia, where it is further developed.

In Italy, soil surveys are generally carried out at local level. The recent transfer of activities of some state authorities, such as the land planning authority, from the state level to the regional level will sustain this situation. Nevertheless, a great effort has been taken to produce harmonised soil related information at national level. In 1998, the former Regional Agency for Development and Promotion in Agriculture, whose current name is the Regional Agency for Rural Development (ERSA), started developing a soil map and accompanying database of the Friuli Venezia Giulia region (the autonomous region around Venice, which has a surface of 7855 km^2) at the scale of 1:100.000. At this moment, about one fifth of the study area has been printed (Michelutti et al, 2003) and another two fifths are in progress. Although the project should cover the whole region, its realisation is much more advanced in the alluvial plain due to the lack of agricultural activities in mountainous areas.

The pilot area between Italy and Slovenia.

A cross border pilot area (figure 1 a rectangle of 400 square kilometres (40.000 hectares), has been chosen. This is according to the technical specifications of the ECALP project. Its borders correspond to the 1km grid defined by the Joint Research Centre of the European Commission. It is located in the transitional area between the mountainous Julian Pre-Alps and the alluvial plain. The area is strongly affected by a Mediterranean climate. The dominating land use is agriculture (mainly vineyards) and natural broadleaves forests. The mean altitude is about 300 m, with a minimum value of about 30 m in the valleys facing the alluvial plain and a maximum around 900 m. Slopes vary widely from flat to more than 60% inclination. The mean annual temperature is around 12-13°C in the alluvial plain and in the southern hills, and 9-10°C in the northern part of the area. Total annual rainfall is about 1400 mm in the alluvial plain and is more than 2000 mm in the northeastern sector.

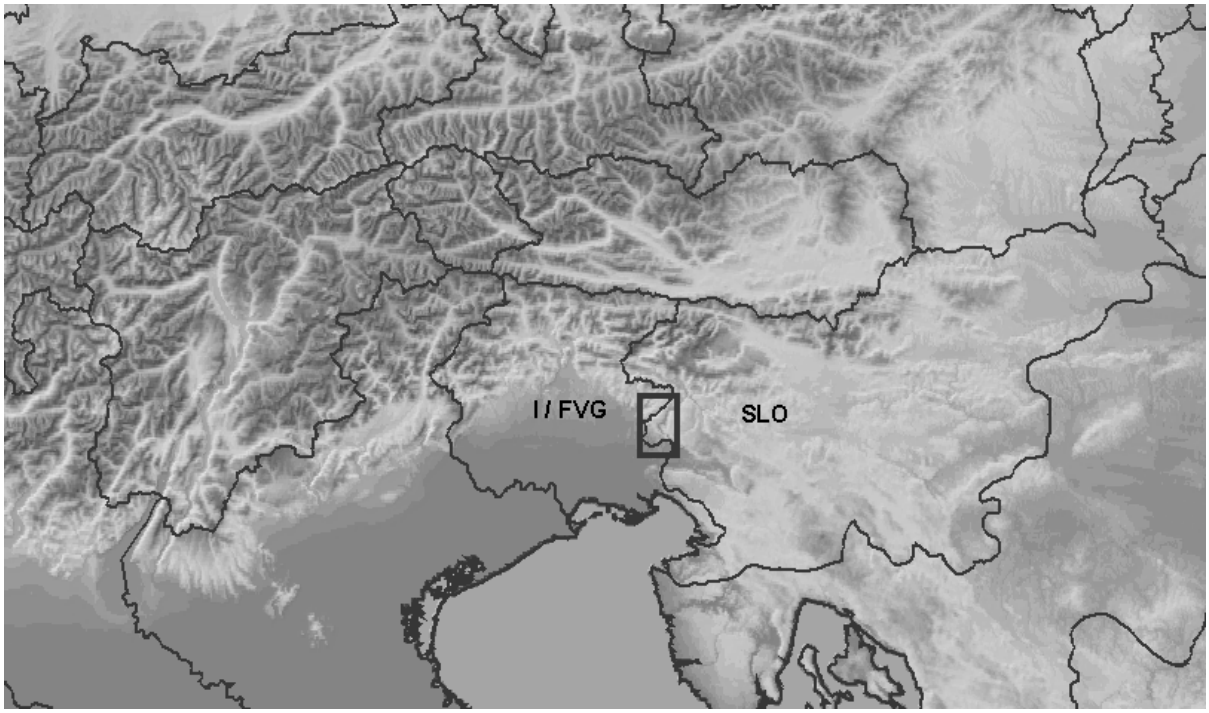

Figure 1. The cross-border pilot area between Slovenia and Italy

Another element taken into consideration for choosing the study area is the use of soil maps with different scales. The largest map scale available in the Italian part of the pilot area is 1:250.000, while the majority of the area is covered by 1:50.000 maps and a small sector, comprised in a wine production area, by even more detailed maps. The whole Slovenian territory is covered in the scale 1:25.000 (DSM25).

To construct a cross-border soil information system that include ancillary data, a thorough data collection and harmonisation process was needed. During this process the following procedures were carried out:

- Defining the pilot area in a Lambert Azimuthal Equal Area projection system;
- Exchange of the national projection definition files;
- Choice of a minimum common set of ancillary data layers (such as Digital Elevation Models (DEM), land use maps, forest cover maps, annual rainfall, …)
- Converting the data available for the pilot area to national projection systems;
- Definition of common legends;
- Joint field work; discussions about the soil/landscape relationships (figure 2)
- Creating vector databases with available soil maps and ancillary datasets;
- Exchange and revision of the preliminary maps;
- Reviewing and matching common borders;
- Common review of the attribute tables;
- Rasterising data at different resolutions;
- Elaborating the final map, database and report.

Figure 2. Joint Italian/Slovenian soil descriptions in the field

Soil data to assess soil threats

The constructed cross-border soil information system allows assessing the decline of organic matter as well as the amount of soil loss due to soil erosion in the pilot area. To do that we determined a baseline level of organic carbon in the pilot area and we calculated the amount of soil loss using the qualitative model of CORINE Erosion (EEA, 1995).

The organic carbon pool for Italy has been retrieved from the ERSA soil database, which is obtained by analysing samples of soil profiles. Since an Italian method was originally used to measure organic carbon content in volume, the data had to be converted according to ISO-approved values (organic carbon content in weight). This has been done using a regression function. In order to obtain organic carbon content for different depths in the required unit (ton/ha), a further conversion using rock fragments volume and soil bulk density was needed. Data about rock fragments were available in the ERSA soil database, while bulk densities have been estimated for each horizon by using a pedotransfer function (Rawls, 1983). Finally, the organic carbon content (ton/ha) for different depths (humus layer, 30cm, and 100cm) has been calculated for every Soil Typological Unit (STU = a unit with similar soil type in the field). The organic carbon content in each pixel in the soil map has been calculated by calculating a weighted average of all the STUs in the pixel.

The parameters required to calculate soil loss with the qualitative CORINE Soil erosion risk model are soil erodibility, climate erosivity, land cover and slope gradient. Soil erodibility has been calculated for each STU by using:

- clay and sand values of the surface horizon that have been converted into CORINE EROSION classes
- soil depth to bedrock or to a horizon with more than 70% of gravel
- the rock fragment content of the surface horizons.

Climate erosivity has been calculated for every pixel by intersecting the Fournier index and the Bagnouls-Gaussen Index. Land cover has been attributed to each STU in each pixel, distinguishing arable soils and soils that are covered by a permanent vegetation. The slope gradient has been derived from a DEM with a resolution of 40 $\times$ 40 m. The final value obtained is a class of erosion (values ranging from 0 to 3). This value is called ASER (Actual Soil Erosion Risk) in the database. For a rough conversion from this value to soil loss in ton/ha values again a regression function has been used.

Final remarks

An important outcome of the common fieldwork was to understand how project partners describe soil profiles. This mutual understanding was essential during the quality check and harmonization of the database in later phases of the project. Another important result of the ECALP project is knowledge about soil data generalisation. Map resolutions to be used were many times a topic for discussion. Generalising soil information from a detailed scale (1:25.000) to a regional scale (1:250.000) should be done very carefully. The results should be checked thoroughly based on expert knowledge. The main encountered difficulties were related to the technical aspects of selected software packages.

The pixel structure used in the cross-border soil information system does not result in the loss of information. The only loss of the information is determined by the resolution of the pixels. Especially in Alpine environment the coarse pixel size sometimes covers two ridges and a narrow valley, comprehending very different types of soils. Evaluating the results of a semi-automatic generalization of maps was very demanding.

The 1 × 1 km resolution used in the cross-border soil information system does not necessarily reduce the soil information if used at a 1:250.000 scale. It has, however, to be stressed that the data should be interpreted carefully when using them at detailed scales (e.g., 1:25.000).

Both vector and raster formats are needed in soil information systems. The vector format is the main form of the basic soil information, which are soil maps and points where soil profile are sampled. The raster information is more important in the further processing of soil and landscape related data. Merely all additional information on environmental properties are in a raster format. Additionally, the raster format enables a fast and efficient processing of multiple data layers and can deal with large data quantities. At this moment, and probably also in the near future, processing raster data is the only feasible way for deriving specific and targeted thematic datasets on soil and landscape properties.

References

EEA, 1995. CORINE Soil erosion risk and important land resources in the southern regions of European Community. Office for Publications of the European Communities, Luxembourg, 124 p.

Michelutti G., Zanolla S., Barbieri S., 2003. Suoli e paesaggi del Friuli Venezia Giulia - 1. Pianura e colline del pordenonese. ERSA, Servizio della sperimentazione agraria, (in Italian).

Rawls W.J., 1983. Estimating soil bulk density from particle size analysis and organic matter content. Soil Science, 135:2, 123-125.

Case study 6

Sustainable management of protection forest
A case study in Austria

Sanneke van Asselen and Bernhard Maier

The main function of protection forests, or 'Schutzwald', is to give protection against natural hazards such as rock falls, landslides, floods and avalanches. Other beneficial effects provided by such forests are for instance social, recreational and economical functions. According to the definition of the Austrian Forest Act (Anonymous, 2002) site protection forests include 'all forests stocking on soils which, unless covered by forests, would be eroded by wind, water and weathering, and which need a special treatment for protection of soil and vegetation'. On extreme sites, protection forests thus protect themselves in order to be sustainable. They protect their sites and the soils on which they stock. In mountainous areas it is thus of great importance that protection forests are managed properly. This case study shows an example of sustainable mountain forestry aiming at permanent stocking in order to protect soils.

The Montafon is a mountainous region located in the south of Vorarlberg, which is the westernmost province of Austria (figure 1). During the Middle Ages, daily life in the Montafon was legally regulated through the so-called 'Montafoner Landsbrauch' (regional law of Montafon), encompassing all aspects of life. In those days, there were 24 of such regional representative bodies and court districts in the province of Vorarlberg. This type of constitution was abolished during the period of Bavarian occupation in 1806. After the reunification with Austria, the ten communities of the Montafon again elected representatives to regulate common affairs, such as forestry, infrastructure and fire control. Today, there are only two of such regional representative bodies in Vorarlberg; 'Stand Montafon' and 'Stand Bregenzerwald'. Stand Montafon encompasses ten municipalities in the Montafon and has some important tasks regarding regional development, traffic, social issues, environment, culture, education and economics. The forestry administration (Stand Montafon Forstfonds), which is part of the Stand Montafon, has the important task of maintaining the multiple functions of the protection forests in the Montafon.

Figure 1. Location of the Montafon region.

In 1832 the villages of the Montafon, except Stallehr and Lorüns, bought all the forest of the Montafon valley from the monarchy. This meant that the delegation of all rights and duties, as well as of administrational work, went to the Stand Montafon. Nowadays, the main objectives of Stand Montafon Forstfonds are management of mountain forests to maintain and enhance the protective function, and to comply with the rights of utilization (including timber utilization rights). The Stand Montafon Forstfonds administers and manages about 70% of the forested area (8400 hectares) in the Montafon valley.

The forests of the Stand Montafon are found to a large extent in mainly steep terrain at 1200m a.s.l. and higher. In order to ensure the ability of the forests to fulfil the expected functions, they have to be managed in a multifunctional sustainable way. This type of management relies on detailed information about the state of the forest over long term periods. For this purpose various economical and ecological stand parameters are usually collected by means of terrestrial forest inventories on a repetitive basis. The Stand Montafon is specialized in mountain forest silviculture. As timber harvesting can reduce soil productivity by altering soil mineral particles, gasses, water, organic matter, soil organisms, and nutrients; the best way to prevent reductions in productivity is to

adopt forest management practices that minimize soil disturbance. At the Stand Montafon harvesting is carried out by means of cable cranes, in order to protect forest soil and remaining trees. Very often management decisions have to address different aspects of various forests functions and have to be underpinned by up to date and site related silvicultural concepts, which can be demonstrated in the case study area of "Außerbacherwald".

The 'Außerbacherwald' covers about 50 ha of forest on a south-southwest-facing slope near the village of Gaschurn which is located in the inner Montafon valley. It stretches from the valley floor (930m) up to 1500m a.s.l. and grows on a uniformly shaped talus slope with an average inclination of 36 degrees. Because of its proximity to the Außerbach hamlet this forest has always been an important resource for local inhabitants in terms of wood production, grazing livestock and above all protection of Außerbach hamlet against rockfall and avalanches. Rockfall originates from a partly overhanging rock face that is up to 100m high on the upper part of the slope. Therefore, the main protective function of the Außerbacherwald is against rockfall and secondly, to prevent the release of avalanches along open gullies.

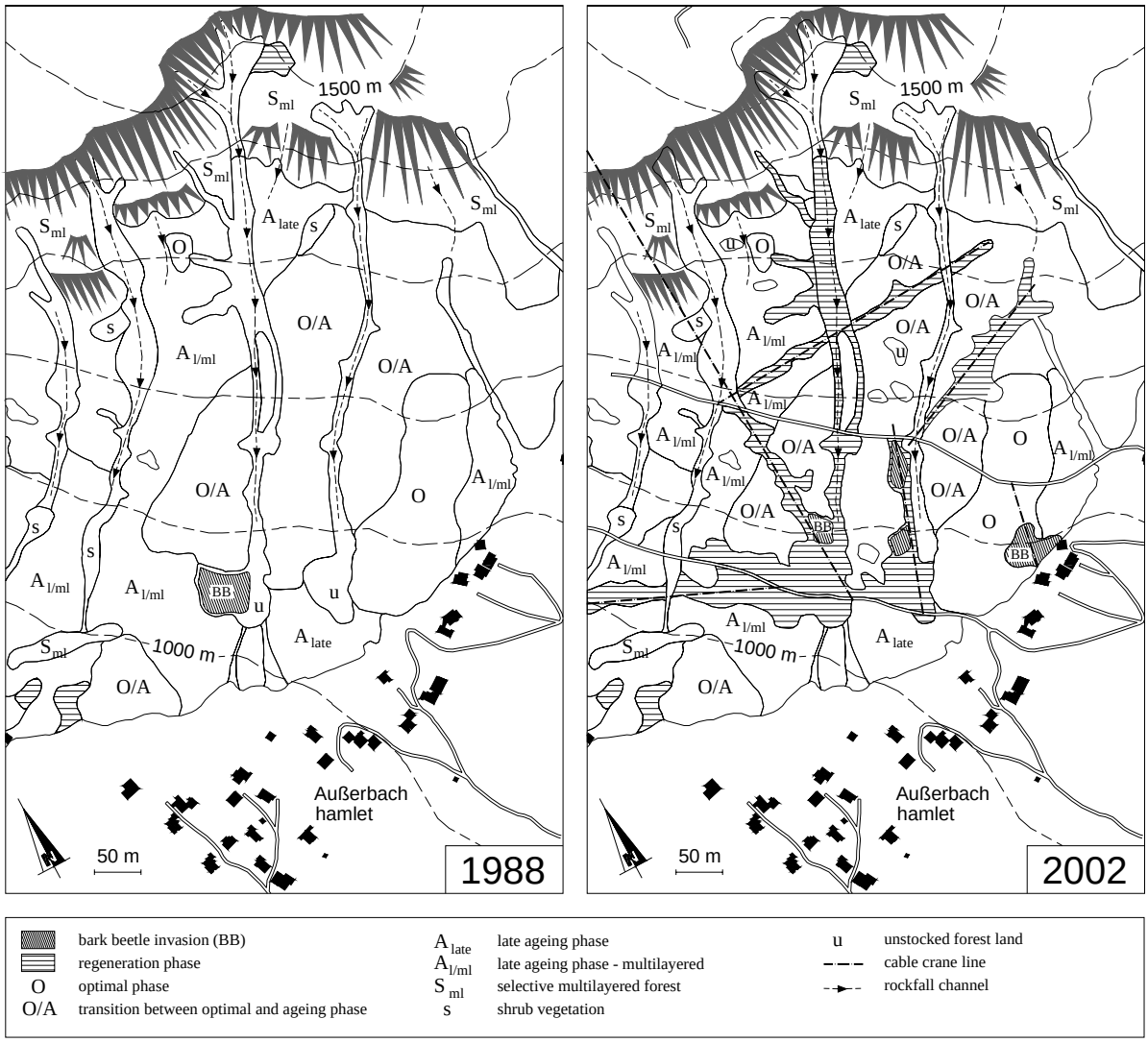

Figure 2. Distribution of developmental phases, natural processes and silvicultural measures.

In 1988 the forest situation was particularly alarming for the residents of the Außerbach hamlet: most of the trees had been damaged by rockfall, the forest did not show substantial regeneration and showed high proneness to windthrow, which had already caused gaps in the lower parts of the forest. The historic high sheep population can be

seen as the main reason for the lack of regeneration. Because of the high proportion of spruce and the sun-exposed location, the windthrow gaps had been widened by a subsequent bark-beetle invasion. It seemed that the natural ecological processes could not sustain the forest structure necessary to safeguard the protective function of the forest. Ecosystem integrity was no longer guaranteed. Because the residents and the local authorities feared that the forest could not protect them in the future a rehabilitation project was initiated.

Based on a stand development assessment, using variables such as density of trees, diameter distribution and gap size, the following silvicultural measures were defined:

- Reduction of ungulate population
- Construction of forest road access
- Construction of avalanche barriers and rockfall nets in the major gullies
- Small scale fellings with oblique on-site deposition of trees
- Narrow irregular stripe fellings by means of cable cranes in oblique arrangement to the slope direction
- Reafforestation on unstocked forest land and coppicing hazel to improve growth

A forest is a dynamic system, so it is not possible to keep a forest in a certain desired condition over a long time. Thus, the aim is to develop a mosaic of stand patches at different developmental stages. In order to achieve such a mosaic, the particularly homogeneous O and O/A phases (see figure 2) had to be split up into smaller patches. By means of irregular stripe fellings, as shown in figure 2, regeneration phases were initiated. This process has to be carried out over a whole developmental cycle of a stand in order to obtain phase-shifted mosaic structures. Once regeneration has reached a secure stage, further cable crane lines will continue the mosaic-creation process.

The silvicultural strategy needed to address both the protective function recommendations as well as economic and technical requirements. Cable crane systems are suitable for selective logging in steep terrain. Cable crane logging minimizes the damage to the soil and the residual stand. If one can rely on an existing forest road infrastructure, mobile cable crane systems can be set up quickly and thus are economical beneficial, even when only relatively few trees need to be felled. Only helicopter logging would offer greater flexibility but is in most cases too expensive.

In sparsely stocked stands in ageing phases (A_{late}, $A_{l/ml}$) cable crane logging is clearly inappropriate as individual trees often need to be retained, since otherwise excessively large gaps might result. This is why in such cases only relatively few trees were felled in carefully selected positions in order to initiate regeneration. The cut stems were left on site and deposited in an oblique way in order to slow down and channel rockfall. Horizontally deposited stems accumulated rocks behind them, which could result in a rock avalanche after the stems have decayed.

Generally, safeguarding the protective function of forests requires stable permanent stocking, which can only be guaranteed by 'close to nature' forest silviculture. In the long run, tending and regeneration of protection forests is the "most inexpensive" way of safeguarding their protective function and the protection of the soil layer. The measures taken in the "Außerbacherwald" helped to regenerate the forest and thus guarantee future permanent forest cover. Harvesting by means of cable cranes ensured that the soil layer remains an undisturbed and intact component of the forest ecosystem.

References

Stand Montafon website: http://www.stand-montafon.at/stand-montafon (in German).

Anonymous (2002): Forstgesetz-Novelle. BGBl. I Nr.59/2002. - Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Vienna, Austria, in German.

Case study 7

Dealing with soil sealing

a case study in Germany

Marion Gunreben

The incidence of soil sealing represents one of the main inroads to which soils are subjected at the present time, especially in industrialized countries. Soil sealing is extremely detrimental to the ability of the soil to exercise its natural function as substrate and regulatory medium. As built-up areas consume an ever-growing proportion of the land available, the consequential sealing of the soil surface is one of the main impacts soils are subjected to. To halt this process the soil quality concept of Lower Saxony, a state in the northern part of Germany, suggests a way of devising compacted structures in schemes for built-up areas.

The steady increase in the standard of living since the end of World War II has resulted that ever more space has been devoted to settlements and transport, especially in industrialized countries, such as the Netherlands, Germany or Italy. The specific causes range from higher individual expectations – i.e. more living space per person, including a larger number of people having more than one domicile – to a larger proportion of singles' households, an increase in communal amenities and an improved infrastructure. E.g. between 1989 and 2001 the proportion of areas devoted to settlement and transport in Lower Saxony in the northern part of Germany increased from 10.6% to 11.8%. That is to say, in just 12 years more than 1% of the total area of the state was subjected to a new form of usage completely different from its previous usage. To get an impression of the dimensions of this trend, this is equivalent to more than 15 ha or about 20 football fields every day.

In this respect Lower Saxony is no exception to the general rule: Throughout the whole of Germany the proportion of such areas increased from 1985 to 1993 by 0.9 %. A particularly dramatic increase from 7.1 % to 12.7 % can be observed for the 'old' federal states, i.e. for the former West Germany, between 1950 and 1992. Here the increase in the total area for settlement and transport amounts to 80% in 40 years. More than 120 hectares are newly exploited for settlement and transport throughout Germany every day, mainly at the expense of agricultural land. This is the equivalent of 166 football fields or living space for 30,000 people. The amount of space used per person is expected to increase from the levels of 38.5 m² in 1990, of 40.9 m² in 2000 to 43.1 m² in 2010.

The total area used for settlement and transport is not simply equivalent to the area of sealed surfaces. Apart from buildings, pavements and tarred roads etc. it includes many types of areas that are not sealed such as gardens, parks, verges and embankments. Thus the usage type 'settlement and transport' is a generic term for usage which includes a high sealing potential and can be thought of as representing the gross degree of sealing. The net degree of sealing, i.e. the area that is actually impermeable to precipitation, can at present only be estimated for Lower Saxony as a whole, because precise data is lacking.

Soil sealing has serious consequences for the ecosystem soil. These consequences are only partly reversible or not reversible at all. Completely sealed surfaces loose their capacity to support plant life and other organisms as well as their function as groundwater filterer and supplier. Because of the close links between soils and other components of the ecological system such as plants, animals, water and the atmosphere, an impairment such as soil sealing affects these aspects as well (figure 1).

Soil sealing usually leads to a total loss of natural soil functions. Many organisms such as fungi and bacteria are dependant on soils as their living milieu. They become isolated from life-giving necessities and die off; and even after the cause has been removed, such populations regenerate only very gradually. The temperature, water household and the structure of the soil change. No exchange can take place between the air in the soil and the atmosphere. Sealed soils play no further role as filters, buffers and transformers for seepage water treatment. Thus the reduction in filter capacity has a direct effect on the groundwater quality.

In respect to flora and fauna, soil sealing means a loss of vegetation and biotopes. Previously connected vegetation areas are separated from one another; the species spectrum changes.

Sealing also has critical effects on water resources. The regeneration rate for groundwater is reduced, whilst the surface runoff of precipitation is accelerated, which leads to attendant problems such as flooding. The loss of filter capacity in the sealed soil increases the threat of higher contaminant input into neighbouring soils or waterways.
The consequences for the microclimate are significant. The temperature above sealed surfaces tends to be higher, because there is less evaporation and artificial surfaces absorb more heat than ones with natural vegetation. The relative humidity is reduced, resulting in poorer air quality: Atmospheric contaminants are less readily extracted because there is less water vapour in the atmosphere and less oxygen can be made available by plants. This can lead to bioclimatic stress situations.

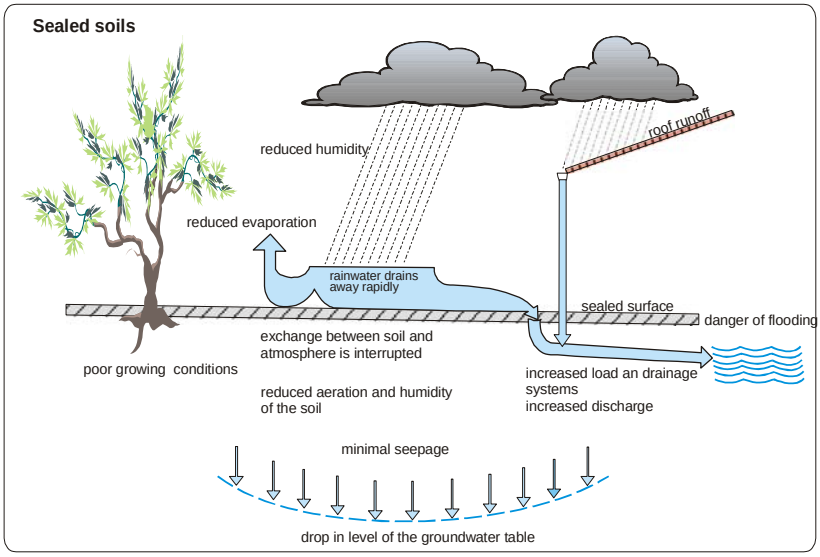

Figure 1. The effect of soil sealing on the environment

In view of the fact that the soil regeneration rate in temperate eco-regions is usually considerably less than one millimetre per year it is essential to reduce the loss of soils, including loss through sealing. Measures to restore sealed soils to their original state by removing the cause of sealing enable a partial recovery, but in view of the extremely slow geological processes involved in soil formation, complete regeneration on a human time scale is not possible.

In a pilot study using detailed cadastral data for selected areas, the Lower Saxony State Agency for Ecology has generated figures on net soil sealing at municipal level for the whole State. According to these results the overall figure for net soil sealing throughout the state is 4.8% in the year 2004. A comparison of the data from 1989 with these from 2001 shows a significant increase in the degree of soil sealing. An average of 5.3 ha was added to the total sealed area daily. This is equivalent to the area of 7 football fields every day.

A concept for soil quality targets has been worked out in Lower Saxony for those parts of soil protection that are not settled by law. These recommendations are directed towards public offices at all levels (e.g. regional and municipal authorities) as well as institutions and organisations which are involved in the assessment and treatment of soil protection issues in planning processes. In a first part of the concept for soil quality targets covering immaterial impairments through soil sealing have already been published.

The following quality targets have been formulated for Lower Saxony: "In the short to mid term demand for space for settlement and infrastructure should be reduced. To this end intra-municipal densification should have priority over expansive development. In the long term the total amount of newly sealed soils should be less than the combined total of de-sealed soils together with areas returned to usefulness through plot recycling, i.e. usage of disused sites."

When a property developer wishes to begin a construction project, a building plan is drafted which contains specifications for the plots involved according to the relevant planning regulations. One of the parameters which is of great relevance for preventing unnecessary soil sealing at the planning level is the measure of building coverage. This can be determined individually for different parts of the area under development or for individual plots. The main components of the measure of building coverage are the so-called site occupancy or coverage ratio and the floor space ratio. The coverage ratio represents the permitted proportion of buildings footprint area to the total area of the plot. The floor space ratio represents the total floor area combining the areas of all the storeys divided by the total plot area.

In Germany legal limits for the measure of building coverage are set by the buildings usage regulations. This 'laisser-faire' attitude regarding the maximum limits and their exploitation is common in Lower Saxony as well as all over Germany, presumably in order to allow more room to manoeuvre in respect of building developments. On the contrary, new development planning generally reflects a very well marked under-utilisation of building coverage limits. This can be seen in the low values for vertical and horizontal building density, resulting in a high consumption of land area.

From the point of view of soil protection, the floor space ratio is of particular significance. An increase in the floor space ratio usually entails a reduction in the amount of space used for the building footprint, i.e. the amount of sealed surface. Thus both gross and net sealing are reduced. In this way soil protection targets can be directly supported by encouraging greater utilisation of the limits allowed by the building usage regulations.
In view of these aspects the Soil Quality Concept recommends the following quality standards: As well as prescribing upper limits, a minimum limit for all types of building development should be set. The lower limits should be 50% of the upper limits. Consequently, the following quality standards for minimum building density result for the various development types given in table 1.

Table 1. Recommended quality standards for minimum building densities.

Type of development	Coverage ratio	Floor space ratio
small development	0.1	0.2
entirely residential area or holiday house development	0.2	0.6
special residential area	0.3	0.8
rural village area or mixed area	0.3	0.6
city centre	0.5	1.5
trading estate, industrial estate or other special area	0.4	1.2
weekend house development	0.1	0.1

In Lower Saxony, in one year nearly 2000 ha previously unused for buildings were devoted to residential developments. The average building plot size was 890 m^2. If these developments had been carried out with an utilisation of 50% of the coverage ratio maximum (for residential areas this would be a density of 0.6), 638 ha less would have been needed, i.e. about one third of the area actually used. Even so, the average building plot size would have still been 593 m^2.

For trading and industrial estates the savings would have been even greater. Had the permitted maximum value for the coverage ratio been utilised to only 50%, a total of three-quarters of the land actually used would have been saved and this area would still be available for its previous purpose!

In addition to implementing a higher building density, soil sealing on building plots should be reduced to a minimum by maintaining as much unsealed surface as possible, preferably with appropriate vegetation.

The trend to ever more developments on the edges of urban areas can only be stopped by means of thorough quality improvement measures in respect of the existing infrastructure within towns and cities themselves. In the future, inner city developments will need to fulfil higher quality standards in respect of location criteria and the urban environment so as to remain competitive with the peripheral developments. However, the greatest potential for checking land consumption is to be found in areas of commercial and industrial development. This involves both the building density as well as so-called plot recycling, i.e. usage of disused sites. Achieving this is a major challenge for the future which will require creative concepts involving many different aspects of the state administration.

References

Dahlmann, I., Gunreben, M., Tharsen, J., 2003: Bodenversiegelung. Nachhaltiges Niedersachsen 23, pp. 30-41 (in German).

Case study 8

Soil erosion leads to soil conservation

a case study in the Netherlands

Luuk Dorren and Anton Imeson

South-Limburg is the southernmost part of the Netherlands. In this hilly area, soil erosion and surface runoff caused huge damages and problems, especially during the late seventies and early eighties. Agriculture in prehistoric times already provoked erosion which led to the construction of hedgerows. These consequently evolved to terraces that mitigated the effects of erosion. Modern farming, land consolidation and reallocation disintegrated the built up structures in the landscape and its soils, which led to increased erosion. As a result, society demands for erosion preventive measures and landscape conservation.

The landscape of South-Limburg could be described as a number of plateaus, which are intersected by river valleys. Many of these valleys today are dry-valleys, which are the remnants of a colder and moister glacial past. The main driving forces that have changed the functioning of the landscape in South-Limburg during the last 15000 years may be generalised as a) the deposition of loess and b) human colonisation and use of the land. The gradual deposition and accumulation of loess profoundly influenced the hydrology. The loess layer in South-Limburg is mostly 2 metres but sometimes even 20 metres thick. This layer behaves as a giant sponge that can retain as much as 40 to 60 cm of water for every metre of depth. Although its water retention makes it ideal for agriculture in a humid region, when it was deposited it buried and fossilised the drainage system. Groundwater recharge would have dropped, springs would dry up, dry valleys would have formed and a new land surface created. In terms of the evolution of the landscape and its functioning, South-Limburg would gain a highly fertile loess soil but this was at the cost of losing the drainage system.

Human beings settling in South Limburg enjoyed the benefits of the fertile and water retaining loess soil from Neolithic onwards (Renes, 1988). Agriculture in Neolithic and later Roman periods has been shown by many paleo-ecological investigations to have had some impact on erosion (Van den broek, 1958, Janssen, 1960; Mücher, 1986). Sunken lanes were formed and soil accumulated as colluvium in valley bottoms. It is likely that some actions at that time were deliberately targeted at soil protection, such as the construction of hedgerows to accumulate sediment behind them. This provoked the formation of terraces, locally called graften (Renes, 1988). These graften can be seen as self-enforcing systems. If erosion occurs, water and sediments are trapped in the vegetated hedges that grow on the edges of the terraces, which promotes vegetation growth and subsequent improvement of the infiltration capacity due to the slowly improving soil structure. Good maintenance of such terrace systems combined with the natural evolution of the vegetation cover and the soil structure, led to relatively stable resilient landscape systems.

Modern farming, land consolidation and reallocation starting in the late sixties and early seventies meant that small-scale plots, which still existed in the fifties and sixties, slowly merged into large agricultural fields. As a consequence, small hedges, trees and shrubs growing on the edges of the *graften* disappeared. Land use changed from a diverse mixed agricultural/natural area to mainly maize, wheat and sugar beet (De Roo et al., 1995). The combination of these agricultural practices and heavy rainfall events resulted in huge erosion problems in the eighties (Schouten et al. 1985, Kwaad, 1991), which is summarised in figure 1. Tons of fertile soil were removed from the agricultural fields and were deposited in lower parts of the landscape. These so called off-site effects of soil

erosion were even more damaging. Sewage systems in the villages were clogged, which resulted in large mudflows on the streets. These led to considerable damage to infrastructure, as many of the villages in South-Limburg have been build in the bottom parts of the dry-valleys, which is of course exactly were all the water accumulates in case of extreme events. These are good examples of the inconvenience the society had from erosion, which is also shown in figure 1. The inconvenience shown is measured from reported erosion events (Dienst Landelijk Gebied Limburg, 2003 personal communication) and interviews with farmers and residents. Here it is interesting to mention that we investigated the soil aggregate stability at different sites in an agricultural catchment in South-Limburg in 1984 and in 2003. We found no significant difference, which means that the soil structure did not change significantly, the landscape structure and the vegetation cover did.

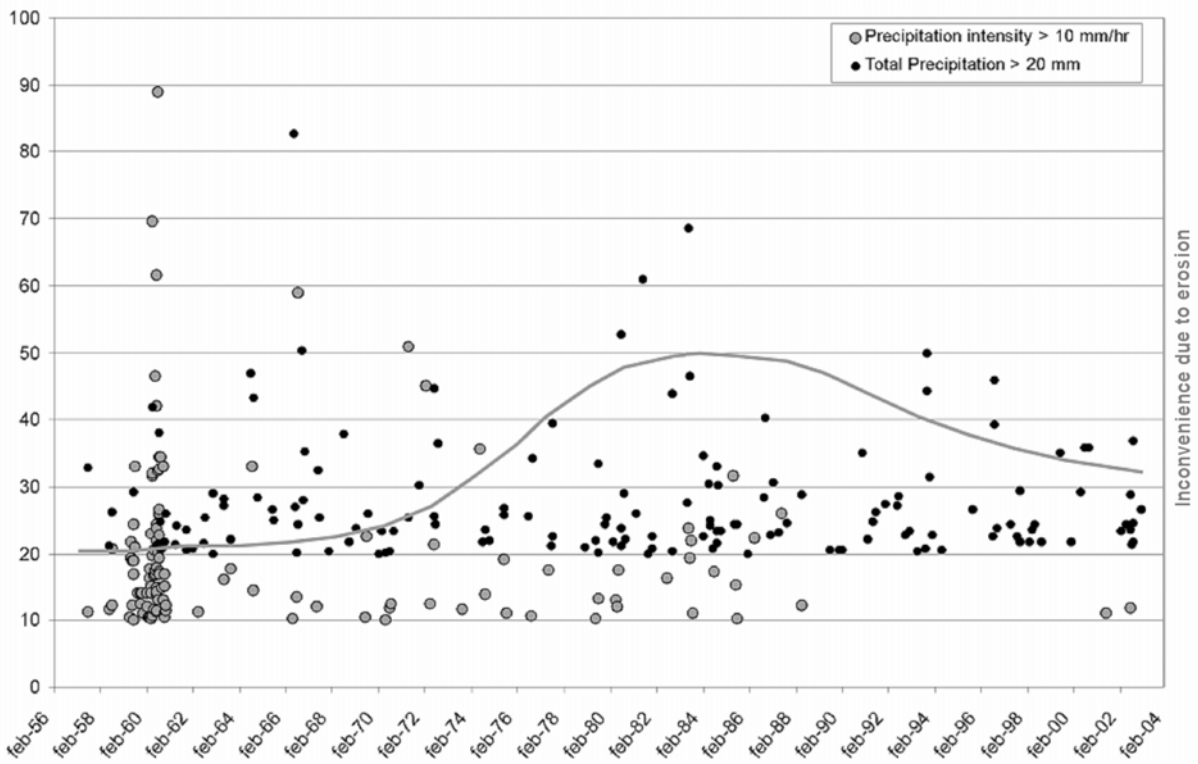

Figure 1. Precipitation measured at the Maastricht station in South-Limburg showing rainfall events with intensities higher than 10 mm per hour and events with a net precipitation amount larger than 20 mm per day (data available at Royal Netherlands Meteorological Institute). The right axis and the dark grey line are relative, which indicate the amount of inconvenience society had from erosion.

Adaptation then occurred in the society as well as in the natural landscape system. Between 1970 to 2000, a number of actions were taken to research and combat soil erosion in Limburg. Examples of combat action following research are different ploughing and seeding systems applied by farmers, prevention of barren land in the winter by seeding winter rye in the autumn, transforming agricultural plots into meadows and the construction of large sediment retention ponds in the valleys bottoms (Bouten et al., 1985; Van Dijk et al., 1996, Geelen et al., 1995, Kwaad et al., 1998).

In the natural system adaptation started with the counterpart of soil erosion, which is deposition or sedimentation in other parts of the landscape. In South-Limburg, loess and the previously underlying gravel were eroded and deposited in the bottom of the dry valley. There, small so-called alluvial fans could develop. These fans slowly migrated upwards into the tributary valley system. As a result the surface slightly rose in height and the infiltration capacity of the soil in the valley bottom increased due to the mixture of loess with coarser material. At the same time, the erosion potential of the tributary valley slopes decreased as more and more loess was removed. Sometimes, farmers

ploughed into the weathered bedrock. This all happened during the last twenty years. Despite some heavy rainfall events, the formation of gullies, which normally initiate from the valley bottom in that area, has not been observed during the last 15 years. In the eighties, gullies frequently formed within these fields. The effect of the adaptation of the natural system is currently also reinforced by the fact that a foundation called 'Limburg Landscape', who aims to protect the landscape in South-Limburg, purchases land from farmers to restore the original landscape and to reintroduce natural herbs and plants on these fields. This vegetation protects the soil during wintertime as well as the stability of the soil aggregates increases. The number of these kind of 'Limburg Landscape' fields is increasing, in many cases they appear at places where farmers previously had erosion problems.

In summary we can state that society adequately dealt with erosion. Erosion itself was stopped, land was assigned other functions by the community and erosion ceased to be an issue. All this can be defined as adaptation in an interlinked human-natural system. An extended analysis of this case is available in Dorren and Imeson (in press).

References

Bouten, W., Van Eijsden, G., Imeson, A.C., Kwaad, F.J.P.M., Mücher, H.J. and Tiktak, A, 1985. Ontstaan en erosie van de lössleemgronden in Zuid-Limburg. Geografisch Tijdschrift 19, 192-208 (in Dutch).

De Roo, A.P.J. van Dijk, P.M., Ritsema, C.J., Cremers, N.H.D.T., Stolte, J., Oostindie, K., Offermans, R.J.E., Kwaad, F.J.P.M. en Verzandvoort, M.A., 1995. Erosienormeringsonderzoek Zuid-Limburg. Veld- en simulatiestudie. Rapport 364.1, DLO Staring Centrum, Wageningen, 234 pp (in Dutch).

Dorren, L.K.A. and Imeson, A.C., in press. Soil erosion and the adaptive cycle methaphor. Land Degradation and Development 16.

Geelen, P.M.T.M., Kwaad, F.J.P.M., Mulligen, E. van, Wansink, A, en Zijp, M. van der, 1995. Optimalisatie van erosieremmende teeltsystemen. Onderzoeksresultaten over 1995 van de Proefboerderij Wijnandsrade, Stichting Proefboerderij Wijandsrade, pp. 93-99 (in Dutch).

Janssen, C.R., 1960. On the Late-glacial and Post-glacial vegetation of South-Limburg (The Netherlands). North-Holland Publ. Company, Amsterdam, 112 pp.

Kwaad, F.J.P.M., 1991. Summer and winter regimes of runoff generation and soil erosion on cultivated loess soils (The Netherlands). Earth Surface Processes and Landforms, Vol. 16, pp. 653-662.

Kwaad, F.J.P.M., Van der Zijp, M. and Van Dijk, P.M., 1998. Soil conservation and maize cropping systems on sloping loess soils in The Netherlands. Soil and Tillage Research, Vol. 46, pp. 13-21.

Mücher, H.J., 1986. Aspects of loess and loess-derived slope deposits: an experimental and micromorphological approach. PhD Thesis, Universiteit van Amsterdam, 270 pp.

Renes, J., 1988. De geschiedenis van het Zuidlimburgse cultuurlandschap. Van Gorcum, Assen, 265 pp. (in Dutch).

Schouten, C.J., Rang, M.C., Huigen, P.M.J., 1985. Erosie en wateroverlast in Zuid-Limburg. Landschap 2, 118–132 (in Dutch).

Van den Broek, J.M.M., 1958. Bodenkunde und Archäologie mit besonderer Bezugnahme auf die Ausgrabungen im Neolithikum von Sittard und Geleen. Palaeohistoria 7, 7-18 (in German).

Van Dijk, P.M., Kwaad, F.J.P.M. and Klapwijk, M., 1996. Retention of water and sediment by grass strips. Hydrological Processes, 10, pp. 1069-1080.

Case study 9

Reduction of soil erosion in Norway

A case study in Southern Norway.

Arnold Arnoldussen

In Norway the restructuration of agriculture contributed to a strong increase of the risk on erosion. The main impact of the erosion is the pollution of fresh and salt water resources. The water pollution resulted in a severe algae bloom in 1988/89. A soil mapping program was established in the exposed watersheds and an appropriate legislation was developed. The main objective was the reduction of autumn ploughed areas. The reduction has been successful, however, more needs to and can be done in specific watersheds.

Norwegian agriculture was significantly restructured in the 1950s; cattle farming was concentrated in the western and north western parts of the country. Arable farming was directed to the southeast. Mixed farms in the southeast had to shift to pure crop farming and many old pastures were transformed into arable farming land. Agriculture became more intensive with the introduction of more efficient and heavy machinery, increased fertilisation and new cropping systems. Agricultural fields were consolidated; small areas of semi-natural vegetation and field margins disappeared. The restructuring and intensification led to land with limited crop production potential changing into arable farming land (Arnoldussen, 2003).
During the 1980s negative consequences became evident: increased erosion, pollution of rivers and lakes by nitrogen and phosphorus, disappearance of the cultural landscape heritage and loss of biodiversity.

In 1988/89 an algae bloom caused the death of many marine organisms in both the North Sea and Skagerrak. Eutrophication by nitrogen and phosphorus was identified as the cause for the enormous increase in poisonous algae. European countries bordering the North Sea agreed upon a plan to reduce nutrient run-off by 50%. The strategy of Norway was to reduce erosion by the implementation of a soil mapping programme in the exposed watersheds and to establish an Agro-Environmental Scheme stimulating ploughing in spring time on the most erosive soil types.
Soil erosion in Norway mainly occurs in autumn and winter, when heavy rainfall on the already saturated soils can cause soil loss through (increased) surface run-off. In (late) winter, erosion is caused by heavy snowmelt, sometimes in combination with a frozen (sub)soil (Øygarden, 2000). Water erosion is a significant soil degradation process on arable land, especially in undulating areas with marine sediments used for arable farming. The land levelling operations from 1970 – 1985 led to severe erosion problems and increased water pollution (Øygarden et al., submitted).

To make an efficient reduction of erosion possible the following instruments were developed:

a. The development of a Norwegian Soil Information System
b. The development of an Agro- Environmental Scheme with the aim to reduce the risk for soil erosion.

The Norwegian Soil Information System

A program was established to map the soil of all agricultural areas in watersheds feeding water into the North Sea and Skagerrak. The Norwegian Soil Information System contains digital soil maps linked to a soil type database containing soil and terrain properties and a soil profile database that includes analytical data related to the mapped soil types (Nyborg et al., 1998).

The USLE (Universal Soil loss Equation) model was adapted to Norwegian conditions to produce soil erosion risk maps. The risk maps are based on soil and slope characteristics. Municipalities, counties and farmers use the maps to reduce erosion. The soil information and derived maps are available via internet. Farmers are able to download specific information for their farm with a password.

Legislation

For the reduction of erosion the following instruments are available (Kollerud, 2005):

a. Regulatory instruments
b. Cross-compliance mechanisms to be eligible to economic support
c. Economic instruments

An important instrument was the regulation of land leveling. The land leveling carried out in the period from the 50s up to the 70s caused a strong increase of the risk on erosion. Now land leveling is not longer subsidized and permission needs to be asked. Now only few areas are leveled.
Since 2003 every farmer is obliged to have an Environmental Plan for his farm. The requirement to have an Environmental Plan is part of the cross compliance mechanism and is directly linked to the existing Environmental Schemes. In the Environmental Plan the farmer describes the environmental status of the farm and which measures he will take to sustain or improve the situation.

To be eligible for economic support the farmers must fulfill certain criteria concerning environmental issues. It is i.e. not allowed to change waterways, level fields and farmers are obliged to have a 2 meter buffer zone along farmland edges bordering watercourses.
By not having an Environmental Plan and not complying with the obligations the farmers get reduced economic support. In 2004 98% of the farmers complied with the regulations.

The following measures to reduce erosion are open for economic support to the farmer (Kollerud, 2005):

- Conservation tillage
- Catch crops
- Buffer strips
- Grassed waterways
- Construction of sedimentation ponds
- Hydro technical measures.

The most important measure to reduce erosion is the introduction of conservation tillage with as the most important objective; the reduction of the area autumn ploughed land. In 2003 approximately €20 million was available for this measure. The level of subsidy is related to the level of erosion risk of the particular field. Table 1 shows the rates of subsidy in 2004.

Table 1. Subsidy rates for amended soil management in 2004.

Measure	**€ per ha.**
In stubble during winter	
- Low erosion risk	50
- Medium erosion risk	75
- High erosion risk	135
- Very high erosion risk	175
Conservation and reduced tillage	
- Autumn harrowing with straw incorporation	40
- Winter grain sown after light harrowing	40
Direct drilling	50
In addition extra support for:	
- Catch crops:	
• Areas vulnerable to N-leak (according N-directive)	135
• All other areas	90
- Grassed waterways	~600

The support to technical measures is up to 70% of the costs and the support is only given once per object. Also support is given if the farmer puts land in the highest erosion risk class under a permanent vegetation cover.

Results and Conclusion

The amended soil management has given good results. The area of autumn ploughed land decreased from 81,5% in 1989 to about 50% in 2004. In 2003/2004 about 45% of the total area with grain stayed under stubble during winter.
In 2002/2003 about 10% of the total grain area is covered with catch crops. At this moment 90% of the support is given to areas with a medium to very high erosion risk (Børresen et al, 2005)

Currently, Norway has nearly fulfilled its obligations of the North Sea Agreement (NIVA, 2000). The problems are now concentrated on particular watersheds. Here extra efforts and measures are needed. Also in relation to the Water Frame Work Directive measures in these watersheds are required. Now the counties have the possibility to take specific measures at regional scale, it should be possible to realize an additional decrease of erosion.

Possible additional measures are the enlargement of buffer zones along waterways, the introduction of conservation tillage and to prevent ploughing of areas prone to flooding in spring time.
The introduction of conservation tillage is generally successful on well-drained loam and clay soils under the relatively dry conditions in southeast Norway, but has proved to be more difficult under wetter conditions, especially on silty and sandy soils (Børresen et al, 2005).
Reduced and conservation tillage has proven to contribute to the reduction of erosion in Norway (see Table 2). The yield levels are approximately equal to the more traditional soil elaboration methods, provided that sufficient weed control is given and that appropriate sowing techniques are used. Ploughing in autumn should be restricted to the areas with a low erosion risk (Børresen et al, 2005).

Table 2. Relative erosion risk associated with different soil tillage systems (Lundekvam, pers. Comm.; in Børresen et al, 2005).

Tillage system	Time of sowing	Relative erosion risk
Ploughing in autumn	Spring	0,85 – 1,00
Harrowing in autumn	Spring	0,55 – 0,65
Ploughing in spring	Spring	0,33 – 0,40
Harrowing in spring	Spring	0,29 – 0,35
Direct drilling	Spring	0,25 – 0,30
Ploughing	Autumn	0,60 – 1,10
Direct drilling	Autumn	0,20 – 0,30

The conclusion is that the data from the Soil Information System, in combination with an Agro- Environmental Scheme with clear objectives, contributed to a quick and successful reduction of erosion.

References

Arnoldussen, A.H., 2003: Reduction of Soil Erosion in Norway. Briefing papers of the first SCAPE workshop in Alicante (ES), 14 – 16 June 2003: p 71 – 74.

Børresen, T and Riley, H, 2005: The Role of No- and reduced Tillage in Norway. In: S. van Asselen (Ed.), 'Briefing Papers' of the fouth SCAPE workshop in Ås, (Norway), 9-11 May 2005, p 57 – 62.

Kollerud, J, 2005: The Reduction of Soil Erosion in Norway. Erosion in Norway – Problem and Goals, Strategies, Instruments, Results. In: S. van Asselen (Ed.), 'Briefing Papers' of the fouth SCAPE workshop in Ås, (Norway), 9-11 May 2005, p 49-57.

NIVA, 2000. Transport of minerals to the Norwegian Coastal areas, based on the TEOTIL Model (in Norwegian), NIVA, Oslo.

Nyborg, Å, and Klakegg o, 1998: Using a Soil Information System to combat soil erosion from agricultural lands in Norway. In: Land information Systems: Developments for planning the sustainable use of land resources. Heineke, H.J, Eckelmann, W., Thomasson, A.J., Jones, R.J.A., Montanarella, L., Buckley, B. (eds). European Soil research report No 4.

Øygarden, L., 2000: Soil Erosion in Small Agricultural Catchments, South-eastern Norway. Doctor Scientarium Thesis 2000: 8. Agricultural university of Norway, Ås.

Øygarden, L., Lundekvam, H., Arnoldussen, A.H., Børresen, T. (submitted). Soil erosion in Norway. To be published in: Boardman, J., Poesen, J. (eds): Soil erosion in Europe.

Case study 10

Land Degradation and Desertification in Iceland

A case study in Iceland

Olafur Arnalds

Soil erosion and land degradation are active processes in Iceland, resulting in severely damaged ecosystems, barren deserts, and an unstable soil environment. Soil erosion has been surveyed in all of Iceland, and the resulting database is a unique tool for land use decisions. The extensive degradation and desertification in sub-arctic and mostly humid Iceland provides an interesting conceptual perspective on the term deserts and desertification. The following text draws from already published papers on land degradation and desertification in Iceland, especially the chapter on Iceland in the forthcoming book "Soil Erosion in Europe" (ed. by Boardman and Poesen). A list of other relevant publications is presented on www.rala.is/desert and in the reference list below.

Background

Iceland is located on the active North-Atlantic Rift Zone. It is about 103 000 km^2 in area. Its northerly oceanic location, strongly influenced by the Gulf Stream, results in a cold temperate to sub-arctic climate with frequent freeze-thaw cycles. Precipitation generally varies between 600 and 1500 mm per year in lowland areas, but large tracts of Northeast Iceland receive less than 600 mm. However, summer months are few (3-6) and much of the precipitation falls as snow in winter in North Iceland and in highlands.
Classified satellite images (LMI, 1993) show that land with relatively continuous vegetation covers about 28 500 km^2, but an additional 23 900 km^2 has less continuous or non-productive plant cover. More than 37 000 km^2 is barren desert, some of which has formed after the settlement (874 AD).
The vegetation composition of rangelands reflects grazing by sheep, with species tolerant to grazing dominating most communities, such as small woody species and sedges. Birch woodlands used to cover a large proportion of the country but are now only about 1% (Aradottir and Arnalds, 2001). The barren surfaces are often sandy, consisting of volcanic glass and crystalline materials that are basaltic, colouring the surfaces dark or black. Almost all of Iceland was covered with glaciers during the Quaternary glacial period, but at the present time glaciers cover about 11 300 km^2 (LMI, 1993).

Soils

The formation of Icelandic soils is influenced by a steady flux of eolian materials which originate from unstable desert surfaces. The rate of deposition commonly varies between 0.01 and 1 mm yr^{-1}, depending on the distance from eolian sources. These materials are primarily vitric in nature (volcanic glass). In addition, most regions are subjected to periodic ash-fall events during volcanic eruptions. The thickness of each layer is also quite variable, often 1-30 mm. Undisturbed soils of Iceland are primarily Andosols (Arnalds, 2004), which are soils that form in volcanic parent materials.
Soil drainage is also an important factor influencing Icelandic soils. Water permeability is rapid within the volcanic belt resulting in freely drained soils. Permeability is slower in the rock strata outside the belt of volcanic activity. This results in more than 22 000 km^2 of wetland soils which are mainly Andosols. Histosols (organic soils) are uncommon in spite of the sub-arctic climate because of the eolian and tephra deposition, which lower the organic matter content of the wetland soils.

The soils of Icelandic deserts are termed Vitrisols (Arnalds, 2004). They consist of coarse grained tephra materials, chiefly volcanic glass, but also varying amounts of clay minerals and some organic matter.
The properties of the Andosols are important in relation to the extensive erosion that takes place in Iceland. The soils are characterized by poorly crystalline clay minerals such as allophane and ferrihydrite, metal-humus complexes and considerable organic content. They are very friable and lack cohesion which is usually provided by phyllosilicates in other soil types and many Icelandic soils exhibit tixotrophic characteristics. These characteristics make the soils susceptible to erosion by water and slope failures.

Soil Erosion Assessment

A National Soil Erosion Assessment was completed in 1997 and published in 'Soil Erosion in Iceland' (Arnalds et al., printed in English in 2001). The book includes both tables and maps for all of Iceland, regions, counties, municipalities and for communal grazing areas. The results are stored in a GIS database, which includes about 18 000 polygons with information about erosion types and severity. The project was awarded the Nordic 'Nature and Environmental Award' in 1998.
Erosion in Iceland occurs on rangelands. Erosion associated with cultivated land is limited in extent. A distinction has to be made between erosion on desert areas, which lack vegetation cover for protection, and erosion associated with Andosols and vegetated ecosystems. A major characteristic of erosion of Andosols is that the entire soil mantle, often 50-150 cm thick, is removed by erosion processes, leaving the barren Vitrisol surface behind. Erosion on deserts follows more conventional patterns, both by wind and water, but frost activity (blocking infiltration) and needle ice formation also play a major role. The assessment was carried out in the field at the scale of 1:100 000.

Erosion

The soil erosion survey was based on erosion forms, with a view on site-specific differences (table 1). It is partly based on geomorphology.

Table 1. The Icelandic erosion classification system (erosion forms).

Erosion forms associated with erosion of Andosols/Histosols	Desert erosion forms
Rofabards	Melar (lag gravel, till surfaces)
Advancing erosion fronts (sand enchroachment)	Lavafield surfaces
Isolated spots	Sandur (bare sand, sand sources)
Isolated spots and solifluction features on slopes	Sandy lava fields
Water channels	Sandy melar (sandy lag gravel)
Landslides	Scree slopes
	Andosol remnents

Of the erosion forms, '*Rofabards*' are perhaps the most distinctive (see also Arnalds, 2000). They are escarpments that range from about 20cm to more than 3m in height. *Advancing fronts* (encroaching sand) are active tongue-shaped sandy surfaces extending into vegetated areas. Sand fronts move into the vegetated land as continuous flux of sand abrades the Andosol mantle and finally the new surface may be 1-2 m lower than the original surface. The advancing fronts are a major problem that threatens fully vegetated systems, and they can advance over 300 m in a single year. Encroaching sand has desertified large areas in South and North-east Iceland, especially during the last part of the 19th century. *Isolated spots* are small bare patches in otherwise vegetated land. They are usually associated with hummocks, and are often a clear sign of overgrazing when they occur in lowland areas. *Solifluction* is active on most slopes, and where those features are most pronounced (lobes and terraces), the danger of landslides

is greater when isolated spots are dotting the landscape. *Landslides* are very common, hence the lack of stability of Icelandic Andosols.

Deserts are divided into seven erosion forms based on geomorphology and stability of the surface. '*Melur*' (glacial till or lag gravel surfaces) are usually surfaces that have lost their Andosol mantle because of erosion processes, but also occur at the margins of receding glaciers. The surface of melur is subjected to erosion by wind and water, and intense cryoturbation processes. *Lavas* are sparsely vegetated rock surfaces of the Holocene lavas that lack Andosol cover. Most often they are recent (< 1000 yr) or denuded surfaces by erosion processes. There is little erosion taking place on the lavas. *Scree slopes* are very common in mountainous areas. Many of these slopes may have been previously vegetated. Gravitational and water erosion processes are active on the slopes. 'Sandur'. The black basaltic desert sand-flats of Iceland are unique on a global scale. They are mostly formed by glacio-fluvial processes, during floods in glacial rivers or where glacial waters disappear into porous bedrock, leaving the sediments on the surface. Some of the sand-flats have been formed by flow of eolian materials from these sources. Sandur also includes sediments deposited during volcanic eruptions. These surfaces are extremely unstable and are subjected to severe and often quite spectacular wind erosion events. The sandy areas of Iceland were reviewed by Arnalds et al. (2001). The sandy materials are often moved by wind erosion and deposited over various desert surfaces. Two sandur surfaces represent such conditions: the *sandy melur* and the *sandy lavas*.

The severity of erosion in Iceland

The severity scale has a direct reference to land use decisions (table 2). A policy statement by the Agricultural Research Institute and the Soil Conservation Service is built into the scale: no restrictions because of erosion are suggested for areas receiving low severity classes (0-2), but areas designated with erosion severity classes 4 and 5 are not considered suitable for grazing. Areas with erosion class 3 need further consideration and usually improvement. If such an area is a desert, it should not be grazed. The decision that grazing of Icelandic deserts is not acceptable land use has been thoroughly explained in several documents (see Arnalds and Barkarsson, 2003).

Table 2. Erosion severity classes and land use policy of the Agricultural Research Institute and the Soil Conservation Service related to each class.

Erosion Class		Suggestions regarding grazing
0	No erosion	No suggestion
1	Little	No suggestion
2	Slight	Care needed
3	Considerable	Reduce or manage grazing
4	Severe	Protect – no grazing
5	Very severe	Protect – no grazing

Areas with severe and very severe erosion, which may be considered erosion hotspots in a European context, occur on about 17% of Iceland. Considerable (severity class 3) occurs on 22% of Iceland and therefore erosion can be considered a substantial problem on 40% of Iceland (classes 3-5), or about half of the country when glaciers, water bodies and high mountains are excluded.

Desertification in Iceland?

Is there desertification in Iceland? This of course depends on how desertification is perceived. If it is considered as a severe degradation, ultimately leading to near barren, unproductive areas, then desertification is a major problem in Iceland. The original

meaning of the word desert is desolate or deserted (see Arnalds, 2000b). It is argued that climatic restrictions on the term are very questionable, and the Icelandic conditions demonstrate that well. Many of Icelandic desertified areas are rather dry (400-600 mm yr^{-1}). But these areas have a short summer and the water in the soil is frozen much of the year. Furthermore: when fertile Andosols are present, moisture shortage is rarely a problem, even in the driest areas. After erosion has stripped the surface of good soils, water shortage becomes acute, even in areas receiving >1000 mm rainfall (lack of water holding capacity, and the black surface gets warm in sunshine). In addition, other stress factors, such as instability of the surface, and damaging frost effects, are even more detrimental than lack of moisture, both in dry and wet conditions. A holistic ecosystem approach to the problem would not limit the stress factors that contribute to severe land degradation to single one (rainfall, evapotranspiration).

Conclusions

Erosion is perhaps more active in Iceland than in any other European country. Natural conditions, the combined effect of such factors as fragile soils, volcanic activity, heavy land use, and harsh climate, differs from conditions in other parts of Europe, resulting in different erosion processes and landforms. The Icelandic National Soil Erosion Assessment is an example of country specific methodology designed for local conditions and objectives. The assessment places Iceland in a different situation than most other European countries, with a detailed coverage of the erosion problems in the country. This view is based on field survey, but not on modeling of erosion/erosion risk or by assessment of erosion in parts of the country.

A complete soil erosion assessment has lead to important changes in how society deals with the problems. Debates about the nature and extent of the problem have changed and the present discussion focuses more on solutions. Important steps towards more sustainable use of range resources in Iceland have recently been taken, partly as a result of the erosion assessment. Its methodology is now used on a regular basis for land assessment on farmland.

Lack of erosion assessment should not, however, prevent development of laws for prohibiting land use that causes soil erosion. This and the facilitation of programs such as land-care or participatory projects that increase land literacy and stewardship are both equally as important venues for securing sustainable land use, and both should be carried out.

References

Aradottir, A.L, and Arnalds, O., 2001. Ecosystem degradation and restoration of birch woodlands in Iceland. In Nordic Mountain Birch Ecosystems. Man and the Biosphere Series 27. Wielgolaski FE (ed). Parthenon Publishing, New York, USA. pp. 293-306.

Arnalds O. (2000a). The Icelandic 'rofabard' soil erosion features. Earth Surface Processes and Landforms 25, 17-28.

Arnalds, O. (2000b). Desertification: an appeal for a broader perspective. In Arnalds, O. and Archer, S. (eds), Rangeland Desertification. Kluwer Academic Press, Dordrecht, the Netherlands. pp 5-15.

Arnalds, O. and Barkarsson, B. (2003). Soil erosion and land use policy in Iceland in relation to sheep grazing and government subsidies. Environmental Science and Policy 6,105-113.

Arnalds O. (2004). Volcanic soils of Iceland. Catena 56, 3-10.

Arnalds O, Hallmark, C.T., and Wilding, L.P. 1995. Andisols from four different regions of Iceland. Soil Science Society of America Journal 59, 161-169.

Arnalds O., Gisladottir F.O., and Sigurjonsson, H. (2001). Sandy deserts of Iceland: an overview. Journal of Arid Environments 47, 359-371.

Arnalds, O., Thorarinsdottir, E.F., Metusalemsson, S., Jonsson, A., Gretarsson, E., Arnason, A. (2001). Soil Erosion in Iceland. The Soil Conservation Service and Agricultural Research Institute, Reykjavik, Iceland. Translated from Icelandic version (published in 1997).

LMI. 1993. Digital vegetation index map of Iceland. National Land Survey of Iceland: Akranes, Iceland.

What can be learned from all these case studies

Similarities and Differences

A great value and virtue of having such a wealth of case studies to our disposal, is the possibility to look at similarities and/or differences and trends that are noted in all biogeographic regions across the different countries. SCAPE acknowledges fundamental differences that affect erosion. For example research findings from the USA may not be applicable to Europe and erosion results from croplands are not applicable to rangelands and vice versa. Against this background, special consideration is given to a) differences between rangelands and croplands, b) regional differences, c) land use differences, d) climate differences, e) ecosystem differences, f) resource availability differences, g) social differences and h) administrative legislative differences. However, one observation that can be drawn from all the different case studies presented at the workshops is actually quite remarkable. This is the observation that, besides the differences many similar problems are found in totally different eco-regions, for instance Norway and southern Spain / southern Portugal. The climate of these countries is very different and indeed these countries are classified in different biogeographic regions. Still, according to the presented case studies, it proves that this is no guarantee that problems cannot be identified as almost identical. The effects of the different driving forces on the soil are the same and results in soil erosion, the development of algae explosions, water pollution etc. Considering measures to prevent damage to the soil and environment, Norway, Southern Limburg (The Netherlands), Spain and Portugal do have much in common. Nowadays one tends to take action in the case environmental problems cause a lot of damage. It should be wiser to pre-evaluate possible damage before big changes in land management systems are introduced and to include control measures straight from the beginning. Looking at the costs this will be cheaper than in the case of solving the problem after the damage is developed. For instance: What can Spain and Portugal learn from the lessons learnt in Norway? We don't say to simply copy measures to other parts of Europe. But the approach in Norway to solve the problems could be a base to find solutions for Spain and Portugal adapted to the local socio-economic and environmental circumstances.

> ***Box 4.1 Natural parks.*** *A similarity found throughout all different workshops is the positive value that is brought about by the creation of a natural park. The implementation of a natural park can be explained as a good practice. Not only does it increase the awareness of our vital resources, such as soil, amongst a broader public, as people go these parks to enjoy 'a sniff of nature'. It also will significantly contribute to raising educational awareness levels concerning soil protection and conservation. Furthermore, in general terms, it implies that soil conservation and nature protection measures are implemented within these natural parks and can be assessed in the long or short term on its effectiveness, mostly showing, considering the case studies presented, positive outcomes in regeneration of species, biodiversity, increase in soil organic matter content, soil quality and so on. Concerning the interdisciplinary nature, positive outcomes are also found in economic status; the preciousness of a natural park also increases tourism incomes for which for instance Parco nazionale della Cinque Terre is a outstanding example.*

Desertification

As was presented at the 3rd SCAPE workshop, the creation of desertification maps under the umbrella of the National Action Programs (NAP) can lead to ambiguity concerning the severity of desertification along borders of different Member States (MS) (Curfs 2004). This was shown based on the desertification maps derived from the NAPs of Spain and Portugal. The differences of the national perceptions on the degree of desertification lead to different strategies on how to treat a specific area. This may lead to the undermining of the concept of desertification itself, as the public sees similar landscapes being treated differently according to different national perceptions of the concept desertification. More

recent research groups; e.g. Desertlinks and DISMED, apply a more common methodology, which doesn't stop at country borders and therefore show more gradual gradations of desertification, especially along country borders.
Processes of desertification are dynamic and are mostly measured and explained through indicators. The NAPs of the Mediterranean countries consist mostly of similar, but also contain different, indicators in relation to desertification. The choice of indicators is very difficult but necessary in making desertification visible and measurable. The knowledge gained in the last decades in combating desertification delivers and justifies the indicators chosen. Each country's own culture though, puts more emphasis on some indicators than on others, which results in a different indicator choice in the NAPs. However, the sole fact that desertification is measured through indicators delivers a tool in creating dynamic desertification maps and methodologies. An indicator can be measured and a threshold value can be applied to it, in relation to the rate and state of the particular process. The threshold values of the indicators are a key element in combating desertification, as exceeding a threshold value leads to 'irreversible' desertification or degradation.

Many successful strategies in combating desertification throughout the world have been presented at SCAPE's various desertification working group sessions. These often lead to vivid discussions which can be downloaded from our website (www.scape.org). Examples from countries outside the European Union often proved to be an eye opener in how successful strategies can be implemented. Often these countries have a long history in combating desertification. Successful combating desertification strategies that are presented concerned, amongst others; afforestation projects, specific drainage measures and certain irrigation and cultivation techniques.

Positive vibrations

If one looks around, or turns on the television, reads a paper or magazine, more often is one confronted with a negative than a positive example in the field of soil conservation or the environment as a whole. There seems to be a relentless array of harms to our 'mother nature' that sometimes it seems that it doesn't matter any more if you do good or bad. One could get hopeless because sometimes we are given the assumption that we have passed the threshold of survival. An aspect that plays a contributing role in this phenomenon is that much focus is put on resolving or notifying problems. If we summarize the case studies it seems that there is an unequal balance in focus on negative cases in comparison to positive cases. It is a human feature to take the good things that surround us for granted instead of nurturing them and to focus on things that are wrong or bad. Many positive measures and results were presented in the case studies and this is one aspect SCAPE likes to show to you. That it isn't only bad. Of course we are not stating that no problems exist in the world of soil conservation and protection, but what we do state is that more focus should be fixed on positive measures and results in order to transcend the positive measures that can be applied. Through its case studies SCAPE is able to develop guidelines and training instruments of best land management practises. Land users can be introduced to management techniques and other options for land use which are less degrading and which stress alternative combinations of functions.

Box 4.2 Demonstration farms. *In the UK there are many demonstration farms where conservation practices are performed. At these farms the techniques are explained to for instance farmers who apply conventional tillage measures, and the pro's and con's are discussed. A great aspect of such farms is that farmers can see the results straight away which can help with the introduction of a good practice. It also proves to be a tool in persuading funding institutions to stimulate the use of good but often innovative measures. At the same time the farmer does get a feeling for the importance of protecting his soil quality and does get knowledge how he himself can take action. With other words: he/she gets involved!*

Chapter 5

Soil Protection: So What?

Prelude

Do our soils need protection? Is European soil threatened? Is the threat to soils a global problem? These are questions often given to specialists such as soil scientists. But is the European public concerned about soil? Do European citizens perceive soil degradation as a problem that needs consideration? Could the price of food increase like the price of oil or cod if there is too little land to produce it? These are crucial questions for any society. Science is not only a quest to fulfil our curiosity about nature. Science serves society, shapes it, and is a driving force for societal changes. In the case of natural sciences it serves society, to help us to use resources wisely, to find new ways to manage resources and to ensure that there will be resources to ensure the needs of future generations: the core of the concept "sustainable development". Currently, society is relying on soil scientists for shaping our perception of soil degradation in the world. Without a general public perception that many European soils are degrading, there will never be the possibility to seriously implement any practical soil protection strategy.

The main resources for producing food and cloths, the essential needs of all people, are soils, water and solar energy. Rainfall we cannot switch on or off when we want to, but our actions can decide what happens to the water reaching the ground. With rich soil on the surface, the rain is stored and kept until the plants above have need for it. The soil purifies the water and prevents toxic substances from entering our drinking water. Moreover, soil in it self is a living and dynamic resource that circulates nutrients and makes them available when they are needed. And this resource is under pressure by an ever increasing demand for productivity; raising threats that have already been explained earlier such as erosion, decreased organic matter content, and contamination. It is also worth remembering that ecosystems of the past used solar energy to produce the fossil fuels that meet the energy needs of today. At present, production of crops for harvesting energy is growing rapidly.

We know that we have a precious and non renewable resource under our feet, on which our future depends. Many countries have detailed maps of their soil resources and the EU has a common soil map giving a remarkable overview of European soils, which now has been published in the Soil Atlas of Europe (2005). Scientists may know how our use of the land affects the natural resources and there is a wealth of studies on how different management systems affect our soils and other compartments of the environment. The study of the degradation and conservation of soils is a field of science in itself. But so what? What can be done to make this information useful for making sure we do not exhaust our resources?

Solutions are many

Ever since the beginning of organized soil conservation activities, there has been a quest to find solutions for maintaining and even improving the quality of our soils. The methods are quite varied as explained earlier in this book. They can range from organized work with land users to both simple and complex interventions. To get an idea, some examples are summarized as follows:

- *Simply doing nothing*. Soils and ecosystems may recover from disturbance on their own, building a nutrient pool and soil functions. More damage can result from interventions if they are not carefully planned. After a forest fire, it is often better not to disturb or trample a burnt soil and prevent physical disturbance. Introduction of non-native species for reclamation can result in ecosystem damage in the long run.
- *Voluntary and participatory approaches* are the preferred method for aiding land users in becoming responsible for the welfare of the land, acquiring ownership of land use problems; thus motivating them to undertake necessary soil conservation practices without the need for regulations.
- *Laws and regulations*. These influence land use methods and land owner's behaviour by means of penalties and rewards. Laws may be a part of dedicated soil conservation legislation, but they could also be included in other legislation such as, for water protection. Finally, laws and regulations for conservation of soils and ecosystems can be part of a societal system for the support of agriculture in the form of specifically directed subsidies and rural aid.

There is a large number of policy functions, global, regional and national, that have a bearing for soil protection, and the list is complicated due to the large number of policy areas that need to be explored (Briassoulis, 2005; see also Hannam and Boer, 2002).

Economic incentives

By economic or financial incentives it is meant that a land user is rewarded for good management that conserves resources, and in many cases, is denied finances (e.g. subsidies) when not. This is, of course, an extremely effective method when farming relies on public resources such as subsidies. Means of providing a rationale for economic incentives have been explained by the Sustainability Index in Chapter 3. Funds can also be provided directly for actions, for set aside policies (land taken out of given production) or direct efforts to improve the quality of the land.

Box 5.1. A foundation for good practices. *There is no simple solution, no single one method that can be used to ensure sustainable use of soil resources. For the best results we think it is necessary to combine methods. It has been proven that working in the field with a farmer is a very successful method, but it is also clear that doing so alone does not ensure results. Good conservation needs to be founded on sound principles carved in the core of the laws of the society.*

Economic incentives for improving the environment are the core of the *Agri-Environmental Measures* of the European Union (see Mitchell, 2004). Funds are provided through the Rural Development program of the EU, which are matched by national authorities. These measures are quite various between countries, but can include such actions as restoring wetlands, improving aesthetical values, conservation ploughing techniques, maintenance of terraces and rare domestic animal breeds. These funds could also be used in the fight against desertification in southern Europe and many affected regions are developing action plans for next year (2006). This could greatly accelerate soil conservation and protection efforts at both local and regional scales.

Legislation, subsidies, cross-compliance and agri-environmental schemes

The prevention of soil degradation and erosion in Europe is not commonly regulated by a specific legislation. Regulations regarding soil protection may, however, be found within the framework of other legislations (Olmeda-Hodge et al., 2004). In many EU countries, the principal instruments to tackle erosion are economic instruments in the form of cross-compliance (imposed) (box 5.2) and agri-environmental schemes (voluntary). EU countries differ in how they implement these kinds of schemes to reduce erosion. Some member states have introduced specific environmental requirements targeted to soil protection in relation to cross-compliance methods. Most agri-environmental schemes aim at building indirect measures to reduce soil degradation; they are specifically planned for soil conservation, enhancing biodiversity and landscape protection.

> ***Box 5.2. Cross-compliance**: if a farmer doesn't fulfil the environmental regulations he can be punished by getting less support.*

Many countries have formulated so-called "Codes for Good Farming Practice" (GFP), which give advice on soil protection and conservation. In many countries, the GFP is the underlying baseline for agri-environmental schemes. This means that farmers only get paid for the measures, which extend further than the advised GFP measures. A philosophy for the payments in agri-environmental schemes is that the farmer gets paid for the financial losses caused by adoption of environmentally protective farming methods. However, in some countries, like Norway, the level of support to farmers is strongly related to the level of erosion risk of a field and not to the loss of income by taking measures. Fields with a higher risk receive a higher support for improved management. In Norway this resulted in a rapid decrease in erosion rates.

It is remarkable that a "Code for Good *Forestry* Practice" is missing. Methods for an environmental friendly forestry practice are available, but these are not embedded in a system comparable with the "Good Farming Practice". Common rules for good farming and forestry practices would be beneficial.

The Common Agricultural Policy (CAP, box 3.7) was initially targeted to enhance agricultural production and food safety. This led for example to the same support for the production of barley in all EU member states. This made it financially more feasible to plough marginal land for the short term profit. Many marginal grasslands in Southern Europe were ploughed, which caused soil degradation, erosion and even abandonment. *The CAP reform of 2003 demands that each measure needs to be evaluated based on its impact on the environment*. However, to prevent the above mentioned situation, legislation should never be in contradiction with the local/regional potentials. A legislation framework at the community level should be developed, but specifications should be subsequently implemented at national and regional levels. To stimulate adaptation of land management to the local land capability, agro-ecological regions across Europe need to be identified, which give information about production capability and possible land use systems. Information about soil quality, relief, climate and type of farming system is essential to define such regions. The current condition of the soil and the environment should also be considered; EU, national or local funds should not be provided for farming severely degraded land. In the United States and Canada such systems are already in place.

The DPSIR framework

The DPSIR framework (*Driving forces, Pressures, State, Impacts and Response*), has been promoted by DG-ENV as a tool for developing soil protection policy. Although the benefits of the DPSIR model for policy decision making are clear, it seems to have the drawbacks of a top-down approach. It is hard to relate to the needs of every-day soil protection. Those unfamiliar with it, find it confusing that indicators can fall into the different DPSIR categories according to the context. It is often unnecessary to go

through the entire DPSIR process, which can involve collecting a lot of redundant information. Further, there is no way of quantifying the outcome in the form of an index. A fundamental limitation is that it describes problems in an abstract and generalised way that can not easily be worked out and verified in detail for specific cases (see Imeson, 2004).

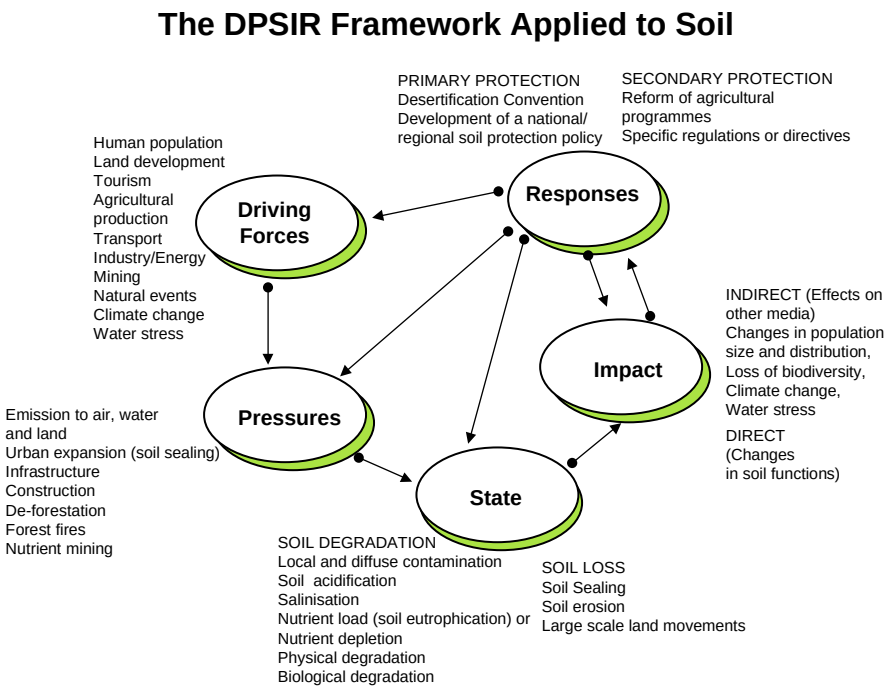

Figure 5.1. The DPSIR framework.

The SI model

The Sustainability Index model, explained in Chapter 3, can easily be adapted for regulatory frameworks that accompany law, by providing a measure for what is good and what is a not acceptable land use practice, independent of type of land use or geography. This is achieved by simply using breakpoints in the SI value. A SI value above a certain limit would then be considered non-acceptable. The method has also bearing for land care and participatory approaches, giving a numerical value to compare and weigh new land use approaches. This can easily be tied into the Agro-Environmental measures of the EU.

Do we stand on firm ground?

"There is not enough research!" This is a common statement when it comes to legislation on soil protection. Many have raised concerns whether it is possible to formulate joint legislation for the European countries for the protection of the soil, let alone to formulate a link between land use and financial subsidies. Well, when is there enough research? The answer is "never", of course, but it is our obligation to *use the best knowledge at a given point in time*. The use of knowledge by society is a stepwise process with no set endpoint, important steps can be made now and other steps will be made later. Considering soils we need:

- Legal basis and principles. But we do not need research for stating that one should not damage the environment or harm the soil.
- Regulatory framework for upholding the law. Such framework develops with knowledge and society.

Many are insisting to fully map erosion or erosion risk in the whole of Europe for this purpose before taking action. It would be good, but not a prerequisite to go ahead. Land-use mapping on farm basis is probably more important in the long run, while erosion scenarios can be established based on less comprehensive aerial data; hence, one method of mapping erosion/erosion risk will not work for the entire EU, not even within countries, and sometimes not even within a single community! There is no single best method for assessing erosion.

It is also wrong to conclude that we can come up with comprehensive legislation that will work from day one. But simple firm rules provide countries and communities with a solid basis to continue developing sustainable land-use. Tying subsidies into the picture is a little more complex, but can also be done, in steps.

What is needed is a combination of simplicity and comprehensiveness. Simplicity helps the scientist and policy-maker to draw a line between knowledge and facts upon which to act, and beliefs about which there is uncertainty. When the limits of belief and knowledge can be agreed upon by interdisciplinary teams of actors, then this is anchored in to all of the represented areas of knowledge.

Developments in Regulations

Agronomic vs. ecological paradigms

Agricultural goods are produced in an immensely variable soil environment. The climate, landscapes, vegetation, and the soils differ from place to place. Also, natural resources respond to cultivation in a different manner from place to place. This means that agricultural production automatically leads to heterogeneity in the landscape, as different areas respond differently to the pressures and impacts of farming. These different responses to land use require site specific-actions to remedy problems that arise from using the land.

The concept of “paradigm” is often used for the background or accumulated knowledge in any given scientific discipline; knowledge we take for granted. Paradigms change with time of course, as our knowledge of a given subject increases. Discussions about soil erosion are sometimes stuck between two paradigms, which can make solutions difficult if no care is taken. The first is the paradigm of modeling (e.g. in t/ha/yr) and that modeling is the solution to all problems (this has appreciation in the accountable yield response curves, agronomists like such response values). The second paradigm is that soil is considered separately from other parts of ecosystems. Both these paradigms are part of the traditional agronomy and represent the so-called “*agrocentric*” views of the soil.

The agrocentric history of soil science is understandable, as crop production has been by far the biggest industry in the world and has been, and still is, the foundation of any society. Nevertheless, this paradigm has become a barrier and to advance beyond this a broader understanding of soil is needed. *In non-agronomic systems, it might even be questioned if the soil alone is the best measure for conservation.* Instead, valued ecosystem services provided by the whole ecosystem, of which the soil is only one part, might be better. Agrocentric rules for protecting soil and its environment should be avoided.

Laws, National Policies and Directives

Laws and regulations need to be soundly justified and should reflect the need of society. Laws have to be as simple as possible, so they can be applied, followed and reinforced. The law is for the people, and ideally laws should not be a complex and stringent text that only lawyers and bureaucrats can argue about. As we know, this happens too often. With that in mind, it should be noted that stating conservation in law and regulations is no simple task. Still we find text in ancient laws of Rome and Greece about soil conservation, and even Iceland has early medieval laws on conserving natural resources. But at present the subject has been driven towards complexity rather than simplicity. Ensuring and regulating sustainable land use is becoming a scientific field in it self. It is not our idea to make the reader tired of such ponderings, but just to explore some basic options that need further considerations.

The history of the soil conservation can teach us many lessons about the drivers needed for the creation of an effective soil protection policy (Arnold, 2004). The necessity of protecting soil and land resources needs to be perceived by the majority of the population in order for legislators to react. Several national soil protection policies have been developed over the past years in a number of countries of the world (Hannam and Boer, 2002). Certainly the most remarkable for its impact and for legislative initiatives in other countries, has been the US Soil Conservation Act of 1935, and its amendments. In the following sections we will briefly review the US Soil Conservation Act, the German federal law for soil protection and the soil action plan for England as examples of national soil protection policies.

The US Soil Conservation Act

The US Soil Conservation and Domestic Allotment Act of 1935 has had a deep impact on soil protection strategies at a global scale. It was conceived as a legislative response to the serious threat by soil degradation in the Midwest of the United States, often referred to as the “dust bowl” (see chapter 1). The dramatic drought and erosion events in the US Great Plains during the 1930’, was immediately perceived as a problem, even though the problem was many decades in the brewing. The soil conservation act was conceived in the context of the dramatic economic depression of the 1930’s. It was therefore aiming on one end on soil conservation, but on the other hand created job opportunities and economic development.

One of the main pillars of the act was the creation of the Soil Conservation Service, an agency within the Department of Agriculture, to deal with soil erosion throughout the US. This agency rapidly developed as a leading institution, both in the US and globally. A key role of local communities was one of the primary factors contributing to the success of the Soil Conservation Act.

The Soil Conservation Service provides technical support for the control of erosion through a strong partnership with Soil and Water Conservation Districts. The Districts are a part of state-level governments aimed to help rural land owners to care for their land and water resources. One of the more notable achievements was showing early on that voluntary participatory programs worked in spite of the diversity of the North-American culture. A major monitoring system, the National Resource Inventory, is now in place to provide more information to guide future policies. However, the people-to-people interactions, and an increased stewardship of natural resources are even more remarkable. Private land owners in rural areas are able to ask for and receive attention concerning use and management of their soil resources.

The 1996 Farm Bill amended the soil conservation act and the Soil Conservation Service has now been replaced by the Natural Resource Conservation Service (NRCS).

The major limitation of the act can be viewed as its narrow view on soil conservation, as it almost solely aims at a single threat: soil erosion. Modern views on soil conservation consider soils in their multi-functionality in relation to ecosystem functions, not only as

tools for delivering food and fibre. Other lessons learned from the US act (Montenarella et al., 2004) include: 1) Soil conservation can best be achieved through participatory approaches involving all actual stakeholders, 2) Sound conservation strategies require a solid legal, scientific and technical background, with an infrastructure for the transfer of knowledge to the stakeholders and 3), last but not least, substantial economic resources to sustain the soil conservation efforts on the long term.

The German Federal Soil Protection Act

A more recent example of national soil protection legislation is the Federal Soil Protection Act of Germany (1998). It is probably the most comprehensive legislation within the EU member states dealing with soil protection and it was one of the elements triggering the new developments towards a thematic strategy for soil protection of the European Union.

The main difference to the US Soil Conservation Act is the incorporation of the concept of soil multi-functionality into legislation. The purpose of this act is to protect or restore the multiple functions of the soil on a permanent sustainable basis. This includes prevention of negative soil changes, rehabilitation of soils, of contaminated sites and of waters contaminated by such sites; and precautions against negative soil impacts. Disruptions of the soil's natural functions, and it's function as an archive of natural and cultural history, should be avoided.

The act recognizes three groups of functions:

1. Natural functions,
   a) as a basis for life and a habitat for people, animals, plants and soil organisms,
   b) as part of natural systems, especially by means of its water and nutrient cycles,
   c) as a medium for decomposition, by filtering, buffering, and especially groundwater protection,
2. Functions, as an archive of natural and cultural history
3. Functions useful to man as
   a) a medium that holds deposits of raw materials,
   b) land for settlement and recreation,
   c) land for agricultural and silvicultural use,
   d) land for other economic and public uses, for transport, and for supply, provision and disposal.

The recognition that soils perform these functions reflects the aim of the policy to protect soil as an environmental resource in analogy with air and water. This is a radical shift from previous policies mostly aiming in protecting soils for single functions, like agricultural production.

Another basic element of the act is the introduction of liability of the land owner for damages caused to the soil. This opens the way to a number of implications in assessing off-site effects of soil degradation, that in several cases can be very substantial, like for example, groundwater contamination, mudflows and flooding. The principle of "the polluter pays" is a key element of the act. This aspect of obligations to prevent hazards is substantially different from the previously described US Soil Conservation Act. In this sense, the German act has a more prescriptive nature, including a large part dealing with thresholds, obligations, values, requirements, orders, investigations and finally, value compensation and fines. Most of the act is focused on the issue of soil contamination, particularly on the problem of contaminated sites. Some provisions are included for the problem of soil sealing and good agricultural practices, including soil erosion, compaction, soil biodiversity and soil organic matter.

The Soil Action Plan for England

A second example of European national soil protection policy is the recently presented Soil Action Plan for England (2004). It commits the Government and partners to actions which will improve the protection and management of soils within a full range of land uses. The Action Plan builds on the earlier Draft Soil Strategy published as a consultation

paper (2001). It is complemented by an Environment Agency report on the State of Soils in England and Wales.

The plan sets out an ambitious programme of work for the next three years, to help move towards a clearly stated vision for the nation's soils and their use. Actions of this kind are often the first step in a process followed by implementation and legislation. The aim for this first plan is to achieve as much as possible by properly embedding soil protection into ongoing work; to gather the evidence, and to build consensus and partnerships with others in Government and outside to provide the foundation for future action.
The Action Plan lists 52 actions on issues such as soil management, soils and biodiversity, contamination, and conservation of cultural heritage and landscape. The actions are scheduled with well-defined milestones and expected results over the period 2004-2006. They are based on the recognition that soil protection crosses many policy areas where legislative instruments are already in effect. By involving the many actors actively operating in the field of soil conservation, a number of synergies can be found that make the soil action plan of England one of the first examples of streamlining the different processes and policies towards a common goal of sustainable use of the soil resource.

Regional Policies

The recognition that soil protection has dimensions that cross national boarders, has initiated several attempts to develop an international legal framework for soil protection (Hannam and Boer, 2002). A European example of a regional but international legal framework is the Alpine Convention.

The Alps represent one of the most sensitive ecosystems in Europe, with steep slopes, unconsolidated glacial sediments and harsh climate. The areas are influenced by aggressive development and large numbers of tourists that has caused severe environmental damage. "The Alps are one of Europe's largest inter-related natural regions that, due to their specific and diverse nature, culture and history, represent an excellent location for habitation and the execution of economic, cultural and recreational activities situated in the heart of Europe". This situation led to the establishment of an Alpine convention following the first Alpine Conference of the Ministers of the Environment in 1989. Members of the Alpine Convention are Germany, France, Italy, Slovenia, Liechtenstein, Austria, Switzerland and the European Community (figure 5.2).

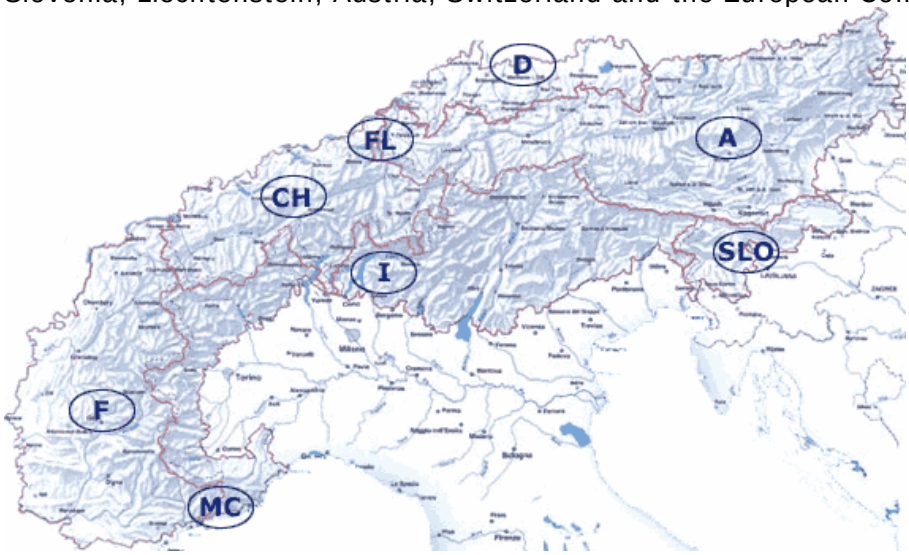

Figure 5.2 Geographic area of the Alpine Convention.

The Alpine Convention states that "the parties to the agreement shall take appropriate measures in particular in the following fields: population and culture, regional planning, air cleanness, soil conservation, water economy, protection of nature and maintenance of the landscape, mountain agriculture, mountain forests, tourism and recreation, traffic, energy and waste management."

Soils are an important component of mountainous ecosystems, in particular for water and nutrient cycling. They constitute the basis for agriculture, including forestry and livestock breeding, as well as recreational and tourist activities. The SCAPE case study in Austria (see chapter 4, case study 6) also demonstrated the importance of soils in protecting people from natural disasters. It is therefore essential to promote the conservation and sustainable use of the soil resource, taking into account the sensitivity of mountainous soils to degradation and disturbance.

The Alpine Convention is based on an ecosystem perspective and recognizes the Alpine region for its ecological diversity and highly sensitive ecological systems whose functional capacity must be preserved. The principal objective of the protocol is to reduce the quantitative and qualitative damage to soil through the use of appropriate agricultural and forestry land use methods which do not harm the soil. It promotes minimal interference with soil, soil erosion control, restrictions on the sealing of soil, and soil rehabilitation. The protocol defines the functions of soil, including natural functions, cultural functions, and land use functions, emphasising that they should be safeguarded and preserved to maintain an ecological balance in the region, including soil diversity, for future generations.

Global policies

Soil degradation is not confined to single countries or national boundaries, it is a trans-global issue. Erosion, contamination, floods and landslides do not follow national boundaries. Land degradation has a pronounced global effect on social and economic conditions. Soil degradation has climatic implications as well, as carbon dioxide cycles between soils, vegetation and the atmosphere; the soils contain the largest terrestrial amount of carbon, a fact that eludes many. Socio-economic aspects of soil degradation, particularly in developing countries, can trigger major migration phenomena in large areas. Soil degradation is relevant to the WTO negotiations, and it has been postulated that some areas suffering from soil degradation result indirectly from agricultural market distortions (Lahmar et al., 2002).

Examples of global or continental efforts for soil protection include the 1972 Council of Europe's *Soil Charter* (see Hurni and Meyer, 2002). *The World Soil Charter* (FAO 1982) and *the World Soils Policy* (UNEP, 1982) later sought to encourage international co-operation in the rational use of soil resources. The UNEP Environmental Guidelines for the Formulation of National Soil Policies set out a procedure for preparing national policy with a built-in sustainable land use element.

At the Earth Summit in Rio de Janeiro in 1992, the international community agreed on a global partnership for sustainable development and established the Agenda 21 framework. As a result several conventions were launched, including the *UN Framework Convention on Climate Change* (UNFCCC), which recognises the importance of terrestrial ecosystems as sinks of greenhouse gases and that land degradation problems and changes in land use can exacerbate the emission of gasses to the atmosphere. The 1997 Kyoto Protocol promotes sustainable development, and policies and measures to protect and enhance sinks and reservoirs of greenhouse gases, including soils. The *UN Convention on Biological Diversity* (CBD, 1992) aims to conserve biological diversity and encourages the sustainable use of its components. Fundamental to the CBD is the concern that biological diversity is being significantly reduced by human activities, including soil and land management. We should note, that biodiversity in soils is

substantially richer in species compared to the world above ground. The 1994 *Convention to Combat Desertification* (UNCCD) aims at prevention of land degradation in arid and semi-arid areas, to rehabilitate partly degraded land and to reclaim desertified land. This is attempted through actions supported by international co-operation and agreements.

Initiatives have been developed during the past years towards evaluating the possible need for a global soil convention (see also Hurni and Meyer 2002). In the late 1990s, much of the non-UN attention on soil conservation issues has been channelled through non-governmental organisations. Examples include the Tutzing-Initiative (Germany), which published a draft text for a convention in July 1998.

The Danish Ministry of Food, Agriculture and Fisheries (Wynen, 2002) published an analysis of the various options at hand for soil protection at global scale. The results of this study show the minimal effectiveness of current UN Conventions (UNFCCC, UNCBD, UNCCD) in achieving soil protection globally. It also concludes that developing a new convention for soil protection would not be the solution either, since implementation of current UN Conventions is already problematic. Two alternatives are proposed. One is to extend current conventions in order to cover soil protection more explicitly and develop guidelines and codes of conduct. The second option is to design an infrastructure that would provide the tools for pro-active approaches to soil protection on voluntary basis, which seems to be more feasible. Such an infrastructure could make use of a solid scientific basis through the creation of an Intergovernmental Panel for Land and Soil (IPLS) in analogy with the IPCC of the climate change convention, a same conclusion reached in the publication "A World Agenda for Soils" (Hurni and Meyer, 2002).
This development was extended at a SCAPE meeting in Iceland (SCAPE, 2005), where international legal measures were discussed. There it was concluded that "*there is inadequate recognition of the fragile state of the world's soils, the fundamental role that soils play, the need to improve their protection for the benefit of society, and the intrinsic value of soils. New policies and incentives, the application of existing knowledge, new and strengthened national legislation and an international instrument are required to reduce soil loss and degradation.*" And that "*A programme of action is required urgently on an international, regional, national and local level to address the conservation and sustainable use of soils. Such a programme of action will contribute to meeting the global goals on sustainable development agreed in the 1990 Millennium Declaration, the 1992 World Summit on Sustainable Development, as well as in the international Conventions on Biological Diversity and Climate Change and the Convention to Combat Desertification*." Further intended and/or recommended steps are reported in the Selfoss Statements (www.scape.org).

The European Union

The EU has long realized the need for conserving the soil resources of its member states. In a special regulation on protecting the water, the *Water Framework Directive*, restrictions have been made on activities that can pollute the precious water resources, which affect for instance how we can use our soils. But recently, there have been remarkable developments in Europe which aim to protect the soils.

The EU Soil Communication: European Thematic Strategy for Soil Protection
Soils are often disregarded by European citizens, particularly since only a small fraction of the European population is currently living in rural areas and thus, has a direct contact with the soil below or use soils for a living. The majority of the urban population has a limited understanding of the functions of soils. However, during the last 2-3 years the need for a coherent approach to soil protection has reached the political agenda in Europe and was therefore introduced as one of the thematic strategies to be developed within the European Community's 6th Environment Action Programme.

It was already pointed out in Chapter 1, that the way forward towards a community approach to soil protection, was stated in the European Commission Communication to the Council and the Parliament titled "Towards a Thematic strategy for Soil Protection" (EC, 2002). It triggered a debate at a European level on the basic principles to be adopted at EU level for soil protection.

The first question was: 'Do we need an EU approach to soil protection or should we leave soil protection as it is now, as an exclusive competence of national and local authorities?' The communication clearly identified a number of issues that need to be tackled at EU level such as the trans-boundary character and need to treat soil protection equally across the EU. In addition, soil degradation has severe off-site effects that make a cross-border strategy for soil protection unavoidable.
The communication introduces a number of innovative concepts in the design of soil protection legislation. It puts the recognition of soil multi-functionality at the core of the legislative process. This has wide reaching consequences on the overall process, since it moves soil protection from a strictly mono-functional perspective, usually linked to agricultural production (see earlier section on agronomic paradigms in this chapter), to a wider environmental and social dimension. As a consequence, soil protection becomes an horizontal issue entering into several of the existing EU policies, like the Common Agricultural Policy (CAP), the water policy (Water Framework Directive), nature protection (HABITAT directive, Natura 2000 network), forestry (Forest FOCUS regulation), regional policy, and development policy.

The debate about the future EU soil protection strategy has had a broad stakeholder consultation that was organized by the European Commission during 2003-2004. This yielded a very comprehensive collection of basic documents elaborated by five technical working groups dealing respectively with monitoring, erosion, organic matter, contamination and research (http://europa.eu.int/comm/environment/soil/index.htm). These documents will be used as the basis for the drafting of a Soil Framework Directive expected to be presented in its first proposal towards the end of 2005 (may change).

The EU soil protection strategy builds upon the recognition that important functions of soils are threatened by severe degradation processes. The major threats identified so far are soil erosion, decline in organic matter content, loss of soil biodiversity, soil contamination, salinisation, soil compaction, soil sealing and major hydro-geological risks (flood and landslides).
Some of the threats will require a specific approach:

- Soil contamination requires taking into account the burden of the existing contaminated sites, which are in the order of millions in EU countries, and therefore will be approached through a locally adapted strategy on a case-by-case analysis of the local situation.
- Soil sealing should be left to the competencies of national and local administrations, since spatial planning issues fall fully under the subsidiary principle of the local community.
- The loss of soil biodiversity will require more knowledge about biota in soils before any action can be taken, since soil biota are still very little known. Further research will be needed in this area of soil science. However, it is known that rich organic soils contain more species than poor soils, and soil conservation will therefore immediately affect soil biodiversity.
- Flooding in Europe is a major natural hazard and is already approached by specific prevention and mitigation strategies.

An efficient soil information system capable of giving answers to the questions raised by policy makers is important for implementing soil protection policies. Soil information is available in Europe. Unfortunately a lot of this information is scattered in different institutions both at national and at European level. The proposal for a common approach to soil monitoring that the Commission will put forward will address this problem.

Solutions can then be proposed that take into account existing soil information systems, a framework allowing for the interchange of data in a harmonized way across the EU.

In the longer term, the availability of policy relevant soil information will increase efficiency of the implementation of measures to achieve soil protection for sustainable development in Europe.

New Effective Methods: Financial Incentives

Linking land use practice with agricultural subsidies may seem problematic and in need of complex bureaucracy. Although monitoring and increased professionalism will be needed at all stages, from national governments and agencies down to local communities, it should be noted that indirect methods exist that are rather simple in use. Research findings on the effect of any given agricultural practice on certain type of soils and landscape (e.g. wheat on a steep sandy slope) are available. Furthermore, extensive mapping of soils and landscapes can be used (and are already in places) to assess the risk and sustainability of a given practice and pinpoint problem areas. However, it is also important to note that it is within the philosophy of Agenda 21 to make local agencies as much responsible for the work as possible (bottom up approach). For this, part of rural development funding aimed at the environment could be diverted.

Subsidies are not a private matter, they are provided by the public as a part of an agreement between the society and producers. As such, all information regarding subsidies should be public, from general overview to expenditure for each farmer. Subsidies have multiple and variable purposes. They are as such a method to maintain livelihood in rural areas. They are also important for encouraging certain land use patterns, providing food security, and conserving landscapes. Subsidies can enhance soil conservation, The implementation of subsidy policies should allow for effective and transparent monitoring and account for the agricultural subsidy system.

The European Union is already using financial incentives to improve the use of soils of Europe. The recent mid-term review of the Common Agricultural Policy (CAP) of the EU has further specified the good agricultural practices, including soil protection measures that should be included in the measures which are obligatory for cross-compliance with environmental targets. Council Regulation (EC, No. 1782/2003) of 29 September 2003 has recognised the main issues that should be addressed by Good Agricultural Practices: soil erosion, decline of soil organic matter and physical soil degradation. It will be left to the EU member states to implement these practices at national level.

Tying land use practice with subsidies seems problematic when it is assumed that every farm in Europe needs to be checked by the EU (top down). This can be turned around. Research findings and risk assessments (already available) can be used to pinpoint problem areas where we should focus attention. In some areas, certification by local experts is needed for subsidy payments. And local agencies/communities should be made responsible for the work (bottom up). This approach has great effect on land literacy within communities (provides incentives for literacy). But this kind of information needs to be firmly established.

Financial incentives are not enough: a need for firm legal ground
If environmental concerns are made solely based on financial incentives (through cross-compliance etc), the system will become vulnerable to production methods that are not subsidized and solely driven by market concerns. This is an additional reason why we need law and regulations, not only incentives and participatory approaches.

Box 5.3. The carrot or the stick. *Regulations, law, and financial incentives or penalties are different sides of the same coin. Financial incentives that state that certain conditions in land use have to be met need to be founded on how society wants to use it's resources, which then, again, needs to be formulated in laws and regulations.*

Changes and time: the "sunset" approach

It is vital for the success of new European soil conservation policies that they are not implemented too hastily. A key to such an approach can be the so-called "sunset" approach, which establishes grace periods for implementing land use changes that are considered necessary for conserving soils and nature. A rationale for such methods could be:

a) If management of the land needs improvement, the land owner is given 2-10 years to do so, but has to submit a plan how he is going to do this (and it is verified).

b) If the land use is entirely wrong and can not be sustained (severely degraded areas), such land use is abandoned but with continued subsidy rights over a given time, or, alternatively, the land owner is granted 7-10 years to quit, but has to minimize impact on land in the meantime (submit a plan developed with local agencies).

Such a "grace period" interacts with generation change of ownership and market property in an important manner. If it is known that certain production is on "grace-period", it is known that the property has no value for that production after the grace period. Therefore, it can not be sold as such, and the subsidy rights do not extend between generations. But the current farmer can live and make plans for other production, or retire with full grace ("sunset"). This reduces negative effects on rural communities; changes are slow but in the right direction, which is quite important where changes in land use are needed. Land taken out of production can be used for other purposes or such as for nature protection, development of landscape and tourism.

A marriage of agriculture and environment

By incorporating environmental conditions, the EU and the USA are using new regulations to de-couple agricultural production from the farm subsidy system. It can be argued that using environmental conditions for financial support to farmers is a method to make sure the EU and the USA can continue to support their farmers in spite of international developments that limit direct subsidies for agricultural production.
Both the EU and United States are moving forward with plans to expand their agri-environmental programs. The agricultural policy reform adopted by the EU in June 2003 significantly increases the CAP's focus on the interactions between agriculture and the environment by shifting some funds from producer support to environmental programs, implementing compulsory cross-compliance. In the United States, the farm bill enacted by Congress in spring 2002 includes the new Conservation Security Program, which will introduce a form of "green payments." These payments are intended to accomplish the task of improving the environmental performance of production agriculture, but may also provide an alternative source of farm income relative to traditional commodity programs.
As environmental movements in developed countries grow more influential, the recasting of farm support programs in a "green" light may become more politically popular. Providing environmental services through agricultural programs may become an increasingly important rationale for continued agricultural support in the future. If new WTO trade negotiations produce an agreement to further reduce trade distorting domestic support, countries may find it necessary to shift support from programs that

are subject to reduction to exempt programs, such as agri-environmental programs that qualify for inclusion in the WTO's "green box". Such a shift will require more than cosmetic changes to price and income support programs if they are to comply with WTO criteria for green box payments.

For both the people of rural areas of Europe and North America, and the protection of its fragile natural resources, this can be considered a win-win situation. Is there a cost? There is for the consumer who could find himself paying for surplus and unnecessary "protection or stewardship" that is not really about protecting the environment but about creating a mechanism for supporting political constituencies. The policy needs to be open with clear set of goals, effective, and just. Not a mere effort to divert funds. Can the resources be used for more sustainable development activities? What about the effect on the development countries?

A very important requirement when changing policy is the necessary knowledge of resources and the capacity of organisations to design, implement and monitor the impacts. To achieve this training programmes are needed.

Chapter 6

SCAPE - The Way Ahead

European issues

Where are the problem areas and how to deal with them?

Approaches that a soil strategy might follow would entail combinations of land use planning, involving some kind of zoning according to the risk or hazard, and the setting of limits, for example on the levels of toxic chemicals, salt content, organic matter or soil erodibility. Our impression is that for these reasons, responsible organisations are pre-occupied firstly with identifying areas at risk and secondly with the need for indicators.

It seems at first logical to prioritise soil conservation and protection efforts according to the sensitivity of areas affected and the consequences of the risks. We know that some areas like wetlands and active river floodplains are both sensitive and absolutely critical. Nevertheless, when addressing soil threats at detailed scales, SCAPE found that what really matters is knowledge about the underlying processes and causes. Addressing processes and causes should always be the main strategy. Sometimes it is appropriate to apply zoning but this should be contingent on the context. If causes are inadequately understood, research and caution are necessary. Regulations have been shown to be pathological if they adopt a command and control application that ignores processes. Whilst data and indicators are needed, they are dangerous in the hands of people who inadequately grasp the nature of the problem (Holling and Meffe, 1996).

A conclusion from our studies is that whilst some areas are more sensitive than others, even the most sensitive areas are not really at risk without a cause. The landscape is characterised by hot spots and hot moments. Strategies should consider that the nature of risk changes in time as a result of the impacts and responses to these by people. With erosion, for example, the main triggers relate to policy decisions (e.g. to initiate land consolidation projects or to promote a land use change that alters the buffering capacity of soils and river channels). We found great similarities between the different regions of Europe regarding both the soil threats and how to deal with them, and always there were strong European and local dimensions. There is a need for new criteria for planners who should be more aware of the way in which landscapes and systems adapt and evolve in response to medium and long-term processes. They need to manage or adapt to threats that were triggered by causes often decades ago, and these need to be absolutely site specific. Using modern remote sensing is practical for this.

In the case of agricultural and afforested land, conservation actions can be tailor-made for each field or slope to take advantage of natural regenerative soil processes. For example, each field could have its specific soil conservation targets and make use of balanced score-cards when evaluating performance.

Implicitly it seems that the current strategy of the EU is to employ the same drivers that helped causing some of problems in the past, as instruments that can now be used combat them. This seems to be the intention behind cross compliance and stewardship policies. If soil conservation and protection is incorporated into Agriculture and Regional Planning, the economic forces that caused many of the past problems will now be applied to their solution. This could be very effective. In order to accomplish this, regulations are needed which are backed up by an organisation that is responsible for co-ordination and monitoring.

A European Soil Conservation Service to safeguard the soil

An important issue is the gap between how soil protection and conservation should be organised to meet goals of sustainable land use and the current situation. Coordination is needed by the agencies responsible for European soil conservation in areas of education and training, monitoring, archiving and research. If a small percentage of the money that is going to be used for soil conservation and protection activities in regional development and agriculture could support a coordinating organisation, this would be exceedingly efficient. It would greatly increase effectiveness and prevent inadvertent impacts of policies.

Expert scientific and practical knowledge in support of soil protection needs a long-term mandate. Soil conservation and protection is a long-term commitment, just as afforestation programmes are. They need to be organised over long periods of time (decades). It is wasteful to rely on organisations or instruments that have limited existence and funding.

The advantage of an organisation that has existed for some time is that it has a memory of what happened in the past and there is a capacity to forecast problems. Complex land use planning decisions should be scientifically sound and anchored in different disciplines (see Briassoulis, 2005). Soil Conservation and Protection should be embedded in an overall strategy that includes all "systems and sectors". An example of how this could be achieved is provided by New Zealand (Grinlinton, 2002 and 2005). With its different Directives and national legal traditions Europe has a long way to go to develop a directive that will meet the expectations of its people, and there must be a focal point that guarantees soil conservation and protection.

Coordination actions are also needed to explain and communicate soil threats. Without coordination people speak different languages and there is wasteful duplication of effort. A soil conservation service would have the task in providing stakeholders with the knowledge and data they need. The USA provides us with a demonstration. The Environmental Protection Agency (EPA) has a scientific strategy with clear action plans. A few years ago principles of watershed ecology and risk management provided a conceptual underpinning. Everyone in the USA could see how all of the different issues and processes are holistically linked. Citizens can better judge the impacts of land use and other policies. The USA makes vast amount of data and information freely available to whoever needs it. The contrast with Europe, that only has effective national monitoring in some countries, is great. Europe is at a huge hidden competitive disadvantage with the USA and other countries because of the lack of coordination in this respect. This is painfully apparent when the information of the EPA and NERC (soil quality) is compared with that on EU websites. So, where does the buck stop?

A story from Portugal

The need for another type of soil conservation and protection authority is illustrated by the current tragedy unfolding in Portugal, reported by Roxo (2005) in a meeting on Desertification held in Brussels. It concerns a semi-arid area in the Alentejo region that has traditionally been used for raising sheep, goats and pigs, and growing wheat. In August 2005, vast numbers of cows started to appear in every field and paddock. Why? There was a new subsidy.

The cows soon grazed all living plants, totally denuding the soil and creating desert like conditions (figure 6.1). The region has too little water to be naturally suited for cattle raising and there is no natural pasture. According to the UNCCD National Action Plan this area is threatened by desertification. When this story was told in Brussels the people who made the subsidy available for cattle said that it was not their responsibility: they only made money available. "It is the responsibility of the region". Where is the UNCCD?

Back in the region, or in fact Lisbon where things are organised, there is a different story. If there is money available, people are assisted in making use of it. Most people were content. "What is done with the money is never an issue". Roxo (2005) explained that there is no organisation in place to give advice; that people are strongly individualistic and see nothing wrong if someone benefits as much as possible from an intervention. If there was a problem then the Government would not be dumb enough to give money. So, as you read this story, the bare soil which was Portugal's future has gone the way of the Dodo, on an Island that was also managed by Portugal. The soil is disappearing into the reservoir that the EU just paid billions for on the River Guadiana. Today, at its Joint Research Centre near Milan, the EU can observe with its satellites the desertification that is accelerating climate change in Portugal, but nobody is doing anything about it. Desertification such as this will really make it hotter and dryer next summer, contributing to regional climate change and further desertification.

Figure 6.1. Due to new subsidies for having cows, the soil was degraded in the Alentejo region, Portugal.

Stewardship

Instead of for sheep or cattle, subsidies could simply be given for soil conservation and protection actions in schemes that involve "Stewardship". This is a publicly accepted strategy but not one without risk. Instead of overgrazing there could be "over soil protection". In many parts of the world landscapes and soil functions have been devastated or vandalised by technically or budget driven soil conservation programmes. It sometimes seems that bulldozers have built often unnecessary soil conservation terraces over half of Africa. Subsidies have led to a proliferation of mechanically built terraces that have resulted in much erosion because they destroy the soil structure and compact the soil. The paradox is that while the rural population was engaged in a process of abandoning its terraces, organisations or businesses funded by public money, were constructing them to grow almost anything that was subsidised. Looking back at our case studies in Chapter 4 and elsewhere, the issue is not just the impact that spending this money has had on

Actions that a European Soil Conservation Service could take

- ✓ *Coordinating and directing the exchange of soil protection knowledge*
- ✓ *Establishing guidelines for good practise, impact assessment, carbon sequestration, biodiversity and flood control*
- ✓ *Supporting the development of specific and integrated legislation*
- ✓ *Training and indicator applications for agriculture and rural development*
- ✓ *Supporting the UNCCD in developing guidelines for NAPs for areas affected by land degradation*
- ✓ *Providing a service to monitor the performance of cross compliance and agri-environmental schemes.*
- ✓ *Providing evaluation mechanisms and criteria (e.g. balanced score cards) to protect soil functions from inadvertent impacts of subsidies or market driven forces.*

the soil. The money might have been spent as part of a plan that could be monitored and controlled and which was guaranteed to do something useful. It is almost as if nobody is managing or evaluating the consequences that spending of vast amounts of capital is having on Europe's soils. The main criterion is that people receive enough support. This explains why a European Soil Conservation Service should be a priority.

A soil conservation service could give direction to national and Regional authorities on whose responsibility this would be. In this whole area of support, the principle of subsidiarity means that decisions about what should be done to protect the soil will be decided locally. This is fine in a well-developed and organised country like Italy, but it creates problems in countries that miss the organisation or tradition of drawing up complex integrated programmes of the kind that are needed.

Popularisation, awareness and education

"Our technical articles are being read by a small coterie of fellow specialists, and the leading national press ignores them completely" (Jenny, H. 1984).

People active in soil conservation and protection are aware of the inter linkages soil has with almost any societal issue. They often wonder why soil is not placed higher on the agenda. They might feel that people do not care about soils or that policy makers are not concerned about them. Throughout the different levels in society -global, national and at the community level- soil fails to be perceived at its expected place in the hierarchy of necessities for life. This might have cultural or historical reasons but, the soil as a vital element, next to water and air, is commonly absent.

Soil is an extraordinary thing for most people, hidden from them even when they dig into it. It slips through our fingers in more ways than one, we walk on it, we use materials from it to build our houses, our food grows from it, and the list is long… No soil is identical to another and in soils very complex processes are at hand. Nevertheless, there is a lot of knowledge of the intricate balances that are relevant to soils. There is clearly a discrepancy in how we treat soils and what soils actually mean and do for us. To tackle these concerns there are ways ahead.

We can explain better the different levels; distinguish between global, national and regional levels, distinguish between governments, policymakers and end-users. But to really address the ignorance about the soils, we should start to make soils part of our daily experience, which can best be done through education and making soil more popular by explaining some crucial, often eluding, influences soil has on for instance success in sustainability and climate change.

At a global and/or national level, scientific findings and discoveries should be better translated to both end-users and policy makers. In the area of soil conservation, more weight should be put on practical science or on making science practical. To achieve this aim, it is suggested to call for a new group of scientists; the multi-linguistic. The multi-linguistic scientists will primarily deal with translating the scientific findings to the other actors involved. Furthermore, they will also encounter and explain the problems that the end-users are facing in the field, to both scientists and policy makers. The implementation of knowledge will be improved through better communication and through practical examples in the field. In short, they will help tremendously in creating a better flow 'top down-bottom up'. In the USA this discipline already exists and these people are confusingly known as "interpreters". They are employed by National and Regional Parks for example to interpret the science to park visitors.

All levels of life are complex, be it a farm or politics, the role of a person within any level of society is complex. It is hard to get attention when there are already many things that demand attention or immediate action. To get soil higher on the ladder of community

assets, soil should be popularly incorporated in education. There are many positive examples of this throughout the world, but often they are scattered and fragmented and thus loose their potential to make soil become a cultural approved and respected aspect.

Today, often little weight is given to the significance of local circumstances on the choice of land management systems. A focus on soil functions and the possible role of landowners in improving soil health could be an integral part of agricultural and forestry education programs. In areas at risk, Extension Services should focus on how to solve the local and regional soil degradation problems. Practical examples of good practices should be made visible to landowners. The link between the results of scientific research and solving the problems of soil degradation in practice should be made clearer and good information channels need to be developed.
It is the opinion of SCAPE that the case studies in Chapter 4 provide a window to the current situation in Europe regarding both the actual threats to soil and the solutions. The case studies were used both to help understand the soil conservation and protection issues involved and to learn from successful experiences. Experiences from good practices should be made available both nationally and internationally. Experiences from one country or region cannot be copied to the other, but may be used in the development of new ideas and approaches.

As mentioned in Chapter 1, raising awareness about the importance of soil conservation and protection for the welfare of our modern societies has to be a major policy goal. The unification of scientific expertise is a key in sustainability of societies. This search for generality would require the cooperation of experts in other fields who share the curiosity and fun of mutual discovery (Holling et al., 2002). This is one aspect for Europe, in which an EU Soil Conservation Service could actively play a contributing role (Curfs, 2005).

Thirty years ago the public was ignorant about climate change. This has now been changed through the persevering struggle of many scientists, who succeeded to raise the awareness among the public concerning this subject (Curfs, 2005). Now we might benefit from this previous struggle to use the general awareness of climate change to increase awareness of the precious resource soil, amongst others by addressing its influence on and interaction with the climate and climate change.

European Service to coordinate:

- ✓ *Communication, training and education programmes to raise public awareness of the importance of the soil*
- ✓ *Translation of science to present soil conservation to decision makers and practitioners using up-to-date more realistic paradigms*
- ✓ *A platform where different actors or agents can come together and freely debate and develop strategies that are anchored in different scientific disciplines, sectors and systems*
- ✓ *A databank of good practices in educational programmes and soil protection and conservation strategies that can be accessed easily*

The Paradox
Although we feel that it is necessary to raise the awareness about the need for soil conservation and protection, we do not want to isolate soil from the systems and sectors in which it occurs. We should leave soil in the landscape and ecosystem, where it is part of the hydrological and bio-chemical cycles as well as a common resource and good. We should not make a mountain out of the soil and then go and study it. This is explained in the section below where soil is considered in a broader context.

Knowledge and Data

Data, information, knowledge and understanding about the soil and its functions is needed to describe the current status of critical functions and to evaluate the performance of soil conservation measures. European countries have developed their own systems to gather and store soil data. This data is not always accessible to people who really need it, which are policy makers, people working on the land and other soil stakeholders. Besides, soil inventories are often incomplete, or at a too coarse scale. If we want an EU Soil Protection and Conservation strategy to be successful, it is essential to harmonise existing data and information systems and, if necessary, complete them. This should be done at a scale of 1:125,000 or greater. A European monitoring system is needed to be able to evaluate changes in soil conditions, for example as a result of changed land management strategies. To assure similar future soil inventories, a common baseline is needed.

It is equally important that such a data and monitoring system is made accessible. Not only for policy makers and farmers to be able make correct decisions on land use, but also to make the general public aware of the changing status of soil under different land management strategies (see previous section). To develop and implement an EU soil inventory and monitoring programme, an EU body such as a Soil Conservation Service is needed.

Soil Indicators

Data should be converted into *indicators* that can be linked to policies and issues in a holistic way that considers all sectors and systems. An example of how this could be done is given by the Desertlinks indicator system (see www.kcl.ac.uk/projects/desertlinks/accessdis4me.htm), in which all kinds of potential customers who need data on any aspect of desertification can select the indicators that they need or understand as a result of their area of expertise. Such an indicator system would be very valuable for the soil as it would direct the user to the indicators that are correct for his/her issue (e.g. soil erosion), and which are matched with a scientific interpretation and analysis of his/her problem and needs.

Great practical progress has been made (for example in the USA and Canada) in monitoring of soil quality and soil health indicators into both soil survey ecosystem monitoring and in assessments made by land users by means of a *balanced scorecard approach*. Responsible stakeholders can set performance targets, for example for soil organic matter accumulation and evaluate the performance by key indicators. All that needs to be agreed upon are the indicators and procedures that could be applied under European conditions. There is much experience in training land-users to make simple measurements and tests that will yield data on soil quality indicators. In the LUCAS programme thousands of fields are being surveyed and photographed each year. The possibility of expanding the LUCAS programme to include scorecard approaches and quantitative measurements of key indicators and digital photos would be a useful strategy. A common European wide programme could be set up at different scales as part of for example, agriculture and rural development programmes. Such data could be accompanied by *remote sensing*, using for example Quickbird, and used to both set and validate the attainment of soil management goals of compliance schemes. It would be possible to use the data collected in this way as a detailed monitoring system that gives immediate feedback to the responsible authorities regarding soil threats and soil quality. A programme such as this would require a European (soil conservation) service for establishing the methodology and protocols, awareness raising, training and supporting extension officers and land users, and for monitoring and archiving.

Soil structure as a key indicator

The structure of the soil and how this reacts to wetting can be used to develop a key indicator for the threats of organic matter decline, soil degradation, biodiversity loss and erosion. Different aspects of soil structure and soil behaviour can be monitored very easily by farmers in the field. An early warning of a future soil erosion, desertification or biodiversity loss problem can be detected from advanced warnings that can be observed in the soil structure. Some of these changes can also be observed using remote sensing. It is recommended that soil structure observations are made by the farmer as a key component of the scorecard method. A farmer could be provided with soil conservation targets (e.g. improving soil structure to retain more organic matter and water). He could use an indicator scorecard to observe how successful he has been and to identify problems. The farmer would in fact be monitoring his own performance and at the same time providing the EU with data to monitor the state of the European soils. Advance warnings of desertification and photos could be included and archived by the Soil Bureau or Soil Conservation Service. This could also be linked to monitoring by remote sensing (GEO).

Data and Monitoring recommendations:

- ✓ *Harmonise existing EU soil data and information*
- ✓ *Develop a common EU baseline for soil inventories at scale 1:125.000 or finer*
- ✓ *Set up common monitoring programmes*
- ✓ *Define indicators for soil conditions which can be linked to different policies and issues*
- ✓ *Assure & verify that indicators are easy to measure in the field*
- ✓ *Use of scorecards to determine soil conditions*
- ✓ *An European Soil Conservation Service (SCAPE) to coordinate above mentioned goals.*

Imeson (2005) explained in detail how this could be done. Experience in Germany (Beste, 2005) and the USA could be used to perfect procedures that are already in use. There is no reason to wait, this can and should be done immediately. As already said, the data collected could be organised as part of a monitoring programme for detecting desertification and problem areas supervised by a European Soil Conservation Service.

Land Ethics and Stewardship

The underlying values of soil conservation and protection are critical. People's attitude towards the land and the legal rights that they enjoy have evolved with colonisation and industrialisation. The concept of land ethics put forward by Leopold in his Sand County Almanac" (Leopold, 1984); the realisation that growth is limited as explained by "The Club of Rome" and the realisation of what we had done with DTT "Silent Spring" (Carson, 1962) were landmarks of awareness raising. These all changed the attitude towards the land and influenced how society perceives the rights of the landowner. Goldstein (2000) describes the different benefits and responsibilities that accompany land ownership. What ownership entails is partly driven by what society wants and is linked to the ethics of the day. At this moment in time, in the USA and Europe one of the core ethical values is "Stewardship". This is a responsibility to take care of the land and to maintain it. The urban population needs healthy food and water but also a safe uncontaminated landscape to explore, and citizens expect the right to enjoy a landscape wherein they can seek self-actualisation. The value of Stewardship as an obligation of an owner must hold promise, but Stewardship must be based on real ethical values and not depend upon payments.

As described in Chapters 3 and 5, Agriculture and Regional Development subsidies will probably be used to support landowners in their Stewardship activities. Recently, at a workshop in Potenza, Quaranta and Salvia (2005) pointed out that it has been agreed that some of the 53 billion euros EU regional development programme could be used to combat desertification as well as many of the soil threats. Several regional authorities in

Italy described ambitious projects that were having success in soil protection. In particular an impressive number of young scientists had been trained to give direction to the work. In the UK stewardship schemes are already being implemented.

Soil placed in a broader and more realistic framework

Nowadays, soil conservation and protection refers not simply to the physical soil itself but to the *soil as part of a functioning and living ecosystem that provides all the eco-services* described extensively in this book. Managing and conserving the soil means that we allow the soil to fulfil its functions of water and flood regulation, to provide a medium for plant growth and at the same time to be a habitat for most forms of life. Soils also provide carbon sequestration and regulate the climate in many ways. Soils and their ecosystems are interconnected by climate, the flow paths of water and sediments as well as by migrating animals. Soil protection and conservation should therefore take place within the broader framework of water and land use management. If it makes no sense to isolate the soil from its ecosystem and its cultural and ecological setting, it makes no sense to have a separate legislation for soil protection.

Soil conservation strategies should be based on sound scientific concepts that are *holistic* in character, and it should be able to forecast both areas that are at threat and successful strategies. A weakness in Europe is that the methodological basis of much thinking is essentially statistical. It is much more efficient to have a planning or management framework that is realistic. Such an approach is widely used in Australia and the USA. Its value lies in the fact that soil threats do not occur everywhere but rather as already mentioned at "hot spots" and at "hot moments".

Placing the Soil in a more Realistic Frameworks

- ✓ *A realistic scientific framework (e.g. Adaptive Management Paradigm)*
- ✓ *A realistic conservation framework that includes the whole landscape and its geo-heritage and biodiversity*
- ✓ *A realistic SOIL-WATER-VEGETATION-CLIMATE Conservation framework covering all sectors (e.g. agriculture, forestry tourism) and linked to land use planning and development.*
- ✓ *A realistic framework for communication.*

Desertification

Today, desertification can occur everywhere, also in central and northern Europe including Iceland, and is not solely linked to poor land management or poverty. Often it can be clearly seen as a kind of collateral damage that follows the implementation of specific rural development or agricultural policies. Combating desertification in Europe therefore requires dealing with the underlying drivers as well as the impacts. It is not so much that people do not always know how to manage the land; it is rather that people are expert at obtaining and using the financial and other incentives on offer (from the market, national governments and EU) and do what is necessary to obtain these regardless of the impacts on the soil and environment. The story from Portugal above illustrates this. More information about desertification can be found at www.scape.org

Land degradation should be addressed holistically by an independent intergovernmental scientific panel, similar to the IPCC (see below). Research and practice should focus on the application and implementation of existing tools and knowledge, based on principles of adaptive management. An understanding of the causes of desertification should become part of common knowledge of society through education. This should explain and communicate the knowledge of the drivers of desertification.

A Conclusion: European Soil Conservation and Protection in the Global Arena

It is now generally appreciated that both the global economy and the global climate are major drivers of environmental change. In a world linked by flows of information, energy and capital, changes somewhere can have an unintended impact almost anywhere. Protecting the functions of the soil in Europe should be part of broader sustainability criteria when land planning decisions are made. Wouldn't the tourists from Northern Europe, who play golf in Crete and the Algarve, like to have the guarantee that what they are doing is sustainable and not negatively impacting the soil and ecosystem functions? Entrepreneurs, who identify opportunities to create wealth that can be to the benefit of both the local and global communities, need to know that the long-term interests of the soil and land resources are not being compromised. Neither Europe nor the World has the organisation and laws that are needed to safeguard soil functions from market and subsidy driven land use and development.

The issue is: how can the global drivers of soil and land degradation be moderated and incorporated into soil conservation strategies?

In particular the impact of world trade agreements, export subsidies, technological innovation and the development of new markets needs to be given attention in order to avert global scale soil and land degradation. This is in fact a major driver of climate change. Examples of catastrophic global scale soil loss and land degradation can be seen in many continents and contexts. These include the current high rates of wind and water erosion and desertification in China, due to a combination of drought and economic development; the catastrophic erosion now taking place in Vietnam as a result of cutting down rain forest to grow coffee; and the erosion in Brazil to produce soya. It is a paradox that the refusal of Europe to accept genetically modified soya from the USA created a demand for soya, and in this way became a driver of forest destruction and land degradation. Decisions about development and land use policy are made by Regional and National Governments. Laws are either not in place or not being applied. There is no information available to local authorities, who may not even exist and in any case have no influence or sufficient power to restrain people from changing the land use to grow coffee, soya or whatever. The UNCCD has not really provided governments with the scientific tools that is needed to regulate land use. Poor people are often blamed for causing erosion. But issues of poverty are misleading, as it is frequently the poor people who are managing the land in the most sustainable way. The link between poverty and desertification that the UNCCD promotes is always contextual and often misleading. Although some organisations are serious about stopping desertification, organising mankind as a whole is not yet engaged. And yet without stopping desertification, we can never tackle climate change or safeguard biodiversity.

The importance of International Co-operation

Internationally coordinated collaboration can be very effective in protecting the environment. Much is being done. A pre-requisite is funding and political will. Soil conservation and protection, needs to be placed high on agendas. Encouraging, strengthening and improving the science behind the programmes of International Organisations that are directly dealing with the issues (for example FAO, GEF and of course the UNCCD) would be highly beneficial. Effective organisations need commitment, capacity and knowledge. There are obviously huge differences in the resources and capacity of different countries, so that the collaboration of nations in regional or even better global action plans is helpful. International and bilateral support is useful (e.g. from UNEP, FAO or INCO) and can be vital in providing resources necessary for nations and organisations to coordinate their activities.

International Conventions are important because they provide legally binding agreements, in which governments and international organisations commit themselves to implement action plans to tackle shared problems.

Addressing the Global Dimension of Land degeneration:

- ✓ *Strengthen the scientific instruments of the UNCCD so that land degradation is detected early (e.g. with remote sensing).*
- ✓ *Land degradation Impact assessments should be on the shelf.*
- ✓ *Soil Conservation Services are needed for training, monitoring and data archiving. These should have a supra national regional mandate.*
- ✓ *A GMES or GEO system to provide information on actual conditions*
- ✓ *Raise awareness*
- ✓ *Develop land ethics and legislation*
- ✓ *Use synergy between different conventions*
- ✓ *An IPCC for soil conservation is needed (IPSC)*
- ✓ *Make inventory of Natural Resources*

Earth Observation and Soil Protection

Until now, one of the main difficulties faced by the UNCCD is that there is no real accurate way of measuring or checking the claims made about the implementation of the convention. New advances in remote sensing now mean that it is possible to track and monitor desertification everywhere. Organisations can now be provided with up to date information of problems so that they can be immediately tackled. One of the tasks of an International Panel on Soil and Land Conservation would be to monitor and provide information. Archiving and organising information could be linked to a programme such as GEO. Recent advances in protecting forests in Northern Brazil have been achieved because there is a more or less real-time monitoring at the scale of individual trees.

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References

So(i)l(e) facts

Eisenberg, Evan. 1998. The ecology of Eden. Alfred A. Knopf. ISBN 0394577507.

Silver, Donald M. 1993. One Small Square Backyard. New York: W.H. Freeman & Co.

Stuart, Kevin. 1984. My Friend the Soil: A Conversation With Hans Jenny. Journal of Soil and Water Conservation. 39:1, 158-161.

The Soil Biology Web Page (from the NRCS Soil Quality Institute) at http://soils.usda.gov/sqi.

Warshall, Peter, 1999. Whole Earth 96, Celebrating soil- Mother of all things.

Wilson, E.O., 1984. Gaian Naturalist, Whole Earth, Spring, 1999.

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Bennett, 1930. http://www.soil.ncsu.edu/about/century/hugh.html.

Bullock, P. 1999. Soil information: uses and needs in Europe in P.Bullock , R.J.A Jones and L. Montanarella (editors) Soil Resources in Europe. Official Publications of the European Communities Luxembourg 177-182.

EC 2002. Communication of 16 April 2002 from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions: Towards a Thematic Strategy for Soil Protection [COM (2002) 179 final]. (At: http://europa.eu.int/scadplus/printversion/en//lvb/l28122.htm).

ELSA e.V. / Policy document: Soil protection means flood prevention, 2002.

Goulding, K. W. T. and Poulton, P. R., 2003. Des experimentations de longue duree sur la recherche en environnement. Un exemple pris en Grande Bretagne. Etude et Gestion des Sols 10, 253-261.

Hannam, I. and Boer, B., 2002. Legal and Institutional Frameworks for Sustainable Soils. A preliminary report. IUCN Environmental Policy and Law Paper No. 45.

Holling, C.S., and G. K. Meffe, 1996. Command and Control and the Pathology of Natural Resource Management. Conservation Biology 10, no. 2: 328-37.

Jungerius and Imeson, 2005. Globalisation, sustainability and resilience from the soil's point of view. In: Proceedings of the International Workshop Strategies, Science and Law for the Conservation of the World Soil Resources, Selfoss, Iceland, 14-18 September 2005, ISSN 1670-5785.

Rapport, D.J., 1995. Ecosystem Health: Exploring the Territory. Ecosystem Health 1: 5-13; Costanza, R., 1992. Toward an operational definition of ecosystem health. in Ecosystem Health: New Goals for Environmental Management. Costanza, R. Norton, B.B., Haskell, B .J. , (eds.) Island Press, Washington, D.C. and Aguilar, B. J. 1999. Applications of Ecosystem Health for the Sustainability of Managed Systems in Costa Rica. Ecosystem Health 5: 1-13.

Rubio, J.L., Imeson, A.C., Bielek, P., Fullen, M.A., Andreu, V., Pascual, J.A., Recatala, L., Año, C. and Rengel, M., 2005. Directory of European Organizations and Persons Working on Soil Protection.

SCAPE, 2005. Strategies, Science and Law for the Conservation of the World Soil Resources. International Workshop, Selfoss, Iceland, 14-18 September 2005. AUI Publication no. 4. ISSN 1670-5785.

Yang Youlin, Victor Squires and Lu Qi, 2001. GLOBAL ALARM: DUST AND SANDSTORMS FROM THE WORLD'S DRYLANDS, United Nations.

Chapter 2

Avery, B.W., 1987. Soil Survey Methods: A Review. Soil Survey Technical Monograph No. 18. Cranfield University, Silsoe, UK.

Bølviken, B., Demitriades, A., Hindel, R., Locutura, J. O'Connor, P., Ottesen, R.T, Plant, J., Ridgway, J. Salminen, R., Salpeteur, I., Schermann, O. and Volden, T. (eds.), 1990. Geochemical mapping of western Europe towards the year 2000. Project Proposal. Geological Survey of Norway (NGU) Report 90-106. 10 p. and 10 appendices.

Bølviken, B., Bogen, J., Demitriades, A., De Vos, W., Ebbing, J., Hindel, R., Ottesen, R.T., Salminen, R., Schermann, O. and Swennen, R., 1993. Final Report of the working group on regional geochemical mapping 1986 – 1993. Forum of European Geological Surveys

(FOREGS), Geological Survey of Norway (NGU) Open File Report 93-092, 18 p. and 6 appendices.
Darnley, A., Björklund, A., Bølviken, B., Gustavson, N., Koval, P.V., Plant, J.A., Steenfelt, A., Tauchid, M., and Xuejing, X., 1995. A global geochemical database for environmental and resource management. Recommendations for international geochemical mapping. Final report of IGCP-project 259, UNESCO Publishing, Paris, France, 122p.
Dent, D and Young, A., 1981. Soil Survey and Land Evaluation. Goerge Allen and Unwin, London.
Dobos, E., Micheli, E. and Montanarella, L., 2005. The Development of a Soil Organic Matter Content Database using 1000 M resolution DEM and MODIS data for a Pilot Area of Hungary, (submitted).
Dudal, R., Bregt, A.K. and Finke, P.A., 1993. Feasibility study of the creation of a soil map of Europe at scale 1:250,000. DG XI, Task Force European Environment Agency. Commission of the European Communities. Leuven - Wageningen. 69 p.
EC, 2003. Regulation (EC) No. 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus), OJ L 324, 11.12.2003, p. 1-8.
EEA, 1998. Europe's Environment. The Second Assessment. European Environment Agency, Copenhagen.
EEA-ETC/TE, 2002. CORINE Land Cover update, I&CLC2000 project, Technical Guidelines, http://terrestrial.eionet.eu.int
European Soil Bureau, Scientific Committee, 1998. Georeferenced Soil Database for Europe: Manual of Procedures Version 1.0. EUR 18092 EN 184pp. Office for Official Publications of the European Communities, Luxembourg.
European Soil Bureau, 2004. "THE EUROPEAN SOIL DATA BASE. VERSION 1", EUR 19945, CD-ROM Cat.Nr. LBNA19945ENZ ISBN 92-894-1947-4. Office for Official Publications of the European Communities, Luxembourg.
FAO-ISRIC, 1995. Global and national soils and terrain digital database (SOTER). Procedures manual.
FAO 1998. World Reference Base for Soil Resources. World Soil Resources Report No 84, FAO, Rome.
Hodgson, J.M. (Ed.), 1991. Soil Survey - A basis for European Soil Protection. Soil and Groundwater Research Report. Commission of the European Communities, Luxemburg. 214 p.
Hollis, J.M. and Avery, B.W., 1997. History of Soil Survey and development of the soil series concept in the U.K. Advances in GeoEcology 29, 109-144.
Jamagne M., Montanarella L., Daroussin J., Eimberck M., King D., Lambert J.J., Le Bas C., Zdruli P., 2001. Methodology and experience from the soil geographical database of Europe at 1:1,000,000 scale. In: Soil resources of Southern and Eastern Mediterranean countries. Zdruli P., Steduto P., Lacirignola C., Montanarella L. (Eds). Options méditerranéennes. CIHEAM, Bari. 27-47.
Jones, R.J.A., Houskova, B., Montanarella, L. and P. Bullock, 2005. Soil Resources of Europe: including Neighboring Countries. European Soil Bureau Research Report No. 9, EUR 20559 EN (2005). 350 pp. Office for Official Publications of the European Communities, Luxembourg.
King D., Meyer-Roux J., Thomasson A.J., Vossen P., 1998. A proposed European soil information policy. In: Land Information Systems. Development for planning the sustainable use of land resources. Heineke H.J., Eckelmann W., Thomasson A.J., Jones R.J.A., Montanarella L., Buckley B. (Eds). European Soil Bureau Research report n°4, EUR 17729 EN. Office for publications of the European Communities. Luxembourg. 11-18.
Klingebiel, A.A. and Montgomery, P.H., 1961. Land Capability Classification. USDA Soil Conservation Service, Agricultural Handbook No. 210, 21pp.
Le Bas, C. and M. Jamagne (eds), 1996. Soil databases to support sustainable development. INRA-SESCPF, Joint Research Centre-IRSA. 149 pp.
Montanarella, L., 1996. The European Soil Bureau, European Society for Soil Conservation. Newsletter N° 2, 1996, Trier: 2-5.
Montanarella L. and Jones R.J.A., 1999. The European soil bureau. In: Soil resources of Europe. Bullock P., Jones R.J.A., Montanarella L. (Eds). European Soil Bureau, Research Report
Montanarella L., 2001. "The European Soil Information System (EUSIS)"; in "Desertification Convention: data and Information Requirements for Interdisciplinary Research", G. Enne, D. Peter, D. Pottier (eds.), EUR 19496 EN.
SGDE ver. 3.28, 2003. Soil Geographical Database for Eurasia & The Mediterranean: Instructions Guide for Elaboration at scale 1:1,000,000. Version 4.0. J.J. Lambert, J. Daroussin, M.

Eimberck, C. Le Bas, M. Jamagne, D. King & L. Montanarella. EUR 20422 EN, 64pp. Office for Official Publications of the European Communities, Luxembourg.
Soil Atlas of Europe, 2005. European Soil Bureau Network, European Commission, 128 pp, Office for Official Publications of the European Communities, L-2995 Luxembourg.
Stolbovoi V., L. Montanarella, V. Medvedev, N. Smeyan, L. Shishov, V. Unguryan, G. Dobrovol'skii, M. Jamagne, D. king, V. Rozhkov, I. Savin, 2001. "Integration of Data on the Soils of Russia, Belarus, Moldova and Ukraine into the Soil Geographic Database of the European Community"; Eurasian Soil science, Vol. 34, No. 7, pp. 687-703.
Van Ranst, E., Thomasson, A.J., Daroussin, J., Hollis, J.M., Jones, R.J.A., Jamagne, M., King, D. and Vanmechelen, L., 1995. Elaboration of an extended knowledge database to interpret the 1:1,000,000 EU Soil Map for environmental purposes. In: European Land Information Systems for Agro-environmental Monitoring. D. King, R.J.A. Jones and A.J. Thomasson (eds.). EUR 16232 EN, p.71-84. Office for Official Publications of the European Communities, Luxembourg.

Chapter 3

Arnalds, O., 2005. Knowledge and policy making; Premises, Paradigms, and a Sustainability Index Model. In: Papers of the International Workshop on Strategies, Science and Law for the Conservation of the World Soil Resources, Selfoss, Iceland, 14-18 September 2005. ISSN 1670-5785.
Bautista, S., Martínez Vilela, A., Arnoldussen, A., Bazzoffi, P., Böken, H., De la Rosa, D., Gettermann, J., Jambor, P., Loj, G., Mataix Solera, J., Mollenhauer, K., Olmeda-Hodge, T., Oteiza Fernandéz-Llebrez, J.M., Poitrenaud, M., Redfern, P., Rydell, B., Sánchez Diáz, J., Strauss, P., Theocharopolous, S.P., Vandenkerckhove, L., Zuqúete, A., 2004. Soil Erosion. Task Group 4.1 on Measures to Combat Soil Erosion. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 199 – 214.
Bullock, P., 1999. Soil Resources of Europe: An Overview. In: Bullock, P., Jones, R.J.A., Montanarella, L., (eds), 1999. Soil resources of Europe. European Soil Bureau Research Report No 6: 123 – 128.
Castillo, V., Arnoldussen, A., Bautista, S., Bazzoffi, P., Crescimanno, G., Imeson, A., Jarman, R., Robert, M., Rubio, J.L., 2004. Soil Erosion. Task Group 6 on Desertification. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 275 – 294.
Crescimanno, G., Lane, M., Owens, P.N., Rydel, B., Jacobsen, O.H., Düwel, O., Böken, H., Berényi-Üveges, J., Castillo, V., Imeson, A., 2004. Soil Erosion. Task Group 5 on Links with Organic Matter and Contamination Working group and Secondary Soil Threats. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 241 – 274.
De la Rosa, D., Mayol, F., Diaz-Pereira, E., Fernandez, M., De la Rosa, D. Jr., 2004. A land evaluation decision support system (MicroLEIS DSS) for agricultural soil protection. Environmental Modelling & Software 19: 929-942.
Doran, J.W. and Safley, M., 1997. Defining and Assessing Soil health and Sustainable Productivity. In: Pankhurst, C.E., Doube, B.M., Gupta, V.V.S.R., 1997: Biological Indicators of Soil Health p.1 – 28. CAB International.
Doran, J.W., 2002. Soil Health and Global Sustainability: translating science into practice. Agriculture, Ecosystems and Environment 88: 119 – 127.
Dorren, 2004. Local care for natural capital in mountain ecosystems. In: Briefing Papers of the third SCAPE workshop in Schruns (AU) 11 – 13 October 2004: p. 107 – 113.
Dorren, L., Bazzoffi, P., Sánchez Díaz, J., Arnoldussen, A., Barberis, R., Berényi Üveges, J., Böken, h., Castillo Sánchez, V., Düwel, O., Imeson, A., Mollenhauer, K., De la Rosa, D., Prasuhn, V., Theocharopoulos, S.P., 2004. Soil Erosion. Task Group 3 on Impacts of Soil Erosion. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 187 – 198.

EC, 2002. Communication of 16 April 2002 from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions: Towards a Thematic Strategy for Soil Protection [COM (2002) 179 final]. (At: http://europa.eu.int/scadplus/printversion/en//lvb/l28122.htm).

EEA, 2003. Europe's Environment: the Third Assessment. Environment Assessment Report No 10. European Environmental Agency. Office for Official Publications of the European Communities.

Elgersma, A.M., Støen, M. Aguilar, Dhillion, S.S., 2004. Status of marginalisation in Norway: Agriculture and land use. Working paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm

Elgersma, A.M. and Dhillion, S.S., 2005. Marginalisation and Multifunctional land use: a case from Tynset Kommune and Tylldalen. Case study paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm

Esteve, J.F., Imeson, A., Jarman, R., Barberis, R., Rydell, B., Castillo Sánchez, V., Vandekerckhove, L., 2004. Soil Erosion. Task Group 1 on Pressures and Drivers causing Soil Erosion. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 129 – 144.

European Commission, 2002. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. Towards a Thematic Strategy for Soil protection. COM(2002) 179.

Fanta, J., Zemek, F., Prach, K., Heřman, M., Boucníková, E., 2005. Strengthening the mulitfunctional use of European land: Coping with marginalization. The case of Sušice - Dobrá Voda. Case study paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm.

GEF, 2003. Operational Program on Sustainable Land Management (OP#15). December 18, 2003. 16 pp.

Geist, H.J. and Lambin, E., 2001. What Drives Tropical Deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series No.4 116pp.

ICONA. 1988. Agresividad de la lluvia en España. Mº de Agric. Pesca y Alimentación. Madrid.

Jones, R.J.A., Le Bissonnais, Y., Bazzoffi, P., Sánchez Díaz, J., Düwel, O., Loj, G., Øygarden, L., Prasuhn, V., Rydell, B., Strauss, P., Berényi Üveges, J., Vandekerckhove, L., Yordanov, Y., 2004. Soil Erosion. Task Group 2 on Nature and Extent of Soil Erosion in Europe. In: Van Camp, L., Bujarral, B., Gentile, A, Jones, R.J.A., Montanarella, L., Olazabal. C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 145

Karlen, D.L., M. J. Mausbach, J.W. Doran, R.G. Cline, R. F. Harris, and G. E. Schuman. 1997. Soil quality: Concept, rationale, and research needs. Soil Sci. Soc. Am. J. 61:000-000– 186.

Lavee, H., Sarah, P. and Imeson, A., 1996. Aggregate stability dynamics as affected by soil temperature and moisture regimes. Geografiska Annaler, 78 A, 1: 73-82.

Mander, Ü., Kuusemets, V., Meier K., 2004. Status of marginalisation in Estonia: Agriculture and land use. Working Paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm.

Rosell, J, Viladomiu, L., Zamora, A., 2004. Status of marginalisation in Spain: Agriculture and Land Use. Working Paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm.

Saturnino, H.M. and Landers, J.N., 2002. The Environment and Zero Tillage. 144pp.

SCAPE, 2005. Strategies, Science and Law for the Conservation of the World Soil Resources. International Workshop, Selfoss, Iceland, 14-18 September 2005. AUI Publication no. 4. ISSN 1670-5785.

Schnabel, S., 2003. Soil degradation in areas with silvopastoral landuse. In: Boix, C., Dorren, L., Imeson, A. (Eds): Briefing papers of the first SCAPE Workshop. Alicante, pp 55 – 58.

Tainter, J. A. 1995. Sustainability of complex societies. Futures 27: 397-407.

United Nations Population Fund (UNFPA), 2001. The State of World Population 2001. UNFPA.

Vihinen, H., Tapio-Biström, M-L, Voutilainen, O., 2004. Status of marginalisation in Finland. Working Paper EUROLAN project (QLK5-CT-2002-02346). http://www.umb.no/ina/forskning/eurolan/index_e.htm

Wiebe, K., 2003. Linking Land Quality, Agricultural Productivity, and Food Security. USDA, Agricultural Economic Report No. 823.

Chapter 4

Curfs, M., 2004, Desertification, Perceptions and Perspectives, Presented at the third SCAPE workshop in Schruns (Austria), 11-13 October 2004.

EEA, 2000. Full references in European Environment Agency: Europe's environment: the third assessment. Environmental assessment report No 10. Luxembourg: Office for Official Publications of the European Communities, p. 231.

Chapter 5

Alpine Convention, www.convenzionedellealpi.org/index.

Arnold, D., 2004. Lessons for Europe: the experience of the U.S. Soil Conservation Service. In: Briefing papers of the second SCAPE workshop in Cinque Terre (IT), 13-15 April 2004.

Briassoulis, H., 2005. Sustainable management of soil resources: policy intergarion , soil property regimes and public awareness raising. In:Proceedings International Workshop on Strategies, Science and Law for the Conservation of the World Soil Resources, Selfoss, Iceland, 14-18 September 2005. ISSN 1670-5785.

Curfs, M., 2004, Desertification, Perceptions and Perspectives, Presented at the third SCAPE workshop in Schruns (Austria), 11-13 October 2004.

CBD, 1992. UN Convention on Biological Diversity, UNEP.

EC 2002. Communication of 16 April 2002 from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions: Towards a Thematic Strategy for Soil Protection [COM (2002) 179 final]. (At: http://europa.eu.int/scadplus/printversion/en//lvb/l28122.htm).

EC, Council Regulation No. 1782/2003, 2003. Official Journal of the European Union

FAO, 1982. World Soil Charter. Rome, FAO 8pp.

Federal Soil Protection Act of Germany (17 March 1998) Federal ministry for the environment, Bonn, 28.8.1998 Nature conservation and nuclear safety.

Hannam, I. and Boer, B., 2002. Legal and Institutional Frameworks for Sustainable Soils. A preliminary report. IUCN Environmental Policy and Law Paper No. 45.

Hurni, H. and Meyer, K., eds. 2002. A World Soils Agenda. Discussing International Actions for the Sustainable Use of Soils. Prepared with the support of an international group of specialists of the IASUS Working Group of the International Union of Soil Sciences (IUSS). Berne, Switzerland: Centre for Development and Environment. Holmeda-Hodge et al., 2004

Imeson, A.C., 2004. The use of indicators in soil erosion and protection. In: Briefing papers of the second SCAPE workshop in Cinque Terre, 13-15 April 2005, p 195-200.

Mitchell, D., 2004. Latest EU soil policy developments concerning agriculture. In: Briefing papers of the fourth SCAPE workshop in Ås, 9-11 May 2005.

Montanarella L., Micheli E. and Arnold R., 2004. Soil conservation services in the European Union and in the United States of America, Proceedings of the 4th International Conference on Land Degradation, Cartaghena.

Olmeda-Hodge, T., Robles del Salto, J.F., Vandenkerckhove, L., Arnoldussen, A., Böken, H., Brahy, V., Düwel, O., Gettermann, J., Jacobsen, O.H., Loj, G., Martínez Vilela, A., Owens, P.N., Poitrenaud M., Prasuhn, V., Redfern, P., Rydell, B., Strauss, P., Theocharopoulos, S.P., Yordanov, Y., Zùquete, A., 2004. Soil Erosion. Task Group 4.2 on Policy Options for Prevention and Remediation. In: Van Camp, L., Bujarral, B., Gentile, A., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.K. (Eds) 2004: Reports of the Technical Working Groups established under the Thematic Strategy for Soil Protection. Volume II Erosion. European Commission Joint Research Centre and European Environmental Agency. EUR 21319 EN/2: 215 – 240.

SCAPE, 2005. Strategies, Science and Law for the Conservation of the World Soil Resources. International Workshop, Selfoss, Iceland, 14-18 September 2005. AUI Publication no. 4. ISSN 1670-5785.

Soil Atlas of Europe, 2005. European Soil Bureau Network, European Commission, 128 pp, Office for Official Publications of the European Communities, L-2995 Luxembourg.

Soil Action Plan for England. 2004. Published by the Department for Environment, Food and Rural Affairs. Printed in the UK, May 2004.

Draft Soil Strategy for England, A Consultation Paper, 2001. Department for Environment, Food & Rural Affairs.

UNEP (United Nations Environmental Programme), 1982. World soils policy. Annex III, pp.15-18. Nairobi, Kenya.

Wynen, E., 2002. A UN convention on Soil Health or what Are the Alternatives?, Proceedings of the l4th IFOAM Organic World Congress, Victoria, Canada, August 2002.

Chapter 6

Beste, A., 2005. Landwirtschaftlicher Bodenschutz in der Praxis Verlag Dr. Köster Berlin, germany 204 p.

Briassoulis, H. 2005. Policy integration for Complex Environmental Problems. The example of Mediterranean Desertification Asgate, Hants England 371 p.

Carson R. 1962. Silent Spring. Boston, Houghton Mifflin Company (2002).

Club of Rome, http://www.clubofrome.org/archive/index.php.

Curfs, M. 2005. Our hands, our soil. Desertification paper at the 4th SCAPE desertification workshop, Åss, Norway.

GEO, 2005. http://europa.eu.int/comm/research/environment/geo/article_2447_en.htm.

Goldstein R.J., 2000. Environmental Ethics and Positive Law pp 1 to 29 in Environmental Ethics and Law, Goldstein Editor Ashgate, Hants. England, 677 pages.

Grinlinton, D., 2002: Contemporary environmental law in New Zealand. In: Bosselmann, K.; Grinlinton, D. ed. Environmental law for a sustainable society. Auckland, NZ Centre for Environmental Law. p. 19–46.

Grinlinton, D., 2005. Using legal methods and strategies to promote the sustainable use of soil. In: Strategies, Science and Law for the Conservation of the World Soil Resources, SCAPE Workshop, 14-18 September 2005, Selfoss, Iceland, p. 135-144.

Holling, C.S., Gunderson, L.H., Ludwig, D., 2002. In Quest of a theory of adaptive change. In Gunderson, L. H., Holling, C.S. 2002. *Panarchy: understanding transformations in human and natural systems, pp3-22* Island Press, Washington D.C., USA

Holling, C.S., and G. K. Meffe, 1996. Command and Control and the Pathology of Natural Resource Management. Conservation Biology 10, no. 2: 328-37.

Imeson A.C., 2005. Addressing Soil Erosion in Europe. Land Degradation and Development. Special Issue. Volume 16, Issue 6, p 505-508 .

Jenny, H. 1984. In: Stuart, K. My friend, the Soil; A conversation with Hans Jenny.

Leopold, A., 1948. A Sand County Almanac, and Sketches Here and There, 1948, Oxford University Press, New York, 1987, pg. 81.

Quaranta, G. and Salvia, R., 2005. Riqualificazione e gestione del territorio, lotta alla desertificazione e sviluppo sostenible Buone practsche per i territor rurali, Franco Angeli Rome Italy.

Appendix 1 – SCAPE workshops' participants

The following people have participated at one or more of the SCAPE workshops. Also, local people, who are not listed here, visited SCAPE workshops. Many more people have contributed to discussions leading to SCAPE's conclusions and recommendations; for example the Technical Working Groups which were set up by DG Environment in support of the development of the EU Soil Strategy. SCAPE Steering Committee members were actively involved in many of these Working Groups.

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Appendix 2. Soil basics

Soils form by interaction of the earth's crust with atmospheric and biological influences. Bedrock is the ultimate source of the inorganic component in soils. When rock is exposed at the surface of the earth's crust, it is broken down into smaller and smaller fragments by physical forces. The fragments may be altered or decomposed by chemical reaction of mineral matter with water and air. Hundreds, thousands, or even millions of years may be required for the **weathering** or physical and chemical alteration of rock to produce the ultimate end products in soils. Once particles reach a sufficiently small size they can be moved by wind, water or ice when exposed at the surface. It is common, therefore, for small particles to be moved from one location to another. A single particle might occur in several different soils over a period of 100,000 years. Eventually, these particles or their decomposition products reach the ocean where they are redeposited as marine sediments.

Soils are dynamic bodies having properties that reflect the integrated effects of **climate** (atmosphere) and **biotic activity** (micro-organisms, insects, worms, burrowing animals, plants, etc.) on the unconsolidated remnants of rock at the earth's surface **(parent material)**. These effects are modified by the **topography** of the landscape and of course continue to take place with the passage of **time**. Soils formed in parent materials over decades, centuries, or millennia may be lost due to accelerated erosion over a period of years or a few decades.
There are five key factors in soil formation:

1. type of parent material
2. climate
3. overlying vegetation
4. topography or slope
5. time

(1) The type of parent material influences the soil pH, structure, color, etc., in a profound way. (2) High-rainfall climates tend to have less-fertile soils, due to rainwater's effect in leaching nutrients down to lower levels of the soil profile, and have more acidic soils. Low-rainfall climates tend to accumulate salts near the surface and have generally higher soil pH (basic). (3) Soils that form under coniferous forests tend to be more acidic than those under deciduous forests, and root action is also critical in soil formation. (4) Soils generally have a harder time forming on steep slopes, due to runoff of soil particles during rain events. (5) The more time a soil has to form, the deeper its profile will be.

The American soil scientist Jenny developed a system for explaining soils as a function of parent material, time, drainage, slope, organisms, vegetation, erosion and management. Patterns of soils occurred in the fields that reflected the interplay of these factors. Similar soils occur again and again under similar geo-ecological conditions. It is a paradox that although each soil is different in terms of its exact appearance and properties, soils tend to evolve into a relative limited number of types. A catena is a sequence of soils that occurs on a slope as the soil forming factors vary in a consistent way (figure A.1). Former soil scientists generally mapped the boundaries between different soil types on the basis of parent material and slope, producing maps that expressed a deep understanding of the processes responsible for soil formation.

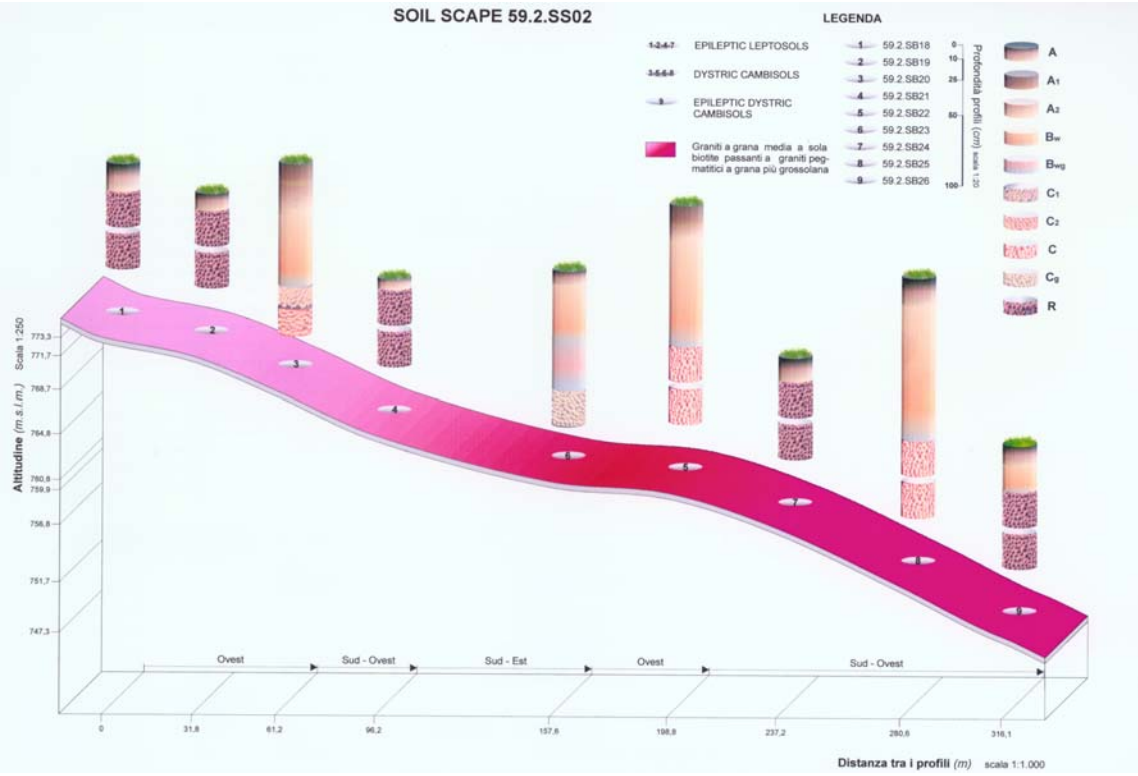

Figure A.1. A soil catena along a slope (source: Madrau et al., 2003)

Mineral matter, organic matter, soil water and **soil air** are the four major components of a soil. The proportions of these components may vary between horizons in a soil or between similar horizons in different soils. The ratio of soil water to soil air depends on whether the soil is wet or dry. The mineral matter, composed of particles ranging in size from the sub-microscopic to gravel or even rocks in some cases, accounts for the bulk of the dry weight of the soil and occupies some 40 to 60% of the soil volume. Organic matter, derived from the waste products and remains of plants and animals, occurs in largest amounts in the surface soil, but even here seldom accounts for more than 10% of the dry weight of the soil.

Soils are classified based on their **parent material**, **texture**, **structure**, and **profile**. Parent material is what the soil was made from, usually mostly inorganic rocks. A soil that has <20% organic matter (O.M.) is a **mineral soil** while one with >20% O.M. is an **organic soil** (i.e. peat). Texture refers to the proportion of sand, silt, and clay in the soil; sandy soils are called light or coarse-textured, whereas clay soils are called heavy or fine-textured. Clay tends to increase the water-holding capacity of the soil. Loamy soils have a balanced sand, silt, and clay composition and are thus good for plant growth. Structure refers to the aggregation of soil particles into platy, prismatic, blocky, spherical, or crumblike clods. The surface of a soil reveals very little about the depth of the soil or its subsurface characteristics. A vertical cross-sectional view of a soil is called a **soil profile**. Each of the horizontal layers, which can be seen in the vertical section, is called a **soil horizon.**

The following part is based on excerpts from: A guide to better soil structure, Cranfeld University, Silsoe, National Soil Resources Institute 2002. (Presented at the SCAPE workshop in Cinque Terre)

What is soil structure?

Many people tend to confuse a soil structure with texture. A soil's texture is the bricks (a mix of sand, silt and clay), which when stuck together with organic matter and other

natural “mortar” make up the larger all-important structural blocks (aggregates). The structure of the soil is the arrangement of blocks around which the roots grow and air and water move.
Just like our houses, a soil is made up of a number of different ‘building’ blocks, which are described according to their shape and size using fairly easily defined terms such as blocky or granular, fine or medium. Soils that naturally have a good structure in the long term have a ‘stable’ soil structure, those that would naturally loose aggregation have an unstable structure. In general, a well structured topsoil (first 30 cm) will have a continuous network of pore spaces to allow drainage of water, free movement of air and unrestricted development of roots. A subsoil (below 30 cm) can be well structured but also allow water to permeate slowly. While there is little people can do to modify texture of the soil, they can influence the way the soil is structured.

Soil structure is important because

- It is the plumbing system for the soil which controls water flow and air flow
- It provides space and a protected home for roots, germinating seeds and soil fauna
- It affects farming operations, for instance the easiness of cultivation
- It affects the impact of landuse on the environment; the amount of run-off and erosion, the amount of nutrients and/or pollutants lost in drainage, runoff and erosion.

Soil structure holds a vital, but often overlooked role in the sustainable food production and the well being of society (Bronick & Lal, 2005).

Soil chemistry

Soluble salts generally disassociate in water into two component ions, one that is positively charged (***cation***) and one that is negatively charged (***anion***). The ability of the salt to dissolve is directly related to the solution's pH, or relative concentrations of hydrogen (H+) and hydroxide (OH-) ions. Higher pH indicates the soil has more OH- than H+, and is thus ***basic*** or ***alkaline***. Lower pH indicates the soil has more H+ than OH-, and is thus ***acidic***. Neutral pH, where a solution has equal concentrations of H+ and OH-, is 7.0. Important soil cations include aluminum (Al^{3+}), ammonium (NH^{4+}) calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), and sodium (Na^{+}). Important soil anions include bicarbonate ($HCO3^{-}$), chloride (Cl^{-}), carbonate ($CO3^{2-}$), nitrate ($NO3^{-}$), orthophosphate ($H2PO4^{-}$), and sulfate ($SO4^{2-}$).

The soil community

Soil organisms are integral to soil processes, including nutrient cycling, energy cycling, water cycling, processing of potential pollutants, and plant pest dynamics. These processes are essential to agriculture and forestry, and for protecting the quality of water, air, and habitat (NRCS, 2004). One teaspoon of good grassland soil may contain 5 billion bacteria, 20 million fungi and 1 million protoctists. Expand the census to a square meter and you will find, besides the creatures already mentioned, perhaps 1000 each of ants, spiders, woodlice, beetles and their larvae; 2000 each of earthworms and millipedes and centipedes; 8000 slugs and snails; 20000 pot worms, 40000 springtails, 120000 mites and 12 million nematodes. If you would envision the soil as a city, it is to put it mildly, densely settled (Wallace, 1999).
Soil organisms can be described by their functions in a soil (Wardle, 2002; Coleman & Crossley, 1996). There are:

- *Decomposers:* Bacteria, actinomycetes (filamentous bacteria), and saprophytic fungi degrade plant and animal residue, organic compounds, and some pesticides.
- *Grazers and Predators:* Protozoa, mites, nematodes, and other organisms “graze” on bacteria or fungi; prey on other species of protozoa and nematodes; or both

graze and prey. Grazers and predators release plant-available nutrients as they consume microbes.

- *Litter transformers:* Arthropods are invertebrates with jointed legs, including insects, spiders, mites, springtails, centipedes, and millipedes. Some litter transformers, especially ants, termites, scarab beetles, and earthworms, are "ecosystem engineers" that physically change the soil habitat for other organisms by chewing and burrowing through the soil.
- *Mutualists:* Mycorrhizal fungi, nitrogen-fixing bacteria, and some free-living microbes have co-evolved together with plants to form mutually beneficial associations with plants.
- *Pathogens, parasites and root feeders:* Organisms that cause disease make up a tiny fraction of the organisms in the soil. Disease-causing organisms include certain species of bacteria, fungi, protozoa, nematodes, insects, and mites.

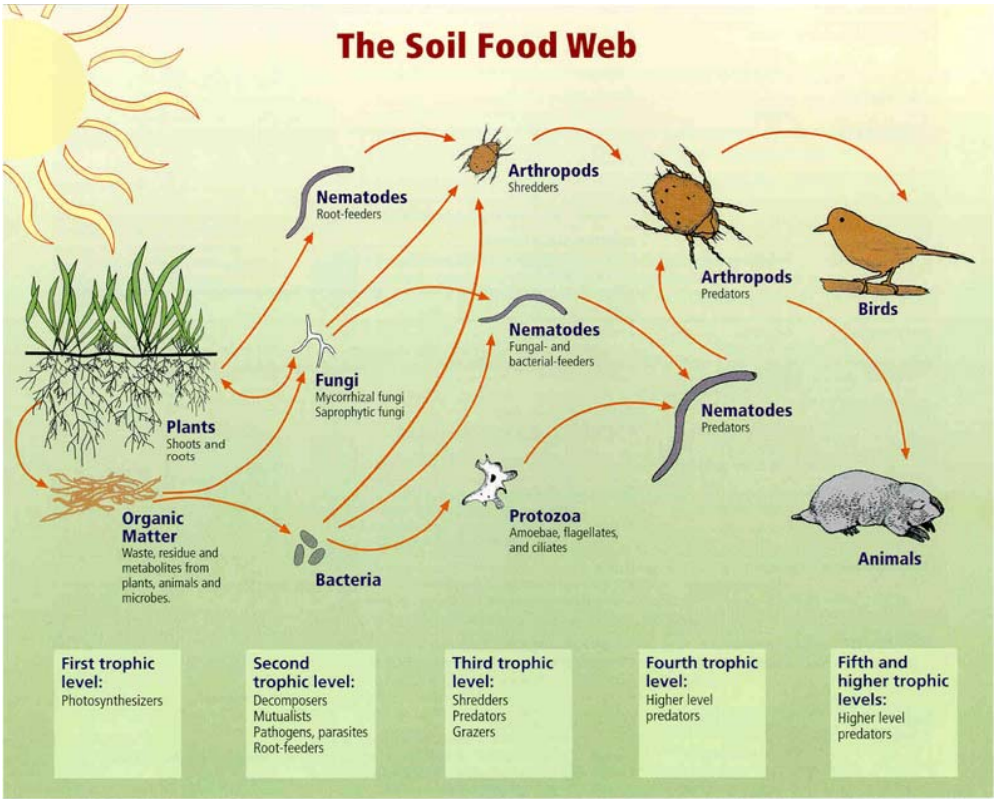

Figure A.2. The Soil Food Web (source USDA NRCS).

References

C.J. Bronick, R. Lal, 2005. Soil structure and management: a review. Geoderma 124, p3-22.

Coleman, D.C., D.A. Crossley. 1996. Fundamentals of Soil Ecology. Academic Press, San Diego.

NRCS Soil Quality-Soil Biology, 2004. Technical note No.4 Soil Biology and Land management.

SOIL BIOLOGY CLASSROOM ACTIVITIES, The Soil Biology Web Page (from the NRCS Soil Quality Institute) at http://soils.usda.gov/sqi.

URL: http://organiclifestyles.tamu.edu/soilbasics/soilformation.html

URL: http://pas.byu.edu/AgHrt100/classif.htm

Peter Wallace, 1999. The soil bank. In: Whole Earth 96, Celebrating soil- Mother of all things.

Wardle, David A. 2002. Communities and Ecosystems: Linking the Aboveground and Belowground Components. Princeton University Press. Princeton, New Jersey.

Appendix 3 – Case study papers

All papers can be downloaded from www.scape.org.

Briefing papers Alicante Workshop (Spain)

THEME I Where in Europe is soil erosion a serious problem and why is that?

Hans-Rudolf Bork	State-of-the-art of erosion research - soil erosion and its consequences since 1800 AD
Mike Kirkby	Modelling erosion – the PESERA project
Valerie Vieillefont et al.	Validation of soil erosion estimates for Europe
Anne-Veronique Auzet	From soil erosion knowledge to soil protection and runoff prevention – COST 623
Luuk Dorren and Anton Imeson	Soil erosion and the adaptive cycle metaphor
Carolina Boix-Fayos et al.	Soil Erosion rates in Alicante and Murcia
Julia Martínez-Fernández	Measures against soil erosion in Spain
Susanne Schnabel	Soil degradation and silvopastoral landuse

THEME II SCAPE, REACTION and MEDRAP: Restoration monitoring and strategies

Asa Aradottir	Restoration challenges and strategies in Iceland
Diego de la Rosa	Soil quality evaluation and monitoring
Arnold Arnoldussen	Reduction of Soil Erosion in Norway
Marion Gunreben	Dealing with soil threats in Lower Saxony, Germany

THEME III What is the role of soil organic matter in soil degradation?

Claire Chenu and Michel Robert	Importance of soil organic matter for soil functions
Sarah Pariente and Hanoch Lavee	Soil organic matter and degradation
Dominique Arrouays et al.	Carbon sequestration in soils: estimates for Europe and France

THEME IV The economics of soil protection and conservation

Rob Jarman	The National Trust policy on soil erosion
Kilian Bizer	Economic instruments for protecting soils - a brief introduction
Kajetan Hetzer	Soil protection from a banking perspective
Diane Mitchell	Agri-environment schemes

Briefing papers Cinque Terre Workshop (Italy)

Arnold Arnoldussen	Reduction of Soil Erosion in Europe; Results of the Technical Working Group on Soil Erosion
Luca Montanarella	Draft conclusions of the Technical Working Group on Soil Monitoring
Michel Robert	Report of the technical working group on soil organic matter

THEME I Experiences and best practices in monitoring and measuring soil erosion

Hanoch Lavee and Adolfo Calvo-Cases	Lessons and Experience gained from 20 years of measuring soil erosion and related data in the Mediterranean: Future challenges and the way ahead
Maria Roxo	Long term monitoring of soil erosion by water Vale Formoso Erosion Centre – Portugal

Dick Arnold	Lessons for Europe: the experience of the U.S. Soil Conservation Service
Artemi Cerda	Lessons and experience of soil conservation in Spain
Selim Kapur	Natural and Man-Made Agroscapes of Turkey: Sites of Indigenous Sustainable Land Management (SLM)

THEME II Cinque Terre and terraces problematic

Franco Bonanini	In the Cinque Terre; cultivation is culture
Avertano Role	Experiences in Malta on the management of terraced Mediterranean landscapes
Luuk Dorren and Freddy Rey	A review of the effect of terracing on erosion

THEME III Challenges in monitoring soil erosion relevant data and its use and its applications

Diego de la Rosa	Site-specific soil protection strategies by using a Mediterranean land evaluation decision support system
Hein Bouwmeester	Monitoring soil erosion from high resolution DTMs: Present possibilities and future prospects
Luca Demicheli	Monitoring and preventing soil loss: impervious surfaces and human activities
Joris de Vente	Evaluation of reservoir sedimentation as a methodology for sediment yield assessment in the Mediterranean: challenges and limitations
Yoram Benyamini	Measuring and monitoring soil erosion for soil conservation and soil protection in Israel

THEME IV Data and information challenges in socio-, economic and policy research targeting soil erosion

Giovanni Quaranta	A bio-economic model to simulate farmers behaviour in a Mediterranean desertificatioin risky area: data needs and empirical evidence
Pandi Zdruli	Enhancing networking and exchange of information in the Mediterranean region: The MEDCOASTLAND Thematic Network
Marion Gunreben	Soil quality standards in respect of water and wind erosion in Lower Saxony, Germany

THEME V The role of indicators in monitoring in soil conservation and protection

Anton Imeson	The use of indicators in soil erosion and protection
Freddy Nachtergaele	Land Degradation Assessment Indicators and the LADA project

Briefing papers Schruns Workshop (Austria)

THEME I Importance of soil protection and conservation in mountainous areas in Europe

Sigbert Huber	Soil protection in Austria – key issues and problems
Bernhard Kohl and Gerhard Markart	The importance of soil protection and conservation in mountainous areas for hydrological purposes
Josef Scherer	The importance of soil protection in Vorarlberg: the most important soil-related environmental problems and measures
Peter Strauss	Effectiveness of soil erosion protection measures in Austrian agriculture

THEME II Data and information to be included in European monitoring programs and databases

Paolo Giandon, Ialina Vinci and Silvia Obber	The Ecopedological map of the Alpine territory

Borut Vrščaj and Sara Zanolla	Building the Cross-border Soil information system in Alpine Region
Harry Seijmonsbergen & Sanneke van Asselen	Relevance of geomorphological data in mountainous areas; past and future trends
Martin Schamann	Results of Technical Working Group Monitoring from an Austrian perspective
Alexandra Freudenschuß	BORIS – an Austrian Soil Information System
Bernhard Maier	Multifunctional forest monitoring at the Stand Montafon Forstfonds
Luca Montanarella	Towards an Alpine Soil Information system
Tjeerd Wits and Luuk Dorren	Morphoseries for soil monitoring in the European Alps – a case study in the Montafon, Austria

THEME III Local and global actions in soil conservation and protection

Luuk Dorren	Local care for natural capital in mountain ecosystems
Wolfgang Burghardt	Soil conservation and protection in human constructed environment

Briefing papers Ås Workshop (Norway)

THEME I The importance of soil protection and conservation in the boreal climate zone

Gunnar Prøis	The challenges for soil conservation and protection in Norway and what is being done
Barbro Ulén	Soil erosion and some recent trends in phosphorus losses from arable land in Sweden
Tyra Risnes Høyås	The Regional Environmental Plan of the County Østfold
Vladimir Stolbovoy	Detection of the changes of organic carbon stock in mineral soils

THEME II Legislation and measures to reduce soil erosion in boreal areas

Petri Ekholm	Soil erosion and recent trends in phosphorus loss in Finland
Ingrid Rydberg	Environmental targets and measures to reduce soil erosion and phosphorus loss in Sweden
Johan Kollerud	The reduction of soil erosion in Norway
Trond Børresen	The role of no- and reduced tillage systems in boreal areas
Lillian Øygarden	Soil erosion in Norway - measures in agricultural catchments
Ove Klakegg	The availability of necessary soil information via Internet and the use of it

THEME III How to actually achieve soil conservation and protection, using existing tools

Anna Martha Elgersma	Marginalisation of agriculture in rural areas of Europe: influences of and changes in soil properties
Diane Mitchell	Latest EU soil policy developments concerning agriculture
Trond Haraldsen	Soil quality requirements for landscaping in urban areas

Briefing papers Selfoss Workshop (Iceland)

Anton Imeson	Strategies for Soil Conservation and Protection: Introduction

THEME I Introductory session: overview presentations

Luca Montanarella	State of European soils
Hans-Rudolf Bork	Development and degradation of the soils of the world since the rise of agriculture

Roger Crofts	Soil conservation: connecting the pieces
Sheila Abed	The role of the World Conservation Union in the development of Soil Law and Policy
Ian Hannam and Ben Boer	Progress toward a Draft Protocol for the Conservation and Sustainable Use of Soil
Craig Ditzler and Michael Golden	Assessment and monitoring of United States Soil resources

Iceland

Olafur Arnalds	Land degradation and desertification in Iceland
Andres Arnalds and Sveinn Runolfsson	A century of soil conservation in Iceland

THEME II Integrating soil into other issues

Pim Jungerius and Anton Imeson	Globalisation, sustainability and resilience from the soil's point of view
Hanneke van den Ancker	Geodiversity and Geoheritage within the framework of the Soil Strategy
Stephen Nortcliff	Are sustainable soil management and increased food production mutually exclusive?

THEME III Law, legal management and solutions

Andrew Waite	Contaminated land legislation and liability, and the impact of waste management legislation
Qun Du	Six Priority Forestry Programs and Legal Issues on Conservative Forestry Development in the PRC
William Futrell	Laws to promote sustainable soils in the United States
David Grinlinton	Using legal methods and strategies to promote the sustainable use of soil
Irene Heuser	Development of EU Soil Protection Law
Steven Berveling	Legal issues regarding the sustainable management of contaminated soils with examples from Australia

THEME IV Research and case studies

John Benson	Vegetation classification and assessment to improve the management of soil resources New South Wales, Australia
Godert van Lynden	Documentation and evaluation of case studies of soil and water protection using conservation tillage in Europe
Mohamed Sabir	Traditional strategies for soil and water conservation in the Maghreb Mediterranean mountains
Anton Imeson	Results of SCAPEs case studies
Winfried Blüm	Future research needs for the sustainable management of soil resources

THEME V Strategies and policies

Jose Rubio	European framework for soil sustainability: Quality indicators for soil as a multifunction medium
Helen Briassoulis	Sustainable management of soil resources: policy integration, soil property regimes and public awareness raising
Andres Arnalds	Barriers and incentives to landcare - experiences from Iceland
Arnold Arnoldussen	Which strategy and policy is needed to establish a more sustainable land management – a SCAPE vision

Giovanni Quaranta	Combating desertification in Europe: NAP's and new Rural Development Programme
Bernard Vanheusden	Brownfield redevelopment
Olafur Arnalds	Knowledge and Policy Making; Premises, Paradigms, and a Sustainability Index Model
Joop Vegter	Towards prevention and management of contaminated land

Commissioned papers

Andrea Beste	Guideline to a simple soil assessment
Brad Wilcox	Healthy landscapes – Lessons from rangeland ecohydrology and monitoring sciences
Nienke Bouma	Soil protection and nature restoration and conservation in the coastal dunes of the Netherlands
Pim Jungerius & Hanneke van den Ancker	Geodiversity and Geoheritage within the framework of the EU Soil Strategy

Desertification discussion papers

Artemi Cerdà	Traditional versus modern irrigation systems in a desertification threatened world. The example of the Riu dels Sants in Eastern Spain
C. Blade, T. Gimeno, S. Bautista and V.R. Vallejo	Post-fire rehabilitation measures to mitigate soil degradation in dry Mediterranean areas: seeding and mulching
Carolina Boix-Fayos	Lessons learnt from soil erosion studies in the 90's: examples of the ERMES project
Luca Montanarella	Synergies between the three Rio Conventions in the field of soil protection
Mark Lemon	The sustainability of research into sustainability: some lessons from desertification research
Michiel Curfs	Desertification; Perspectives and Perceptions
Michiel Curfs	Our soil, our hands, 'SCAPE-lifting'
Nichola Geeson	Strategies for combating desertification
Yoram Benyamini	The lesson we learned in Israel in Combating Desertification

scape

Soil Conservation And Protection for Europe

Li Europan lingues es membres del sam familie. Lor separat existentie es un myth. Por scientie, musica, sport etc., li tot Europa usa li sam vocabularium. Li lingues differe solmen in li grammatica, li pronunciation e li plu commun vocabules. Omnicos directe al desirabilitá de un nov lingua franca: on refusa continuar payar custosi traductores. It solmen va esser necessi far uniform grammatica, pronunciation e plu sommun.

SCAPE is a concerted action funded by the European Commission. It will provide opportunities for discussing the development and application of soil conservation and protection strategies. It will consider data on soils and their use, including the socio-economic driving forces. It will support the organisations responsible in their efforts to obtain the data and information needed for end users and the sustainable protection and conservation of European soils.

Authors:

Epsum factorial non deposit quid pro quo hic escorol. Olypian quarrels et gorilla congolium sic ad nauseum. Souvlaki ignitus carborundum e pluribus unum. Defacto