European Commission

DG Environment

Assessing the Economic Impacts of Soil Degradation

Final Report

Volume II: Case Studies and Database Research

Final Version, December 2004

Study Contract

ENV.B.1/ETU/2003/0024

D. Darmendrail, O. Cerdan, A. Gobin, M. Bouzit, F. Blanchard, B. Siegele

Géosciences pour une Terre durable

brgm

Key words: European Level, soil deterioration, impact, economy

In references this report will be cited as follows: D. Darmendrail, O. Cerdan, A. Gobin, M. Bouzit, F. Blanchard, B. Siegele - Assessing the economic impact of soil deterioration: Case Studies and Database Research.

Table of Contents

List of figures

List of tables

1 Introduction

1.1 SCOPE AND CONTENT

The project “Assessing Economic Impacts of Soil Deterioration” (Study Contract ENV.B.1/ETU/2003/0024) is a contribution to the European Community's activities to support the actions of the technical working groups in preparing the “Thematic Strategy on Soil Protection”, usually referred to as Soil Thematic Strategy (STS). This report, which contains a review of five case studies of areas faced with some of the identified threats and a database search, is part of the project that will assess the economic impact of the main types of soil degradation in Europe. The project is being carried out by Ecologic, the Institute for International and European Environmental Policy, and BRGM, the French Geological Survey.

This case study and database report is contributed by BRGM. Other results of the project are documented in separate volumes, including a literature review (Volume I) and a report giving empirical estimates of the impact of soil degradation in Europe (Volume III of this project).

1.2 OUTLINE OF THE PROJECT

This report consists of three sections, describing:

1. Research done for the selection of case studies: exemplary sites/regions that are considered to be representative of the threats identified in Europe.
2. The example sites/regions selected on the basis of the results of the literature review, of which five were selected for in-depth case studies.
3. Accessible databases that provide both environmental and economic data.

The case studies serve as examples and are used to test the application of the economic assessment methodology. They serve to highlight certain crucial aspects of the methodology for measuring and assessing economic impact. They will also be used to provide new data input for extrapolation.

1.3 GENERAL LIMITS OF THE CASE STUDIES

As discussed and agreed in February 2004, the study attempts to determine the costs of soil degradation but no cost-benefit analysis are done. The study simply estimates the costs that soil users must bear if soil quality deteriorates. Indeed, the reduction or elimination of these impacts would, alone, be a benefit.

2 Background: Methodology for the Selection of Case Studies

2.1 TYPES OF SOIL DETERIORATION TAKEN INTO ACCOUNT

The greatest threats to soil identified in the European Communication document "Towards a Thematic Strategy on Soil Protection" (European Commission, 2002) are:

- Erosion
- Contamination (point-source and non point-source)
- Salinisation
- Decrease in soil organic matter
- Sealing
- Floods and landslides
- Compaction
- Loss of biodiversity

The literature review (Volume I of this report) sought information concerning the structure, types of costs and availability of economic data and relevant explanations. The lack of economic data on compaction, sealing and biodiversity became evident during this review. Most of the available literature focuses on the cost of erosion (water and wind). The cost of contamination and floods/landslides is less well documented.

2.2 METHODOLOGY FOR THE INITIAL SELECTION OF CASE STUDIES

As required by the European Commission, the selection should reflect:

- the situation in the Member States and Candidate Countries, if possible,
- different types of soils,
- different climatic conditions (Northern, Central, Southern Europe),
- different economic uses.

The available data must be homogeneous, in order to facilitate combination, interpretation and comparison, and address the questions posed by this project

The five case studies ultimately selected should focus on erosion, soil contamination, and salinisation threats, with, if possible, examples of floods and landslides.

Based on the literature review (Volume I of this report), a questionnaire and sent to:

- European Ministries for Environment (EU, plus some Eastern European countries such as the Czech Republic, Hungary, Poland, Romania),
- experts on specific threats, members of Soil Thematic Strategy working groups,
- scientists working on soil issues related to Soil Protection,

in order to obtain environmental and economic data (see table 1) on specific areas subject to one or more threats.

Table 1. Types of data sought

Environmental data	Economic data
▪ Site location, size ▪ Type of threat(s) ▪ Predominant use of the area, population density ▪ Geography/Topography ▪ Soil category ▪ Conservation measures (typology, efficiency) ▪ Description of the event generating the threat(s) ▪ Vulnerability of the area	▪ On-site costs (e.g., production loss) ▪ Off-site costs (e.g., water pollution and environmental monitoring) ▪ Non-use Value costs (e.g., impact on landscape or biodiversity) ▪ Estimation of short-, medium- and/or long-term effects ▪ Method used for cost estimation

After several possible case studies had been identified, addition official documents and scientific literature that were not included in the literature review concerning these cases were reviewed in order to gather related environmental and economic data. Discussions were held with the data providers in order to better estimate the cost of the various measures that had been implemented.

In most cases, these data were obtained from one or two sources, mainly scientists studying the threat to the environment and public authorities in charge.

The most recent sources of information are:

- (draft) reports of the various working groups of the EU Soil Thematic Strategy,
- public reports of European R&D projects containing both environmental and economic data.

2.3 IDENTIFIED CASE STUDIES

The following table shows the results of the investigation of potential case studies on soil threats.

Table 2. Summary of identified case studies

Type of threat	Country	Economic data availability	Type of site
Erosion	UK, general case	Satisfactory - Secondary data covering several areas in England	17 areas in the UK. Economic data are combined
	France, Pays de Caux	Limited. Primary data collected in a small area.	Small site
	France, Lauragais	Limited. Primary data collected in a small area.	Small site
	Norway, Morsa region	No economic data	
	Spain, Donana region	No economic data	
Contamination	France, Metaleurop	Satisfactory. Primary data collected by BRGM	Megasite with off-site effects
	Belgium, Kempen area	Primary data collected by OVAM	Megasite, spanning two countries, with off-site effects
	Finland, Arabianranta	Primary data collected by Finnish Ministry for Environment	Small site with mainly on-site effects
	Finland, Juankoski	Primary data collected by Finnish Ministry for Environment	Small site with mainly on-site effects
	Netherlands, Maastricht	Primary data collected by Dutch Ministry for Environment	Urban brownfield
Salinisation	Italy, Delia Nivolelli	Little data	
	Spain, Central Ebro	Satisfactory - Secondary data	Related to irrigation
Flooding	Italy, Northern area	No economic data	Large area subject to major flooding
	Italy, Central area	No economic data	Limited to the Island of Elba
Organic matter loss	Sweden	No economic data	Two small areas where peat is extracted
Landslide	Sweden, Vagnhärad	No economic data	

During discussions to select sites for in-depth case studies (for both environmental and economic issues), certain countries, through representatives of their Environment Ministries, confirmed the following data gaps, which had become apparent during the literature review (Volume I of this report):

- Finland: No major problem at the national level with erosion, organic matter loss or salinisation. No economic data on their impact.
- Ireland: Existence of environmental data at the national level (Irish EPA, 2002), especially on erosion. No specific economic data available for the affected areas.
- Netherlands: The main identified threat is contamination. Some specific local impacts have been identified (such as a sinking peat soil in the Gouda region).
- Italy: Identified threats are contamination and floodings. One documented case study was prepared (Appendix 1).

Some contacts in Germany, Austria and the Czech Republic could not be finished in time for the collected data to be included in this project.

Concerning the threat of contamination, most countries have information on point-source pollution. No case studies of non-point-source pollution were proposed by the national contacts. An initial selection of countries was made for cases of contamination, most of which have detailed information on this particular problem at the local level.

Information sheets for those cases that were not studied in greater detail can be found in Appendix 1 below.

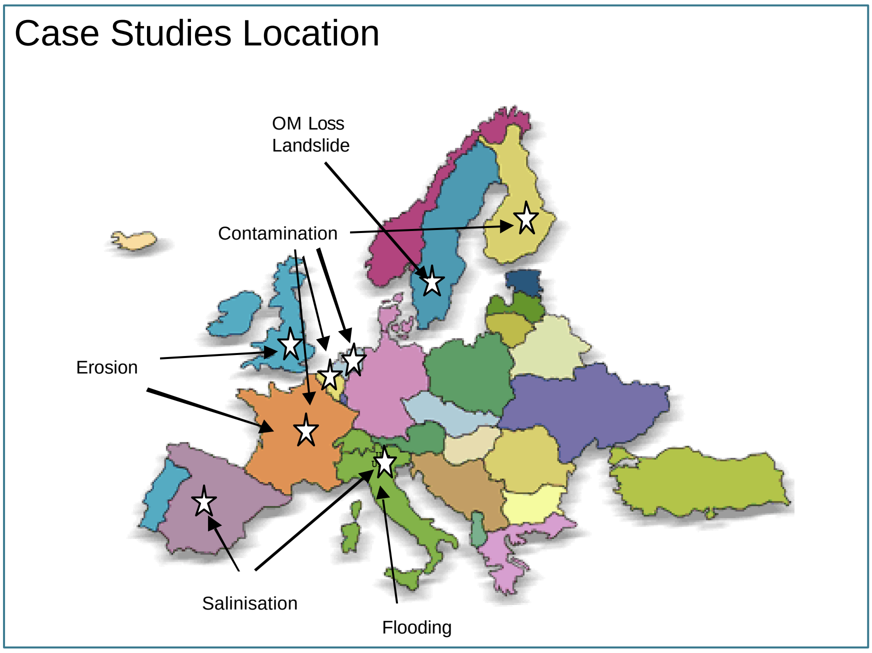


Figure 1. Location of case studies

2.4 SELECTION OF FIVE CASE STUDIES FOR IN-DEPTH STUDY

After discussion with DG Environment, the following five cases were selected for further study:

- Erosion in UK concerning a multi-site case study
- Erosion in France concerning two local case studies (Lauragais and Pays de Caux)
- Contamination in France concerning a primary data collection and analysis of a Megasite (Metaleurop Noyelles-Godault)
- Salinisation in Spain in the Central Ebro area
- Loss of Organic Matter in Sweden (peat extraction)

Detailed descriptions of these five case studies are given in chapter 3 and in Appendix 2.

Erosion

Two case studies of **erosion** were selected in order to better represent the diversity of situations in Europe. The first, in the United Kingdom, was chosen mainly because of the availability of data at a large scale - a feature of the case study likely to be useful for conducting the extrapolation in the following step of the project. Erosion in the UK has been quantified in England and Wales since the early 1980s by means of field-based assessment rather than plot experiments, as is usually done for this particular threat. This extensive study, involving 17 townships, therefore, provides valuable information on the rate, frequency, and extent of erosion, as well as on off-site effects such as sediments carried out of the catchments, etc. Costs have been evaluated in order to estimate short- and medium-term impact both on- and off-farm. Although the figures are imprecise and open to criticism (even by the authors of the studies themselves), they are considered to be adequate for an overall comparison of the impact of erosion.

The second case study is in France where two small sites[1], located in very different climatic and soil conditions, have been monitored and studied in detail for several years. France has a wide range of different erosive contexts due to its diversity of soil types, climate, geomorphology, land use and agricultural systems. To account for this variety, two very different systems were studied, in the Pays de Caux and in the Lauragais. The Lauragais is hilly and is covered by fine-grain (clay fraction) soil with a relatively good structural stability. It is characterised by a temperate oceanic climate with some Mediterranean influence (heavy spring storms). The Pays de Caux is representative of the loess belt of Northern Europe. The land is relatively flat and is covered by a silt-loam soil that is very susceptible to soil crusting because of its low clay (13-17%) and low organic matter (1-2%) contents. Runoff and soil erosion problems have reached an alarming level both in terms of rate and of geographical extent in this area where catastrophic muddy floods still occur regularly and there is recurrent pollution of drinking water sources by both sediments and agricultural chemicals.

[1] These case studies come from research done within the framework of the French GESSOL projects (Le Bissonnais et al., 2003), the aim of which was to investigate the cost effectiveness of conservation measures to combat soil erosion caused by changing agricultural practices.

Contamination

Point-source soil **contamination** often comes from abandoned industrial plants, former industrial accidents and inappropriate municipal and industrial waste disposal. Near industrial plants still in operation, soil contamination is commonly associated with past activities, although current activities can still have a significant impact (EEA-UNEP, 2000). The Métaleurop Nord site is representative of this type of local point-source contamination. It is also a "megasite" (a large-scale contaminated site that poses a major potential or actual risk of deterioration to groundwater, sediment, soil and surface-water quality). Among the millions of contaminated sites identified in Europe, only a few hundred are megasites. They are, however, in most cases, the only ones having off-site effects, generating different types of costs. For the smaller sites, as described in other case studies (Appendix 1), costs are related mainly to site remediation, now often included in redevelopment project costs in order to accelerate the re-use of the site. Métaleurop Nord is located in a major industrial area, the Nord-Pas de Calais region of France, where several industrial sites could impact the same natural resources.

Erosion and contamination constitute threats that are studied in both environmental and economic terms. For the other threats identified in the European Communication on Soil Protection, however, there is much less data.

Salinisation:

The case study chosen to represent **salinisation** is located in Spain, one of the European regions affected by this threat. This particular case is caused by extensive irrigation, which enables plant growth in otherwise water-deficient conditions. Although irrigation increases plant growth and Soil Organic Matter (SOM) builds up, the negative effects (i.e., salinisation) can outweigh these positive effects. Irrigation is done mainly in arid and semi-arid regions. The STS working groups have found that no detailed studies exist on the extent of salinisation in Europe and the assessment of the economic impact has been limited to the consequences of the use (and non-use) of irrigation in agriculture. There has been no cost estimation of the environmental impact (e.g., on biodiversity) of salinisation. Studies of the effect of various possible means of maintaining or even improving the situation are just beginning due to efforts to increase agricultural production. Here again, the figures are open to criticism, with the effects being short-lived in relation to climate conditions. Annual variations in crop yield due to variations in weather conditions are likely to be large enough to mask any decline in yield due to soil structure or salinisation problems.

Organic Matter Loss (OM Loss):

There is even less data on **Organic Matter Loss**. Soil quality is determined by its organic matter content, which is dynamic and responds rapidly to changes in soil management. Except in areas where there is a surplus of animal manure, the organic matter content of cultivated soils across Europe is decreasing as a result of intensive modern agricultural practices. Organic matter in soils plays a wide range of key roles that influence many of the activities undertaken on the surface of the earth, it is therefore essential that soil organic matter levels be maintained and that effort be taken to improve them in places where they have declined significantly. A key measure in most degraded soil systems is the addition of organic material to improve the soil organic matter content and thereby maintain soil functions and uses. The STS Working Group on Organic Matter stated that data on soil fauna and flora, organic matter and heavy metals are inadequate at the European level and that it is extremely difficult to estimate organic matter content (and thus OM losses) on a level broader than the local scale.

At the European scale, three types of situations are associated with OM loss: i) peat extraction in Northern Europe (Scandinavia, Ireland), ii) intensive agriculture and progressive depletion of organic matter content in middle-latitude regions (e.g., France, the Netherlands, Germany), iii) historic and extensive OM loss due to climate and desertification in Southern Europe. Peat extraction differs from the two other situations in that it is neither natural nor reversible.

The Swedish case studies concern peat cutting and OM extraction, and therefore only address one specific facet of the OM loss issue. Although peat soils cover only a small part of Europe's total land area (about 2.3%), they are estimated to represent as much as 23% of the total organic carbon stock in European soil. This case might be considered a hotspot of SOM loss.

Flooding:

An Italian **flooding** case study related to a major climatic event that occurred in 1999 was pre-selected. Determining the role that soil degradation (compaction and sealing) played in the flooding has, however, been difficult and highly uncertain[2]. There is not enough economic data available to describe and quantitatively assess the impact that flooding has had on soil contamination and erosion (two indirect impacts of flooding). Consequently, the case study was done using qualitative data (Appendix 1).

The five selected case studies could not fulfil all of the preliminary objectives (good geographical balance, representative of the major threats, availability of environmental and economic data). To cover the different forms of each threat at the European scale, several more case studies would be needed.

The areas for which there is abundant available data, in particular economic data, are not necessarily the ones that are most severely affected by the soil threats.

The different case studies represent one of the main types of each threat:

- medium erosion rate in two different areas
- contamination of a megasite
- salinisation due to intensive irrigation
- organic matter loss due to peat extraction

They only cover impacts on the two economic sectors most often studied in the past– agriculture (erosion and salinisation) and industry (contamination and OML).

The selected case studies cannot, therefore, alone represent the situation in all of Europe and, therefore, will not be the only data source for the extrapolation task.

2.5 DATA QUANTITY AND QUALITY

It should be noted that:

- Data sources at the European, national and even regional level are fragmented, regardless of the threat studied.
- The use of national and regional data is often restricted to the country or the region of origin.

[2] The extent, frequency and severity of the damage are closely related to the actual climatic event. Therefore, in order to calculate costs on a regional, national or European level, it would be necessary to simulate the size of the area affected by specific events, how often the damage would occur in relation to the magnitude of the event, and how severe the damage would be. This is still a major area of research.

- The same data found in the different sources is similar, but also, in some cases, different. This is probably due to different protocols for recording data collection procedures and results.
- Access to primary data is limited, without any interpretation or expert judgement.
- It is difficult to assess data reliability. Some data sources give either primary or secondary (interpreted) data. The source of primary data is not always known.
- Various technical and economic standards are used for quantification. Data must be homogeneous to enable combination, interpretation and comparison. Consequently there is a need for harmonisation of data and scope.
- Certain data are related to changes in the legal framework or to new social expectations (which should be defined and implemented in order to gain a better economic assessment). The data 'standard' is not static.

Some of the overall cost estimates must be considered to be conservative because:

- Estimates of non-use value costs are lacking for some consequences of threats (e.g., loss of patrimonial value, anxiety due to flooding, biodiversity loss, ecosystem damages for almost all threats, etc.).
- In some cases, MC costs are covered by government budgets (e.g., all expenditures during actual emergency periods for the flooding case).
- Some data for events take only short-term issues into consideration.

As a result:

- Non-use value costs are not estimated in this study.
- Some costs arise after a time lapse that is not necessarily compatible with the time schedule of certain actors.
- The interests of some harmed groups are not represented due to the level of complexity of the threats (interference at individual, local, regional, national, international levels).

Given the lack of any scientific basis in some cases and the scarcity of information/resources, it was not possible to consider all of the effects of soil deterioration (on-site and off-site effects).

2.6 ANALYSIS OF THE COLLECTED DATA

2.6.1 Types of threats covered by economic data

During this part of the project (case study), in-depth economic information was obtained for:

- several cases of water erosion
- one case of point-source contamination (no cases of diffuse contamination)
- two cases of salinisation

However, the cases of organic matter loss, flooding and landslide were incompletely analysed because of the lack of economic data.

This is in line with the results of the literature review (Görlach et al., 2004) in which many "studies focus on the costs of erosion, whereas other aspects of soil degradation receive less attention". Information is available at a local/national level from Ministries or scientists, and at the European level from European networks or the European institutions currently dealing with these particular threats.

Data availability varies from country to country (when available at this level) and from threat to threat.

2.6.2 Types of costs

Generally, data on on-site private damage costs (PC) and private mitigation and repair costs (MC) were more easily obtainable than off-site social costs (SC), defensive costs (DC) or non-user costs (NC). As seen in the literature review, there is no data on non-use value of soil associated with the threats studied here.

The situations for erosion and contamination can be rather different:

- For erosion, off-site costs represent a significant proportion of the total cost, exceeding on-site costs (related to decreased yield and therefore loss of income).
- For contamination, the situation varies from site to site, depending on the type of emission at the origin of the contamination. At megasites, where there are off-site effects such as health impacts on the neighbouring population, the cost can be great, often exceeds on-site impact costs and is covered by government bodies. At small sites, the on-site impact costs represent the major part of the total cost and can be incorporated into individual redevelopment projects.
- For contamination, costs vary from country to country, depending on the national legal framework, in particular the level of tolerable risk, possibly leading to different remediation objectives for the same type of site.

In almost all cases, the primary data sources are not identified or known by the data providers (second-hand data), which prohibits us from providing a comprehensive and reliable cost estimation.

2.6.3 Evaluation of the proposed indicators

Environmental and economic indicators are based on the results of the literature review and there is a direct and logical link between the two types of indicators. For erosion, contamination and salinisation, environmental indicators can be developed partly on the basis of publicly available information.

Unfortunately, some of the data necessary to establish environmental indicators are not yet available as a synthesis of European-level data. The surface areas affected by contamination are an example of this. Some countries inventory:

- **the surface area of contaminated soils**. This information is necessary for the evaluation of reclamation costs, but requires site investigations. Information is, therefore, not necessarily available for all sites but depends on the state of progress of management.
- **the surface area of sites**. This information, easily accessible and sought at an early stage of the investigation (historical analysis), is necessary for the redevelopment. A direct link with the real estate market exists in some cases.

Depending on the objectives, both types of information are of interest. Data collection recommendations could be made so that both management requirements would be satisfied.

Therefore, for erosion and contamination, the methodology described in Paragraph 4.6 of the literature review could be derived, in part, on the basis of the theoretical and case study considerations.

2.6.4 Information at the national level

All Member States were contacted either through their Ministries for Environment, Environment Agencies or Scientific Experts involved in European soil quality networks. There are enormous discrepancies in the data situation, which is generally barely satisfactory. However, some European countries have partial information on soil quality and the economic impact of its deterioration. The data collected is presented in Appendix 3.

3 Case studies

3.1 EROSION / UK, GENERAL CASE

In Europe, it is mainly water and winds that cause soil erosion. Repeated erosion causes irreversible soil loss over time, thus reducing the ecological functions of soil: mainly biomass production, crop yield due to the removal of nutrients for plant growth and reduction in soil filtering capacity due to disturbance of the hydrological cycle (from precipitation to runoff). The major reasons are unsustainable agricultural practices and overgrazing in medium- and high-risk areas of land degradation (EEA, 1999a), together with deforestation, urban and industrial activities.

In the early 1980s, the Ministry of Agriculture in England and Wales took the decision to assess whether water erosion was a true problem, deciding to answer the question through field-based assessment rather than plot experiments. Although giving valuable information on the rates, frequency and extent of erosion, as well as the delivery of sediments outside catchments, the results do not allow identification of a relationship to individual parameters, so that erosion rates cannot be predicted.

This case study is mainly based on a peer review of the UK report on soil erosion, with particular reference to the costs of erosion at farm level and the identification of intertemporal aspects for soil degradation (Evans, 1995, 1990a, 1990b, 2000).

Most of the work was carried out between 1982 and 1986, on 17 surveyed traverses covering a wide variety of soil landscapes, representative of much of the arable England and Wales, with topsoil textures ranging from clay to sand (figure 2).

Whilst the plot-based approach can aid our understanding of the processes and factors governing water erosion, it is of little help in predicting water erosion rates in cultivated fields or the landscape as a whole. The major drawback of plot experiments is that the runoff and associated transported soil are either collected by directing the flow over the lower edge of the plot, and consequently via a rapid fall in height into containers, or are discarded. Other reasons are related to variations in slope shape and angle, the necessary up-scaling from plot to field and landscape, etc.

3.1.1 Presentation of the case study

In the past, the UK countryside was covered mainly with woods. As the population grew, the woods were cleared and replaced by grassland and arable land. Under this natural or semi-natural vegetation cover, the British landscape is generally not vulnerable to erosion, except during rare heavy storms when slopes can become unstable and landslides may occur.

The main origins of erosion are (i) water erosion (80.7%) and (ii) wind erosion (9.1%). Additionally, (iii) upland erosion and (iv) overgrazing need to be considered. Studies have been conducted at the local level to evaluate the actual risk of erosion (Evans, 1990). The survey covered an overall area of 151,207 km^2 (England and Wales) representing 296 soil associations: note that urban and industrial areas were not surveyed (1.8% of total area).

- 38.2% (53,449 km^2) of the surveyed land was considered as having a very low risk of erosion (erosion rare or not existent): this part of the area is mostly covered by grass (52%), arable land (36.1%), forests (0.8%) and heather and moorland (12.0%).
- 38% was classified at low risk (fields and moorland subjected to erosion are likely to cover 1% or less of the land each year), mainly arable land (53%) and grass cover (32%).

- 18% (25,157 km^2) was at moderate risk (for arable land, between 1 and 5% shows a risk of erosion each year), of which 75% is arable land,
- 4.4% (6,198 km^2) was at high risk (more than 5% of fields affected per year)
- 1.5% was classified at very high risk (more than 10% affected per year and two years in five as much as 20-25% affected).

The pre-dominant land use in the study areas is agriculture with a low population density, apart from on the edge of urban areas where a high population density occurs. The main threats in these areas are erosion and runoff. Flooding can affect densely populated urban areas.

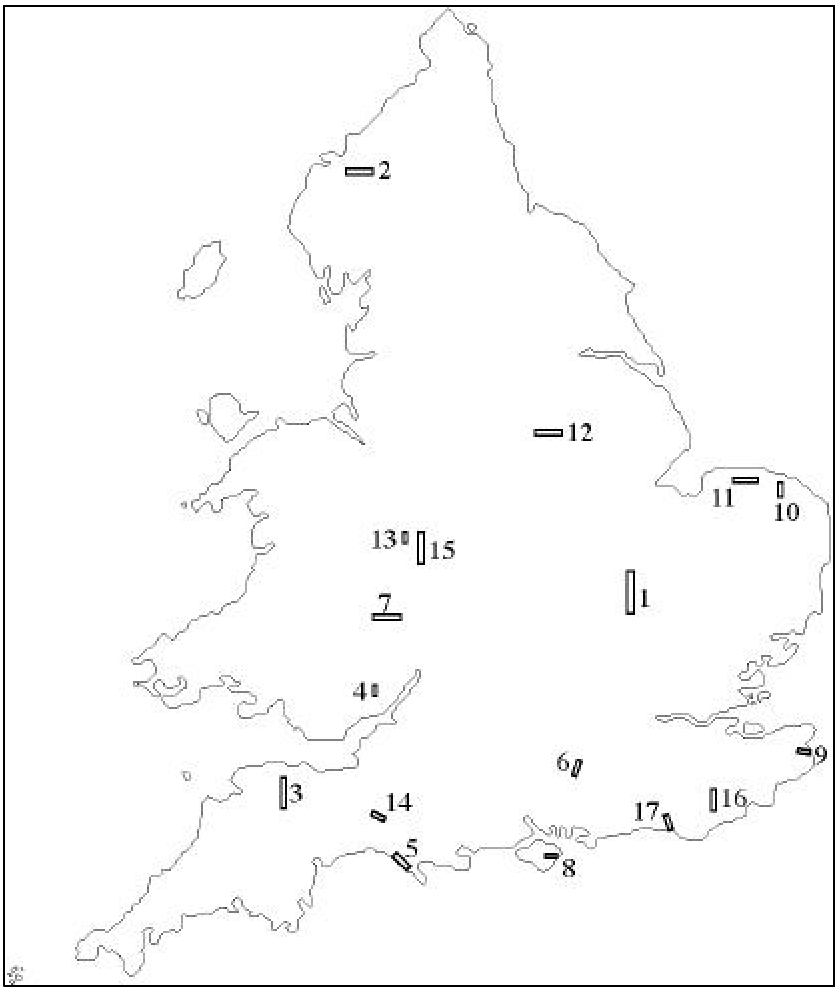


Figure 2. Location of sampling areas for the UK Erosion case (source: Evans, 2002)

(1) Bedfordshire/Cambridgeshire; (2) Cumbria; (3) Devon; (4) Gwent; (5) Dorset; (6) Hampshire; (7) Herefordshire; (8) Isle of Wight; (9) Kent; (10) Norfolk East (11) Norfolk West; (12) Nottinghamshire; (13) Shropshire; (14) Somerset; (15) Staffordshire; (16) Sussex East; (17) Sussex West / Shropshire.

3.1.1.1 Local conditions

Erosion generally affects rolling terrain where slopes are steeper than 3 degrees. Water can run off flat land into ditches and rivers but will carry little soil. Storms causing runoff and erosion will generally be greater than 10 mm. All soil textures can be eroded by runoff, although soils with a high proportion of coarse silt or fine to medium sand are the most vulnerable. Wind erodes soil from fields, which are generally flat, and where soils are composed of fine sand or peat. Evans describes the physical characteristics of sites showing a risk of erosion (1990a, 1995), the vulnerability of soil associations to erosion by water, wind and in upland settings (where both weather and animals are important) (1990b) and the risk of erosion occurring in relation to particular crops (2002).

3.1.1.2 Extent of erosion

The monitored erosion in the 17 localities covers 70,000 ha/year. Erosion and its impacts are analysed for areas ranging in size from one hectare, to an individual field (average area 7.5 ha), through to soil associations up to hundreds of hectares.

The area most affected by erosion was the sand land of Nottinghamshire in central England where, on average, 14% of the arable landscape was eroded each year, with a range of 1.5 – 24.0%. Erosion was less common on silty (3.9% of fields) and clayey (1.6%) soils. Eight other localities where erosion was widespread (5-10% of fields) also had erodible topsoil with high sand or silt contents, and where a wide range of crops that were vulnerable to erosion, both during winter and spring storms, were commonly present.

3.1.1.3 Rates of erosion

The highest erosion rates (4-5 m^3/ha) were associated with fields where the topsoil had high contents of silt or fine sand (Kent, Somerset, Isle of Wight, and Hampshire). For the sandy soils in Staffordshire and Shropshire, these erosion rates were halved. In many other areas, the erosion rate was about 1.0 m^3/ha. The highest rates of erosion by crop type were related to market garden crops such as maize, ley grasses, hops and sugar beet.

Fields in Kent, the Isle of Wight, and Somerset can have their land surfaces lowered by about 0.25 - 0.5 mm/ha*yr for soils eroded every one or two years.

3.1.1.4 Frequency of erosion

The frequency of erosion was greatest in Kent (average about once a year) where irrigation is used to grow field vegetables and over half the fields are eroded twice or more per year. In most of the other areas, the fields that suffered erosion were eroded every 2-4 years.

3.1.1.5 Conservation measures

Conservation measures are rarely applied to protect the land from water erosion. The set-aside technique is known to be particularly effective in stopping erosion (Evans and Boardman 2003), and at a very reasonable cost for the farmer. Other techniques also deployed are grass buffer strips (funded by EU or the government), small dams, cultivating and drilling roughly along rather than across the contour of valley floors and depressions (being careful not to funnel water into these depressions) as well as planting cover crops. There are various ways to protect land and crops from wind erosion, with most of the costs being borne by the farmer. Farmers thus generally only protect high-value crops, such as sugar beet, carrots, onions, but not cereals. A nurse crop is most commonly used, which is later sprayed off. On sandy soils, rolling the land when slightly damp can produce a protective crust into which the sugar beet seeds are drilled; however, such a crust can exacerbate runoff. The following table shows a synthesis of the soil erosion characteristics in the 17 surveyed localities.

Table 3. Median volume of erosion (m^3/ha) and total surface area of the 17 surveyed localities

Localities	Total surface area [ha]	Main soil type	Median Volume of erosion [m^3/ha]
(1) (Bedfordshire) / Cambridgeshire	222,700		0.2

Localities	Total surface area [ha]	Main soil type	Median Volume of erosion [m^3/ha]
(2) Cumbria	680,900		
(3) Devon	674,700		1.6
(4) Gwent	356,400		0.6
(5) Dorset	252,000		1.5
(6) Hampshire	427,100	High silt or sand content	0.6
(7) Herefordshire	218,300		0.6
(8) Isle of Wight	39,500	High silt or sand content	2.1
(9) Kent	395,000	High silt or sand content	1.2
(10) Norfolk East	532,200		0.5
(11) Norfolk West			
(12) Nottinghamshire	218,600	Sand (also silty (3,9%) and clayey (1,6%) soils)	1.8
(13) Shropshire	348,900	Sandy soils	1.4
(14) Somerset	418,500	High silt or sand content	2.8
(15) Staffordshire	298,900	Sandy soils	1.3
(16) Sussex East	377,900		0.5
(17) Sussex West			0.4

3.1.2 Impact of soil erosion

Soil erosion impacts are generally divided into on-site and off-site impacts. While on-site impacts are direct effects of soil loss (expressed in t/ha*yr) and affect mainly agricultural activities, off-site impacts are the consequent damages to natural ecosystems and entire water bodies. In the UK study, the impacts are classified as "on-farm" and "off-farm".

On-site (or on-farm) impacts

- Loss of soil fertility: fertility and productivity of eroded land are reduced. Farmers have to apply more fertilisers in order to compensate yield losses.
- Changes in crop yields: water erosion typically affects crop production through a decrease in plant rooting depth, as well as a removal of plant nutrients and organic matter.
- Water erosion can locally lead to uprooting of plants and/or trees, together with dissection of the terrain by rills and gullies.

Off-site (or off-farm) impacts

- Damage to roads and property: soil can be carried out of the fields and deposited on roads and in ditches. Impacts felt by the highway authorities and the water supply industry can be considerable and much more severe than those at farm level.
- Impacts on water pollution: sedimentary deposits can have severe implications for human health - heavy metals, phosphate or pesticides attached to sediments need to be removed to make water supplies drinkable.
- The water-holding capacity of the soil can also be lowered through erosion, leading to disturbance of drainage, an increased occurrence of flooding and landslides.
- Effects on natural ecosystems: for example, soil material eroded from agricultural land disturbs natural ecosystems. The input of sediments into watercourses can harm fishery activities.

In addition, losses of soil by erosion can be considered irreversible over a period of 100 years, due to the very slow rates of soil formation. In Southeast England, wind erosion has been recorded at 21 t/ha*y over a period of 30 years. Therefore Evans (1995) introduced a temporal distinction of impacts: short-term (5-10 years), medium-term (10-50 years) and long-term (>50 years) impacts. On-site impacts occur mainly in the short- to medium-term period, whereas off-site impacts occur in the medium- to long-term period.

3.1.3 Cost estimation

The typology of the costs elaborated by Evans has been used as a conceptual framework to describe different costs of soil erosion in these case studies. The UK evaluation made in the mid-1980s and early 1990s for England and Wales for the costs of the impacts of erosion is based on the following three steps:

- Estimation of the area of the land affected
- Assessment of how often the damage occurs
- Evaluation of how severe the damage is

All monetary values that were derived from the UK study are reported in Euro values, using the Consumer Price Indices of 2000 (UK National Statistics)[3].

3.1.3.1 On-site costs

This category refers to the direct costs of soil erosion incurred mainly by farmers. The estimated costs of the individual arable farmer are small, both in the short and medium term. On average, about 4% of arable land are concerned by erosion in the 17 localities.

The loss of fertilisers, crop and yield will generally be no more than a few Euros per farm, and costs can be recouped by the CAP subsidy payment on 1 or 2 ha. Costs of water and wind erosion of a field sown with winter cereal are about 13 €/ha. For a higher-value crop, such as sugar beet, costs are of the order of 20 €/ha. Wind erosion of a high-value crop costs the farmer more, which is why more efforts were made in the past to stop wind erosion. Action was taken not to protect the soil but to protect the crop, meaning that wind erosion of sugar beet on sand would cost a farmer 53-107 €/ha, and on peat, which is more vulnerable to the effects of wind, some 154-456 €/ha.

[3] 1£ = 1.49€. The consumer price index can be found at www.statistics.gov.uk

Table 4. On-site costs of erosion for the individual farmer (source based on Evans, 1995)

	€/ha	**€/Field**	**€/farm**
Water erosion			
Winter cereal	13	91	94-189
Sugar beet	20	154	157-315
Wind erosion			
Winter cereal	13	91	94-189
Sugar beet - Sand	53-107	397-796	787-1573
Sugar beet - Peat	154-456	1161-3458	2360-3147

Evans also distinguishes between input loss (reduced usability of seeds, plants and fertilisers) and output loss (reduced crop and yield production). These are "on-crop" damages and directly affect the farmers' revenue. There is also "on-soil" damage, such as the degradation of soil structure (mitigation costs by labour for tillage) or the decline of organic matter (output loss of soil fertility). The figures in Table 5 only take the costs of "on-crop" damage into account.

At national level, on-farm costs of erosion for England and Wales as a whole amount to less than 10 M€$_{2000}$ (the cost estimation is based on 1991 prices), which is less than 0.1% of total agricultural production. Water erosion accounts for 67% of the total on-site costs.

Table 5. National on-site costs of erosion in England and Wales

	lost inputs [M€$_{2000}$]	lost outputs [M€$_{2000}$]
Lowlands		
Water erosion	0.97	3.19
Wind erosion	0.71	2.39
Uplands		2.09
Total	1.68	7.67

3.1.3.2 Off-site costs

This category refers to direct and indirect costs generated by erosion of soil for third parties (costs to society). The UK study deals with costing the damage of: sedimentation in ditches and on roads, water pollution, stream channels, degraded footpaths, etc.

<u>Costs of sedimentation in ditches, on roads, and damage to property</u>

The impacts of erosion associated with this cost category can easily be listed. These costs have been estimated at national level. The defensive expenditure and clean-up costs taken into account are associated with:

- Soil carried onto roads, which has to be removed by Highway Authorities,
- Soil transported into ditches, which has to be cleared by Highway Authorities and Internal Drainage Boards,

- Flooding and windblows causing damage to properties, paid for by insurance companies and home owners,
- Measures to alleviate flooding paid for by Local Authorities.

Table 6. Estimated costs of flooding and windblows in the different sampling areas (Source: Evans, 1995b)

Locality and impact	Erosion process	Costs [€ / ha]
Cambridgeshire fens – roads	Wind	0.031
Nottinghamshire sand lands- roads	Water	0.134
Lincolnshire sand lands - roads	Wind	0.144
Norfolk fens - roads	Wind	0.786
Isle of Wight greensand - roads	Water	1.020
Somerset - roads	Water	1.042
Sussex downland – mostly houses and flood alleviation	Water	1.065
Isle of Wight light loams – houses and roads	Water	1.255
Lincolnshire fens - ditches	Wind	1.818
Kent chalk and greensand – roads only	Water	2.349
Isle of Axholme sand and peat – roads and ditches	Wind	3.601
East Anglian fens - ditches	Wind	8.491
Mean for 12 localities		**1.87**

By applying figures from Table 6 to those areas known to be the most vulnerable to erosion, we can estimate the national costs of the impacts of erosion on ditches, roads and property: 6.9 M€$_{2000}$ per year. On average, the cost of clearing up and alleviating erosion was 1.9 €/ha.

In addition, flooding of roads can also cause motor accidents. An estimation of the costs, assuming five slight accidents per year, gives a cost of ca. 200,000 €/year.

The estimated costs of casualties due to flooding are not considered. This would significantly increase the off-site costs caused by erosion.

Costs of water pollution

Soil erosion is a major source of phosphates and pesticides, which become bound to sediments and that need to be removed in order to render water supplies drinkable. The sources of pesticides in water are mainly from spraying winter cereals. Only rough estimations can be made as to what extent the pollution is caused by erosion or leaching from farmers' fields. Most drinking-water reservoirs in eastern and southern England are filled with water pumped from rivers at high-flow periods, especially in the winter when erosion and leaching take place.

The costs of the water industry of making water drinkable by removing nutrients, pesticides, sediment and colour (from organic colloids mainly from peat) is estimated to be 504.4 m €$_{2000}$ per year. This figure represents approximately 1% of the expenditures covered by the water company to improve water quality (Anglian Water, 1990), in Central and Eastern England (for more detailed assumption under this estimation see, Evans, 1995).

Costs of stream channels

It has been estimated that erosion and sedimentation of stream channels costs National Rivers Authority (NRA) 13.6 M€$_{2000}$ per year.

Costs of maintaining footpaths

Footpath degradation in England and Wales costs an average of 1.9 M€$_{2000}$ per year. This figure includes restoring national trails but does not cover, for example, the costs of repairing footpaths in local country parks.

Costs related to fisheries and fishing

The enrichment and sedimentation of water courses has other impacts, especially on fisheries and fishing (disappearance of or threat to fish populations) which presently are difficult to quantify and cannot be easily monetized (loss in revenues of fisheries or due to fewer fishing permits and licences). To give some perspective to the costs of erosion on fishing, the NRA spent 42.87 M€$_{2000}$ / year on fisheries (based on financial year 1991/92). This includes the loss in revenue of fishing sport clubs as decreasing in fishing permits and licences.

Costs related to monitoring erosion

This category refers to the cost of the measures implemented to limit off-site impacts of erosion. The estimated costs only include erosion monitoring. The NRA spent a further 148.2 M€$_{2000}$/year monitoring water quality in 1992, of which a certain proportion must be allotted to erosion. If we assume that at least 10% of NRA expenditure is related to erosion monitoring, then associated costs can be approximated at 15 M€$_{2000}$/year.

The total off-site costs of erosion for England and Wales is summarised in the table below:

Table 7. Off-site costs of erosion in England and Wales (source based on Evans, 1995)

Type of cost	**Cost at national level [M€$_{2000}$ / year]**
Damage to roads, ditches and property	6.9
Traffic disruption or traffic accidents caused by flooding – on the basis of 5 accidents per year	0.2
Water pollution (cost of making water drinkable by removing nutrients, pesticides, sediment and colour)	504.4
Damage to stream channels	13.58
Damage to footpaths	1.9
Indirect damage to fisheries and fishing	42.87
Monitoring erosion	14.82
Total off-site costs	**584.67**

3.1.3.3 Non-use value costs (NC)

Within the category of non-use value costs, someone who is not currently using the soil, nor intends to use it, experiences erosion damage affecting the degradation of the ecosystems as a loss. Non-use value costs are much more difficult to assess economically. In this case study, the costs of non-use values concern the destruction of archaeological monuments, such as in the Yorkshire Dales and the Lake District. However, archaeological damages are very specific to local sites and not representative for national erosion damage. The non-use costs have not been assessed in this case study.

3.1.3.4 Synthesis of cost estimation

The estimated costs were derived from the 17 survey localities that were then combined to reflect the national situation. The figures contained in this UK study do not allow unit cost per ha or per ton for each cost category, as developed in the literature review (Volume I of this report).

At national level, the total off-site cost of soil erosion outweighs the total on-site cost by a factor of 60. This shows that the costs for farmers are very small compared to the costs for society.

Table 8. Synthesis – costs of soil erosion for the UK case study

On-site costs (PC & MC)	Off-site costs (SC & DC)	NC
Production loss due to eroded agricultural soils	Damage to roads, ditches and property - Road accidents due to erosion Water pollution Restoring footpaths Stream channels Fisheries and fishing Motoring erosion	Impact on landscape Values and biodiversity Destruction of archaeological monuments
9.35 M€$_{2000}$/yr	584.67 M€$_{2000}$/yr	Not estimated

These costs are estimated on the base year 1990. It's an average total cost for this year that has been brought up to date for the reference year, 2000. It should not be considered as an annual cost: calculation does not take into account the cumulative effects undergone the previous years. To consider a cost annual average, it would have been necessary to know the growth rate of erosion (intensity and surface of eroded areas).

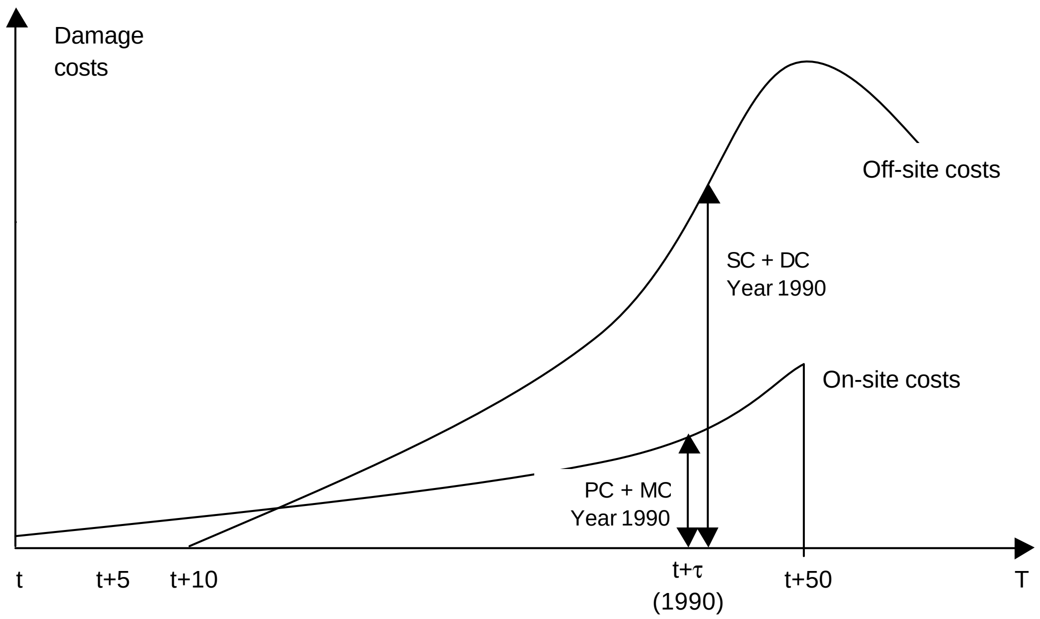


Figure 3. Temporal aspects of erosion costs

The figure 3 gives a schematic representation of the evolution of one-site and off-site costs. The on-site costs occur mainly in the short-medium term period (5 – 50 years), after that arable land are subject to the abandonment from farmers and the agricultural loss are considered equal to zero. However off-site costs began to occur in the medium (10-50 years) and continue over a long-term period (>50 years).

According Evans, if agricultural land is degraded one class (on the classification grid of erosion risk), the on-site costs are increased by 40%. Under the assumption of a degradation of one erosion risk class every 5 years, the annual increase of on-site revenue losses will be around 8%.

3.1.3.5 Who bears the costs?

The main actors are farmers (from whose land the soil is washed away), property owners (those on the receiving end of the flooding), council taxpayers (who pay for repairs to highways), water ratepayers (who pay for water clean up), and insurance companies (that reimburse other stakeholders).

The results from the monitoring scheme explain why farmers think erosion is of little importance: in the vast majority of instances, erosion does not either affect how the farmer manages the land, or lead to a sufficient removal or burial of the crop to affect profitability.

The costs are borne primarily by the households and the taxpayers. As regards industry, the costs are borne by the water and insurance companies rather than the agrofood producing and selling/retailing (supermarkets) industries.

The bulk of the various costs are not borne by the farmers, but by the actual UK public. This is felt presently, and directly, as both a council and national taxpayer (for highway and local authorities), a water consumer and payer of insurance contributions and, both presently and in the past, through the costs imposed by a loss in agricultural productivity.

3.1.4 Conclusion

The methodology for cost estimation is based on erosion survey data and other information relating to costs obtained in several of the studies by Evans (1995a, 1995b, 1996). These studies attempt to estimate the total costs of UK soil erosion damage from the detailed survey of 17 localities. Given the multifaceted and long-term nature of erosion and its economic impact (mainly on agriculture), many assumptions have to be made concerning the data. Although these results are not very accurate, they do provide an order of magnitude for soil erosion costs.

Off-site costs are usually broader than on-site costs. The British situation described in this case study is representative of the Northern and Central European situation. The costs could be derived taking into consideration the variation of population density, which is the only parameter changing in the different countries and affecting the off-site costs.

In some instances, it is not possible to give monetary values for erosion. For example, the costs of damaged or lost items that, although considered by their owners as irreplaceable (such as landscape historical value), cherished items of great personal/sentimental value, have very little value in concrete terms.

In addition, the fear of being flooded by sediment-laden water can become substantial if a change in the land use leads to more frequent flooding. It is impossible to give an economic value to worries, but these can nevertheless have a significant negative effect on health.

The links between soil erosion and its impacts and economic uses are immediate. In a context of intensified land use in England and Wales over the last ca. 50 years and farmers responding to government and European Union economic policies, erosion has become more extensive, frequent and severe; in turn, the impacts have become more widespread and pervasive, especially in the last two decades in the wetter western parts.

The actual erosion risk depends mainly on the present-day land use. It may change over time for economic (e.g. with the introduction of new crops with high added value or an increase in the number of grazing animals) and political reasons, or because of climate change. Changes in soil erosion risk category have been estimated so as to assess the consequences of land-use changes or intensification, although this has not been used in this case study to evaluate the consequences on erosion costs.

3.2 EROSION / FRANCE, LAURAGAIS AND PAYS DE CAUX

Soil erosion in France, as elsewhere in Europe, concerns mainly arable land (except for the badlands near the Mediterranean). Over the last 30 years, technological developments, commercial considerations and Common Agricultural Policy subsidies have influenced agricultural practices. These include changes in plant varieties, a simplification of crop rotation systems, and an increase in farm input (mainly a concentration of labour and increased work pressure during sowing and harvesting, and the reduction of grassland area due to an increase in fodder production and a drop in livestock farming), which, in turn, has led to an increase in environmental problems such as erosion and runoff (Souchère et al., 2003).

Crop and grassland trends have been accompanied by an evolution in production structures: concentration and specialisation of holdings, and mechanisation of farming methods. For example, as ploughed areas have increased, farmers have simplified crop management and now use larger, heavier and more complex machines. To work faster with the larger machines, farmers have consolidated fields and removed ditches, hedgerows and ponds that used to regulate runoff (Chaïb, 1989).

The Lauragais and Pays de Caux case studies come from a research study conducted within the framework of the French GESSOL projects (Le Bissonnais et al., 2003), the aim of which was to investigate the cost effectiveness of conservation measures to combat soil erosion caused by modern agricultural practices. The cost and efficiency of the implementation of conservation measures was compared to the cost of soil erosion before the conservation measures were implemented in two representative areas in France.

3.2.1 Presentation of the case studies (regional settings)

France has a wide range of different erosive contexts due to its diversity of soil types, climate, geomorphology, land use and agricultural systems. Each context has a specific combination of physical processes of soil detachment, transport and deposition (Figure 1, from Le Bissonnais et al., 1998; 2003). In some cases (e.g., Pays de Caux), prevention and remedial measures are significant only if they are taken collectively by all of the actors that own or manage the different fields, but in other cases (e.g., the Lauragais), this is not always necessary. To account for this variety, these two different systems were studied.

<u>The Lauragais</u>

The Lauragais soil is made up of marls and molasse deposited by the erosion of the Pyrenees. It has rolling hills with altitudes typically ranging between 120 and 350 m (slope gradients can, in places, be more than 30%). In this hilly topography, soils with a rich clay fraction and a relatively good structural stability developed during the inter-glaciations (Bruno and Fox, 2002). The soil is fertile and the region has been cultivated since early times.

The Lauragais is characterised by a temperate oceanic climate with some Mediterranean influence (heavy spring storms). In spring, the fields cultivated with spring or summer crops have a very low vegetation cover and are therefore vulnerable to erosion (Bruno et Fox, 2002). Spring is therefore the most vulnerable period, as it combines barren soil and heavy storms (this being accentuated on steep slopes, which are common in the area).

In terms of physical processes, the hillside represents the operational scale and the hydrologic unit. Hillsides used to be subdivided into numerous fields, but are now cultivated as whole units and most often worked up- and down-slope.

Pays de Caux

Located in the loess belt of northern Europe (northwestern part of the Paris Basin), the area is covered by silt loam soils developed on the Quaternary loess deposit. These soils are very susceptible to soil crusting because of their low clay (13-17%) and organic matter (1-2%) contents. The terrain is relatively flat with slope gradients ranging between 1% and 5% on the plateau and 4% to 20% on valley sides.

The intensification of agricultural practices has increased pressure on the environment (Upper Normandy lost 200,000 ha (48%) of its grasslands between 1970 and 2000 (Boatman et al., 1999; Agreste, 2003)). Runoff and soil erosion problems have reached an alarming level in terms of both rate and geographical extent in loamy soils (Papy and Douyer, 1991; Boardman et al., 1994). As water erosion is characterised by the connectivity between areas producing runoff and waterways, its control requires concerted management at the catchment scale.

Two types of erosive events can be distinguished: high frequency-low magnitude winter rainfall, and low frequency-high magnitude spring and summer storms. Both on-site and off-site damages are observed. Despite the implementation of anti-erosion measures upstream of urban areas, catastrophic muddy floods still occur regularly and the pollution of drinking water sources both by sediments and agricultural chemicals are recurrent. Soil conservation and erosion prevention is now one of the top priorities of regional councils in this area (DRAF, Regional Council).

3.2.1.1 Local conditions

Pays de Caux

The Pays de Caux site is an 80-ha catchment farmed by three farmers. The land is planted with wheat, flax, peas, beet root and potatoes. Two thalwegs (where ephemeral gullies usually form) cross the catchment toward the outlet. They are a constraint for agriculture and a threat to the quality of the water pumped in the river downstream. After damage caused by erosion was observed, soil conservation measures such as retention ponds and vegetative filter strips were installed.

Lauragais

The Lauragais site consists of one 24-ha field that covers an entire hillside. It is planted with wheat (50% of the area), sunflowers, peas and rape. The slope gradient in the upper part of the field is relatively low (5 to 6 %), but sufficient for rill initiation. At the bottom of the slope, the gradient reaches 25% in places. In the steepest slope direction, the flow length is, on average, about 430 m, which makes the hillslides suseptible to erosion. As for the Pays de Caux site, conservation measures were implemented after damage caused by erosion was observed.

3.2.1.2 Extent of erosion (before implementation of soil conservation measures)

Pays de Caux

Every year, 5 ephemeral gullies (two 700 m long, two 100 m long and one 400 m long) form on the catchment. Some crops (potatoes and flax) are damaged by runoff or covered by sediments. In all, 3.22 ha of arable land are affected by erosion each year (average from 6 years of observation). Sediments are also deposited on roads and in the river.

Lauragais

The main signs of erosion are parallel rills (about 15 cm wide and 10 cm deep) that form every 15 to 20 m. The bottom of the slope is covered by sediment except when storms is intense, in which case the sediments flow off the field, filling the ditches and covering the road (D18). There are no precise figures for the affected surface area.

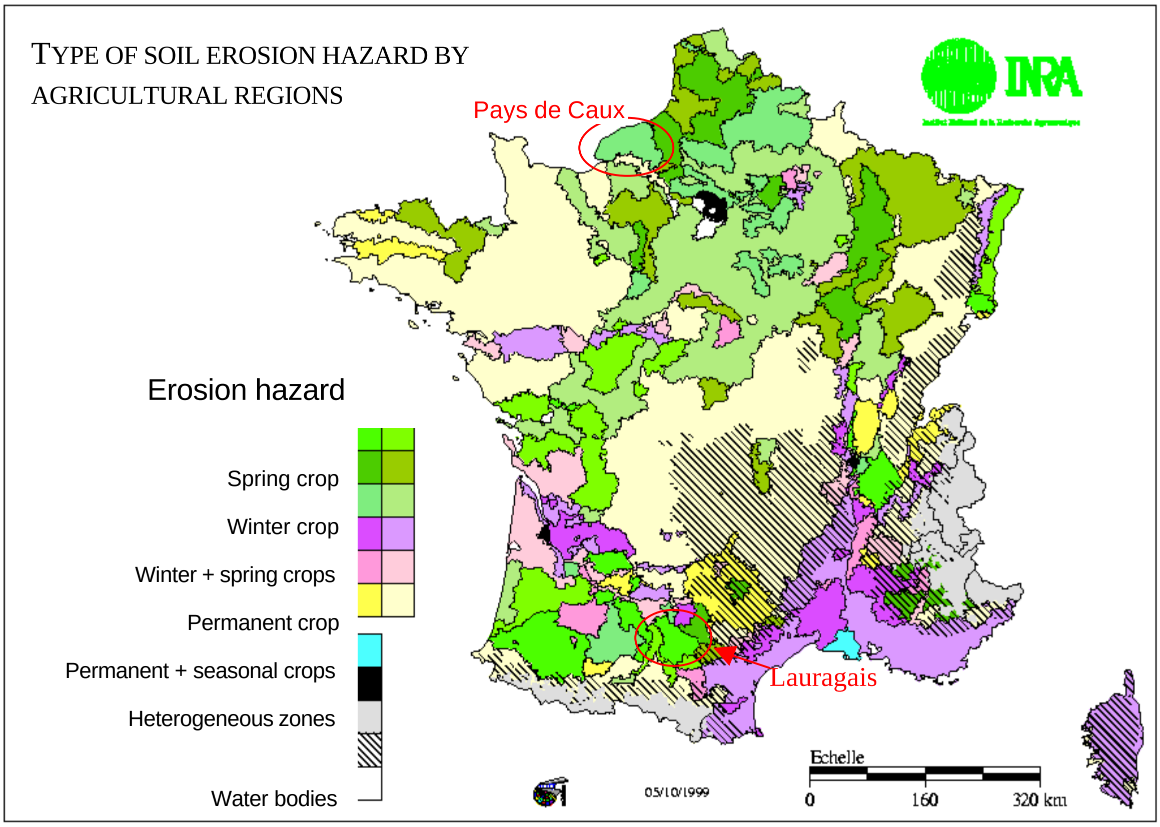


Figure 4. Location of the two French sites for soil erosion on the map presenting the types of soil erosion hazard by agricultural regions (Le Bissonnais et al. 2003).

3.2.1.3 Rates of erosion (before implementation of soil conservation measures)

Pays de Caux

Each year, 300 m^3 of sediment were lost by concentrated erosion vs. 60 m^3 that were deposited within the catchment. Sheet erosion was not measured, but as a first approximation, the customary ratio of sheet erosion to concentrated erosion, from 10 to 50%, can be used. The catchment, therefore, loses between 340 and 470 metric tons of sediment per year (i.e., an average rate of between 4.3 and 5.9 MT/ha/year).

Lauragais

Depending on climatic events, rates of soil erosion vary between 6 and, when there are heavy storms, 180 m^3/ha (for a hillside with an average slope of 20%). In 1996 and 1997, on the hillsides studied, more than 380 m^3 was dredged from the ditches below the field, which is the equivalent of an average rate of 10.3 MT/ha/year.

3.2.1.4 Frequency of erosion (before implementation of soil conservation measures)

Pays de Caux

Soil erosion is not the result of exceptional climatic events in the area; hence it is a recurrent phenomenon that takes place every year. Five ephemeral gullies formed on the site each year.

Lauragais

The frequency of storms is irregular. During the last three years, there have been 2 or 3 heavy storms each year in the vicinity of the field. But if we consider a longer time span of around 10 years, the average frequency is only one storm every two years. As an indication, it is considered that the return period of a storm on a field is five years.

3.2.1.5 Conservation measures

Two types of soil conservation measures were implemented on the sites.

The aim of some is to decrease runoff and reduce its sediment load. These measures are implemented upstream in the catchment, in or between fields. They include:

- Conservation tillage to preserve soil macroporosity and increase its organic matter content, thus increasing soil surface infiltrability and aggregate stability.
- Subdivision of large fields into smaller fields to reduce the flow-length and thereby reduce the flow velocity and erosive power).
- Vegetative filter strips (or hedges) planted upstream to reduce the production of runoff and the detachment of soil particles.

Others aim to control and “clean” the overland flow to reduce its impact on downstream areas. They include:

- Retention ponds to store runoff and trap the sediment load.
- Vegetative filter strips (or hedges) planted downstream to reduce the flow velocity and trap sediment particles.

<u>Pays de Caux</u>

One of the thalwegs was reshaped, two vegetative filter strips planted and two retention ponds created.

<u>Lauragais</u>

Several different soil conservation measures were implemented on the hillsides studied.

- The hillside was subdivided into four fields planted with different crops (to alternate between summer crops and winter crops that protect the soil in spring).
- Two 6-m wide vegetative filter strips were sown down-slope and at mid-slope.
- A hedge was planted upstream to anchor the soil.
- Conservation tilling was done on certain fields.

3.2.2 Impact of soil erosion

<u>Pays de Caux</u>

On-site, the impact of erosion is mainly characterised by the destruction of crops either by rilling (need to refill), deposition, or because they are carried away by runoff (flax). Damages to the public domain (off-site impact) consist of contamination of drinking water sources (nitrate, sediment or pesticide) and sediment deposition on the road. Almost no damages have been observed since the conservation measures were implemented.

<u>Lauragais</u>

On-site and off-site damages are similar to those observed on the Pays de Caux site. However, in addition to the consequences of erosion that are easily observed, one of the main concerns in the Lauragais area is the loss of topsoil. In some places, the layer of topsoil is relatively thin and fertility can be irreversible lost on the steepest slopes. Here also, almost no damage has been observed since the conservation measures were implemented.

As for the UK case, the impacts of soil erosion can be qualified either as on-site or off-site. On-site impacts are the direct effects of soil loss and affect mainly agricultural production (also called on-farm impacts), whereas physical damage to natural ecosystems and water bodies are off-site impacts.

3.2.3 Costs estimation

In the methodology described in the literature review (Volume I of this report, chapter 4.6) the distinction between on- and off-site costs is based mainly on the location where the damage occurs. On-site costs are related to the soil degradation (i.e., the removal and loss of soil–formation of gullies, reduction of topsoil layer, etc.), which occurs in agricultural fields. Off-site costs are caused by the transport of sediments and their deposition in other places (land, roads, rivers, etc.) where they generate a damage cost for third parties (negative external effect). The off-site cost of soil erosion depends on the cost of conservation measures and how effectively they reduce erosion damage. If measures have not yet been implemented, erosion damage estimation is based on expert evaluation (for example, from sizing calculations of the structural protection). On the other hand, if the measures were implemented long ago, past damage can only be estimated. All cost figures are calculated on the base year 1999.

3.2.3.1 On-site private costs

On-site private costs are the direct costs of soil erosion, incurred mainly by farmers, and other non-agricultural damages. They can be broken down into several distinct items:

- *Profit loss and crop loss:* income loss due to the destruction of planted crops is estimated by multiplying the destroyed cropped area by the average market price of the crop. The estimate of the financial loss caused by erosion takes into account the fact that the farmer spent money for production but did not make any profit on the crop (except farm subsidies, which are granted even if a crop is lost).
- *Working time loss:* erosion damage can lead to a loss of time during harvesting, the cost of which depends on the crop. Also, subdivision of one large field into smaller fields to reduce the flow velocity and erosive power increases the time spent on mechanic soil work and pesticide treatment (spraying).
- *Losses inherent to the measures:* areas necessary for the implementation of erosion prevention measures are excluded from production activities. This generates a loss of income, which can be estimated by multiplying the surface area taken up by the measures by an average gross margin of the crop usually grown in this area.

Without entering into details, the estimation of agricultural profit loss caused by erosion is based on:

- Farmers cropping patterns in the catchment field (main crops grown are: oats, beet root, wheat, carrots, rape, flax, barley, peas, potatoes and clover)
- Average gross margin and the average net selling price associated with each crop (EU subsidies are subtracted from the calculation)
- Surface area affected by erosion and the percentage of crops damaged in eroded fields (10% for oats, 20% for rape, 40% for beets and wheat, 50 % for flax and 100% for others crops). These figures are estimates based on interviews with farmers.

Working time loss is estimated on the basis of an average number of additional hours spent by farmers and a unit hour cost (150 €/h for machinery and labour). The annual loss of time ranges from 1 to 3 hours per farm, depending on the location. Loss of productive land: the total area removed from production for the implementation of the conservation measures is 0.95 and 0.76 ha for the Lauragais and the Pays de Caux, respectively. Considering an average gross margin of 1,522 €/ha, the loss inherent to conservation measures is about 1,450 and 1,150 €/year for the two catchment areas.

Costs related to the loss of agricultural productivity would be about 860 €/year for the entire Lauragais farm, or 36 €/ha. The cost estimate in the Pays de Caux is based on a 6-year period and depends on the specific crop value and farm location in the catchment. At the farm level, the loss due to erosion is between 211 and 2,415 €/year. For an average farm size of 26.7 ha, the annual unit cost in the Pays de Caux ranges from 8 €/ha to 90.5 €/ha. The total estimated cost using these assumptions is given for the two sites in Table 9.

Table 9. Annual on-site costs of erosion at the farm level (based on Le Bissonnais et al., 2003)

Catchment	Field size [ha]	Loss [€/year/ha]	Loss [€/year/farm]	Total loss [€/year]
Lauragais (1 farm)	24	36	860	860
Pays de Caux (3 farms)	80	8 / 16 / 90.5	211 / 423 / 2415	3048

The total on-site cost has been estimated at 38 €/ha/year (average for the 3 Pays de Caux farms and the Lauragais farm in the case studies). This is consistent with the range of values given in the UK case study and with others found in the literature review.

3.2.3.2 Off-site costs

When soil erodes, the runoff loaded with sediments is likely to generate damage costs outside the eroded area. Roads, bridges and private property can be severely damaged by mud flows or sediment deposits during storms. Aquatic ecosystems can also suffer serious ecological damage due to the increased sediment load in surface water. Also, various categories of water users can be affected by an increase in sediment load: water utilities, commercial fisheries, property owners along the river, etc). Damage entails repair costs (clean-up measures). To prevent recurrent damage, erosion prevention measures can be implemented in the area where the erosion threat is the most serious (conservation measures). The cost of these two types of measures is assessed in the two study sites.

Remediation/clean up measures

Damage caused by the deposition of sediments on roads and other property*:* this refers to the cost of damage caused by sediment deposits on roads, which has to be cleared by third parties (private or public). Note that the cost of surface water pollution is not directly taken into account in this cost category.

Costs of monitoring

Monitoring costs concern mainly the monitoring of water quality in experimental catchments. This cost has not been estimated because it is considered to be low compared to costs related to the effect of erosion on water quality.

Soil conservation measures

To reduce the off-site impacts of erosion (in particular, on water users), preventive measures can be implemented: installation of vegetative filter strips, hedges, ponds, thalweg reinforcement, etc (see above for details). This generates investment costs, usually a one-off expenditure for the owner, and maintenance costs, which are recurrent on an annual basis.

Public subsidies exist for the implementation of such measures but not for their maintenance, which remains an expense for the owners. In some circumstances, the government purchases land for implementing soil conservation measures, but there is no example of this in these case studies. Financial subsidies are, therefore, deducted from the on-site costs.

Table 10 summarises the estimated annual off-site costs. Note that the costs of conservation measures that cover several years are reported as annuities or spread out over the lifetime of the implemented measures. It is considered that the cost of capital opportunity (interest rate) is equal to zero.

For the second catchment, the cost of vegetative filter strips and retention ponds and the cost of thalweg reinforcement are combined (28,193 €$_{1999}$ spent in 1997). Assuming that the lifetime of all of the various conservation measures is 15 years, the average annual cost is 1,880 €$_{1999}$/year.

In the Lauragais, the one-off expenditure (installation of 2 vegetative filter strips in 1997) is about 261 €. If we assume the same 15-year lifetime, the annual cost is 17 €$_{1999}$/year.

Annual maintenance costs are about 116 €/year in the Pays de Caux catchments. In the Lauragais catchment, this cost is covered by the farmer (on-site cost).

The financial cost of the reduction of field size is calculated with the 0.76 and 0.95 ha removed from the productive area to create conservation measures

The clearing of sediments from roads and ditches cost 2,300 € in 1997 and was incurred by the highway authorities. Assuming that erosion damage occurs mainly when farmers plant summer crops (farmers alternate summer crops and winter crops, which protect the soil in spring), the damage occurs every other year and the annual cost is, therefore, on average about 1,150 €/year. We also assume that there is one storm per year that causes erosion damage. The same assumption is used to estimate the cost of non-agricultural damage.

Table 10. Off-site costs of erosion in the 2 catchments (based on Le Bissonnais et al., 2003)

Types of costs and measures	**Cost at catchment level [€$_{1999}$/year]**	
	Lauragais	Pays de Caux
Soil conservation measures		
Vegetative filter strips (2 hedges)	17	
Ponds, vegetative filter strips, thalweg reinforcement		1,880
Maintenance	farmer	116
Financial subsidies for the reduction of field size	123	98
Remediation /clean-up measures		
Clean-up of sediments on roads and in ditches	1,150	NA
Costs of remediation / non-agricultural damage	20	675
Costs of monitoring	NA	NA
Total off-site costs	**1,187**	**2,554**

The off-site costs are respectively about 1,187 €/year (49 €/ha/year) for the Lauragais and 2,554 €/year (32 €/ha/year) in the Pays de Caux. The difference in off-site costs in the two catchments can be explained by the difference in total surface area (24 ha and 80 ha, respectively), and by the lack of major investments in soil conservation measures in the Lauragais.

In the Pays de Caux, the main objective of conservation measures is the protection of drinking water supplies. We can, therefore, consider that the cost of water pollution due to erosion is at least as high as the cost of conservation measures.

Note that in the Pays de Caux, the on-site costs (38 €/ha/year) exceed the off-site costs (32 €/ha/year). The unit off-site costs are expected to be conservative estimates because the clean-up costs of sediments are not counted. The off-site costs appear to be lower because not all aspects could be quantified. They would probably exceed the on-site costs if these other factors had also been taken into account.

3.2.3.3 Non use value costs (NC)

Within the category of non-use value costs, erosion damage to ecosystems (degradation) can be perceived as a loss by someone who is not currently using the soil, nor intends to use it. Non-use value costs are much more difficult to assess economically. In this case study, the non-use value effects can only be listed but cannot be estimated at the catchment level.

3.2.3.4 Synthesis of cost estimation

The table below summarises cost estimates at the catchment level.

Table 11. Average annual cost of soil erosion for the French case study

On-site costs (PC & MC)		Off-site costs (SC & DC)		NC
Production losses due to eroded agricultural soil Area loss (without government subsidies) Working time loss		Soil conservation measures (cost of implementing measures and maintenance costs) Remediation/clean-up measures (removal of sediments on roads and property repair) Government subsidies for the reduction of field size		Impact on landscape value and biodiversity, etc.
Lauragais	860 €$_{1999}$/yr	Lauragais	1,450 €$_{1999}$/yr	Not estimated
Pays de Caux	1,187 €$_{1999}$/yr	Pays de Caux	2,554 €$_{1999}$/yr	
Lauragais	36 €$_{1999}$/ha/yr	Lauragais	49 €$_{1999}$/ha/yr	
Pays de Caux	38 €$_{1999}$/ha/yr	Pays de Caux	32 €$_{1999}$/ha/yr	

The total off-site cost of soil erosion far outweighs on-site costs by a factor of 1.7 in the Lauragais and 2.2 in the Pays de Caux. We can consider the latter to be more representative of erosion damages in agricultural regions since more erosion impacts are taken into consideration in the cost estimation, particularly the cost related to drinking water pollution caused by erosion.

These cost figures may be regarded as under-estimations because they do not take into account the temporal distribution of the costs. Because soil conservation measures are often expensive to implement, their cost must be measured over the long-term. The cost estimation must therefore include several years and all of the actors in the catchment (not only farmers). It notably enables us to evaluate the cost distribution over time.

3.2.3.5 Who bears the costs?

The costs of measures are borne mainly by the land owners, usually farmers, at the local level. When necessary at the river basin level, costs are borne by public authorities because the benefits are for the entire catchment. Implementing soil conservation measures upstream in a catchment has consequences downstream. In theory, cost analysis should include costs for one actor but benefits for the entire catchment.

The costs of soil conservation measures are borne mainly by the government (subsidies), which pays more than 85% of the total cost. Farmers pay for remediation and maintenance (labour, farm machines, etc.).

Remediation/clean-up measure costs are borne by the highway authorities.

3.2.4 Conclusion

The French case study on erosion impacts is based on the study done within the GESSOL research program (INRA and Ministry for Environment). The original objective of this program was to conduct a cost-effectiveness analysis of soil conservation measures from the viewpoint of the various actors, but mainly that of farmers. This can explain why the on-farm impacts are studied in much more detail than the off-farm impacts.

As opposed to the UK case, the French erosion impact case is a micro-case and may not be representative of erosion effects all over France. Firstly, the off-site costs are certainly underestimated. The off-site impacts in the catchments are not taken into consideration. Secondly, only agricultural effects are considered and the non-user costs (associated with decreased land values, for example) are not estimated in this study. However, the two French case studies are based on data gathered over several years (to account for the temporal variability of soil erosion processes) and are complementary (in terms of soil types, topography and climate) and representative of larger eco-physiographic contexts–Northern France being part of the Central and Northern European agricultural zone and Southern France being closer to the Mediterranean.

The conclusion that off-site costs are greater than on-site costs is in agreement with what is generally observed in Europe. However, it should be kept in mind that the ratio of on-site to off-site costs depends on the type of soil erosion and on where the vulnerability is. The two extreme values would be 1) a muddy flood in a densely populated area with a deep layer of topsoil (off-site costs would far exceed on-site costs), and 2) recurrent erosive events in a remote arable land with a shallow layer of topsoil (the ratio of on-site to off-site costs would be very high and increase until the land was abandoned and badlands formed). The Pays de Caux case is closer to the first case and the Lauragais to the second.

3.3 CONTAMINATION / FRANCE, METALEUROP

The following figure shows the geographic location of the Metaleurop Nord site near Douai.

Figure 5. Location of the Metaleurop Nord Site for the French contamination case

3.3.1.1 Local conditions

The Metaleurop Nord site is located in a semi-urban area with a low population density, characterised by a dispersed habitat (105 inhabitants per km^2) and significant agricultural activity. The landscape has been considerably modified by mining activities (in the coal mining basin), industrial activities (smelting), and transportation facilities (waterways, roads and motorways, railways). The Metaleurop Nord plant was the last major industrial activity in this area.

3.3.1.2 Soils

The industrial plant is located on chalky permeable ground in the south, and on semi-permeable alluvium near the valley of the Courant Brunet, now being channelled. In the Northeast, the soil is increasingly clayey. The chalk formation is the largest groundwater reservoir in the region. This aquifer is tapped south of the site to supply drinking water.

3.3.2 Impact of contamination

The industrial activity has had an impact on several environmental compartments, in particular soils on-site and nearby, air (although atmospheric emissions are regulated under the authorisation permit), and water resources (both surface water and groundwater) by effluent discharge. It has also had significant socio-economic impacts:

- Impact on air: copious atmospheric emissions from the Pb smelter operating from 1894 to 2003 by initial melt heat processes. In 2001, the site disposed of 18.3 tons of channelled lead, to which can to be added around 10 to 15 tons of diffuse effluent – 0.8 tons of cadmium, 26 tons of zinc and 8,600 tons of sulphur dioxide.

Air pollution has, however, decreased over the last 20 years: 350 tons of lead were emitted per year in the 1970s, 146 tons in 1978 and around 12 tons in 2003.

- Impact on surface water: the water in the Haute-Deule canal (effluent discharge) falls in class 3 (bad quality). The estimated sediment contamination values are: Cd up to 2,000 ppm, Hg up to 80 ppm, Ni up to 500 ppm, Pb up to 10,000 ppm, Zn up to 9,000 ppm, Cu up to 380 ppm, As up to 350 ppm. Surface water discharge was significantly reduced when a sewage treatment plant was built in 1988 (150 tons of lead discharged in 1988, 4 - 5 tons of lead in 2003, 1.9 tons of cadmium, 10 tons of zinc).
- Impact on groundwater: contamination of the chalk aquifer by lead and arsenic is confined to the site by hydraulic trapping. To avoid dispersion of the pollutant plume, 100 m^3/h are pumped from wells on-site. Water quality is monitored using a network of 15 piezometers in the chalk aquifer and 4 in the sandy aquifer in the north of the area. The aquifer is still tapped for drinking water without treatment downstream of the site.
- Impact on soil: heavy metals are confined mainly to the upper soil levels (0-40 cm), except for zinc, which migrates deeper. Six hundred hectares of urban soil are heavily contaminated (>250 ppm Pb) and 4,000 ha have a lead concentration of >200 ppm.
- Impact on agriculture: about 400 ha of soils used for agriculture are heavily contaminated (>250 ppm Pb). As a result, high levels of contaminants are also found in crops and animal products.
- Impact on public health: human health has been affected by atmospheric pollution emitted by the production units, by the smelter residue deposits (essentially by dust emissions), by the raw materials of the site's “soil” (principal source, by leaching, of groundwater pollution), and by the old industrial waste dumps of certain production units. High lead concentrations in blood samples have been reported, and some correlation has been observed with distance to the Metaleurop plant. The consumption of vegetables grown in private gardens and contaminated drinking water is partly responsible for this. Children are particularly affected. In 1995, 14% had lead blood levels higher than the normal 100 µg/L. In 2002, 11% of children 2-3 years old living in the five nearest towns were still affected. The adult population is also affected, with 29 people declared inapt for work every year (average for 1996-2001). It must be noted, however, that this health problem is not only due to soil contamination but also to air pollution: assessing the relative impact of each contamination vector is almost impossible.
- Socio-economic impact: the decision to shut down the plant resulted in the laying off of the company's 830 workers. The company’s assets are far from adequate to meet the social liabilities. This social crisis has also caused economic difficulties (“domino effect”) for subcontractors (3,000 indirect jobs are concerned). Although unemployment is a direct consequence of the actions taken to reduce contamination (soil and air), these impacts have not been taken into consideration in this study.

3.3.3 Conservation measures

Two types of conservation measures have been implemented:

Land use restrictions

In January 1999, government agencies issued a set of regulatory measures aimed at reducing the population's exposure to contamination through land-use restrictions ("servitudes – Plan d'Intérêt Général") targeting both urban development and agricultural activities.

- Zone with a lead contamination exceeding 1,000 ppm (255 ha): the construction of new buildings is not permitted, agricultural production is not allowed, and land cannot be used even for recreational activities (football pitches, playgrounds, etc.).
- Zone with a lead contamination of 500 to 1,000 ppm (590 ha): land use is permitted with certain constraints–contaminated soil must be treated before use and no materials can be taken out of the zone.

Additional measures

Given the fact that Metaleurop went bankrupt, a government agency (ADEME) had to step in and fulfil the obligations imposed on the company. In particular:

- Purchase of agricultural land with contamination levels higher than 250 ppm of lead for afforestation.
- Removal and replacement of the upper layer of polluted soil (>500 ppm lead) and the demolition of buildings.
- Operation and maintenance of the on-site pumping to prevent contamination from reaching the aquifer, and monitoring groundwater quality.
- Monitoring the level of contamination of agricultural products and elimination, by incineration, of crops unsuitable for human or animal consumption (in zone >250 ppm lead).
- Cleaning up and decontamination of school playgrounds.
- Completion of the detailed risk assessment study, in order to determine the duration of conservation measures.
- Organisation of public information campaigns: recommendation of precautionary measures to be adopted by the population to prevent health risks.

3.3.4 Source of data used in the case study

Due to the particular situation (closing down of the plant in 2003 due to bankruptcy), economic data had to be collected from numerous sources, mainly the public authorities in charge of managing the current situation (public health impact, ecosystem impact) and the private investor in charge of reclamation and economic redevelopment of the site (plans for a waste treatment plant).

Existing official documents (authorisation permits, environmental diagnosis, detailed risk assessments, draft description of the redevelopment project) were reviewed in order to identify and describe the different impacts and protection/mitigation measures that have been implemented in the area. People currently involved in the site remediation were then interviewed in order to supplement the information found in the reports.

All information related to costs when the site was in operation are now considered to be lost due to the disappearance of the former operator, Metaleurop. In particular, the main items concerning the cost of conservation measures (investments, operation and maintenance) are not available.

Social costs have been estimated using generic national data through national databases.

3.3.5 Economic damages and costs

The cost typology elaborated by Ecologic in the literature review (Görlach et al., 2004, section 4.6.1) has been used as a conceptual framework for describing the different costs of soil contamination in this case study.

In addition to the difficulties encountered in our attempts to access quantitative economic data, several methodological difficulties were also encountered in differentiating the costs:

- Some damages caused by contamination are due not only to soil contamination, but also to air and water pollution (this is typical, for instance, in the case of the impact on public health).
- Some costs could not be estimated in monetary terms, making it impossible to provide an average annual cost of contamination.
- Since it was not possible to collect time series data, it was not possible to assess the total cost of pollution generated by this plant over the last 110 years of activity.
- It is difficult to assess costs on an annual basis because some of the costs are one-off expenditures (e.g., soil decontamination) and others are recurrent costs that may continue over very long periods of time (more than 50 years). Estimating an average annual cost requires converting one-off expenditures into a perpetual annuity equivalent. This has been done assuming that the annual cost of one-off expenditures is equal to the capital opportunity cost (using a 4% discount rate, as required by the EU guidelines for extended impact assessment).

3.3.5.1 On-site private costs (PC)

This category refers to the direct costs of soil contamination incurred by the operator of the industrial plant. The following on-site private costs were reported:

- Demolition of contaminated buildings and pre-treatment of the site for a new industrial use. This generated costs of 22.5 M€ (one-off expenditure), which was financed by the private operator in charge of site redevelopment (SITA) and public subsidies to the private investor.
- In-depth diagnosis and detailed risk assessment on the site to be redeveloped for industrial use, with two specific targets (groundwater resources and human resources) - 200,000 €, financed by the private operator of site redevelopment (one-off expenditure).

Due to the existence of specific subsidies from public bodies to cover on-site damage costs, it was difficult to distinguish between private and public expenditures. To avoid double counting, the on-site private costs are included in the on-site mitigation costs category (see below).

3.3.5.2 On-site mitigation and repair costs (MC)

This category includes the cost of soil removal and treatment, decontamination of buildings, etc. There are two types of activities: measures taken by the previous operator and measures taken by the caretaker. Due to data availability constraints, the former is excluded, but the latter is included in the cost evaluation. The caretaker is considered as a third party obliged to take measures since the site owner failed to fulfil his environmental and managerial obligations. The MC costs also includes:

- Costs related to land acquisition and afforestation in the most contaminated zone (>250 ppm Pb). In 2003, 70,000 € was spent to acquire 5 ha of contaminated agricultural land (unit cost for land purchase is about 14,000 €/ha) and 80,000 € was spent to turn 80 ha into forest (unit cost for afforestation is 1,000 €/ha). In addition, 400 ha of land located around the site should still be acquired with public funds and turned into forest.
- Costs of the in-depth diagnosis and detailed risk assessment. The two diagnoses done in 2003 concerned only public health and groundwater considered being the main targets in the area. These cost 200,000 € and 250,000 €, respectively. Buildings and natural ecosystems were not considered to be primary targets to be protected. This is due to the common assumption that measures to protect human health aimed at ensuring that national acceptable risk levels are met will entail protecting the ecosystem. These costs must be considered as minimal, but a broader risk assessment taking into account environmental compartments (surface water resources and ecosystems) would have been far more expensive.

Mitigation and repair costs are typically one-off costs aimed at reducing the level of contamination and human exposure. Indeed, although remediation measures are often implemented over 5 to 10 years, they eliminate damage costs for an infinite period of time. It is therefore impossible to calculate an equivalent annual cost by dividing this cost by a service life (which is infinite). To overcome this methodological difficulty, we assume that the annual cost is equal to the capital opportunity cost of the measure (calculated by multiplying the present cost value by the discount rate).

Reported cost figures and estimated annual averages are given in the following table.

Table 12. On-site mitigation and repair costs (MC) for the contamination case (in €$_{2003}$)

Description of cost	Type of measure	Reported cost [€]	Estimated annual cost [€/yr]
Demolition of contaminated buildings, pre-treatment of the site for industrial use, 22.5 M€ (4 years)	7.5 M€ for demolition, from public subsidies 6 M€ for re-industrialisation, from public subsidies 9 M€ from private sources	22,500,000	900,000
Soil decontamination and treatment	Excavation of contaminated soils and replacement with clean soil in residential areas	195,000	7,800
Acquisition of farms located around the site (>250 ppm Pb)	Acquisition of 5 ha of contaminated agricultural land (up to now).	70,000	2,800
Afforestation in contaminated zone	80 ha (in 2003, 1000 €/ha)	80,000	3,200
	400 ha (in the future)	400,000	16,000
Monitoring impact (mainly groundwater and worker exposure)	In-depth diagnosis detailed risk assessment (on-site)	200,000	8,000
	In-depth diagnosis detailed risk assessment (near the site)	250,000	10,000
		Total on-site costs	**947,800 €/yr**

In 2002, a Ministerial Commission estimated the overall cost of remediation and excavation of all of the soil (which presented an unacceptable risk for the population and agricultural activities) would be 400 M€. The remediation measures were, however, only partly implemented due to the limited budget of the caretaker and by the fact that most of the costs would have to be borne by the public. This may partly explain the large difference between the original estimate of clean-up costs and the total estimated cost provided later. Although this cost appears to be very high, it covers a period up to 2023 – the year the lead content in the water is expected to have dropped to 10 µg/L. The resulting annual costs would be about 36 M€ per year (4% of discounting rate).

3.3.5.3 Off-site social costs (SC)

This category refers to all costs generated by soil contamination for third parties. Some of these costs are borne by private actors: farmers whose land cannot be used for agricultural production, local home-owners whose property has depreciated due to contamination, etc. The various categories of social costs are listed below. These costs, often not considered in the site approach, are partly estimated using the assumptions presented below.

<u>Public health impact</u>

Two types of impacts have been reported: contamination of the population living in the area (very high blood lead concentrations) and contamination of workers exposed to the contaminated site who are inapt for work.

- The surrounding population has been exposed to Pb contamination. 14% of children and more than 5% of adults have blood lead concentrations higher than the normal concentration of 100 µg/L. This concerns about 60,000 people living on 4,000 ha surrounding the site (results of studies carried out by regional public health inspectors). Assuming that the age distribution of the population in the area is similar to the national age distribution (15% being children under the age of 15, 85% being adults), and knowing that approximately 14% of children and 5% of the adults have symptoms of high blood lead concentrations, the affected population is estimated to be 1,260 children and 2,550 adults. In the absence of medical data on the cost of treatment of high blood lead concentrations, we estimate the cost of medical visits and medication at 900 €/year for children and 450 €/year for adults[4]. Based on these assumptions, the total annual cost is estimated to be 2.28 M€ (recurring costs).
- The number of people declared inapt for work out of a population of 3,836 workers represents a certain cost. Analysis of historical data shows a marked inaptitude with, on average, 29 workers judged inapt for 200 days of work each year. Using an estimated cost of 140 €/day (for health care and medication, national estimation), the total cost is estimated to be 812,000 €/yr (cost likely to be recurring during the entire life of the affected workers).

Other costs are related to measures aimed at reducing the risk of exposure of the population:

- The cost of medical follow-up (monitoring networks) of the population and retired workers from the industrial site: three medical monitoring campaigns have been conducted since 2002: 1) tracking lead in children in five nearby villages (80,400 €), 2) an extension of the area of the first monitoring campaign (205,000 €), and 3) medical follow-up of former workers (200,000 €). The total cost of medical monitoring is 485,400 €. Similar campaigns are likely to be done every 5 years as long as the human health risk remains significant (average annual cost estimated at 97,000 €).
- The cost of public health and environmental information campaigns: recommendations aimed at the local population to promote better hygiene (washing vegetables before cooking, hand washing before eating, etc.). Information campaigns are also likely to be repeated every 5 years, as long as the risk remains significant.

[4] 25 € for one medical consultation per month and 50 € for medication.

It must be noted that the public health problems described above are not due only to soil contamination, but also to air and water pollution. Although it is difficult to isolate the impact of soil contamination, we assume that soil contamination can only be held responsible for one third of the total cost.

Agricultural damage costs

The cost of damage to agricultural activities is estimated from the subsidies paid to farmers to compensate for foregone income - in relation to the environmental impacts on the quality of crops and animals.

- 10,000 € in 2003 for 1.5 ha of potatoes unsuitable for human and animal consumption (compensation for foregone agricultural income);
- Approximately 30,000 € for crops downgraded to animal feed and products withdrawn entirely from the food chain, in accordance with the European regulations.

To this must be added the cost of monitoring agricultural production:

- Monitoring of agricultural production and elimination of products unsuitable for consumption (in most cases, the products were incinerated) - 150,000 €.
- Monitoring of agricultural production (milk, meat, fodder, etc.) done by the local authorities to assess quality, 32,000 € for plants and for cattle.

The cost of farmer compensation is considered to be recurring (perpetual loss of income for the farmer concerned) and will probably be paid annually as long as agricultural use is not permitted. The cost of monitoring agricultural products is also considered to be recurring on a 5 years basis (average annual cost estimated at 33,200 €).

Urban impact

The impact of site contamination on land transactions and the value of private homes in the area was estimated using the Hedonic method and local real estate values (Letombe and Zuindeau, 2001). There were 341 real estate transactions between 1995 and 1999 in the area, for an average price of 49,509 €, an average interior living space of 85 to 98 m² and an average property area of 540 to 650 m². The price per m² in the three towns studied was 518 € to 625 €.

Contamination has decreased real estate values by 12% 500 m from the site, by 6.3% 800 m from the site, and by 3.5% 1,000 m from the site. Considering a price of 48,000 € for a house and the number of houses to be 10,000 in the 4,000 ha contaminated area, the total loss on housing value is estimated at 34,88 M€. This cost is a one-off cost, which can not be added to the annual estimation quoted above. To convert it into an annual cost, we assume that the average remaining service life of the houses is 30 years. The annual cost is estimated by dividing the total loss (34.88 M€) by 30 years, or 1,16 M€.

Table 13. Off-site social costs (SC) for the contamination case (in €$_{2003}$)

Description of cost	Currently funded(1)	Estimated annual cost(2)
Human Health impact		
Cost of illness in the population exposed to Pb contamination		2,281,500 €/yr
Cost of worker inaptitude		812,000 €/yr
Medical monitoring of the population - tracking of blood lead concentrations	485,400 €	97,000 €/yr
Agricultural impact		
Monitoring of agricultural production, sampling and analysis of all food	182,000 €	36,400 €/yr
Loss of farm income due to the impact of contamination on the quality and production of crops and animals	40,000 €	40,000 €/yr
Urban impact (decrease in real estate value)		
Impact on real estate prices in the contaminated area		1,162,667 €/yr
Total off-site social cost (SC)		4,429,647 €/yr

(1) Based on the observed expenditure in year 2003.
(2) Monetary assessment based on the hypothesis described above (section 3.3.5.3).

3.3.5.4 Defensive costs (DC)

This category refers to the recurring costs of the measures implemented to limit the off-site impacts of contamination (measures to avoid propagation of pollution into non-contaminated areas and groundwater resources). DC costs include:

- Cost of hydraulic pumping in the aquifer to avoid extension of the pollution plume and treatment of the water before discharge into the canal (100m^3/h pumped from former wells on site). These costs are mainly for electricity and the water treatment plant and have been estimated at 300,000 € per year. They are likely to be repeated every year (recurring cost).
- Cost of environmental monitoring (groundwater quality downstream of the site). The cost has been estimated by the private investor involved in the redevelopment of the site at up to 12,000 € per year. It is also considered to be a recurrent cost.
- One-off cost for the decontamination of schoolyards, estimated to be up to 10,000 € in 2003 (ADEME Budget). Assuming that this is a perpetual cost, the annual cost is estimated to be 400 € per year (multiplied by the discounting rate of 4%).

Table 14. Defensive costs (DC) for the contamination case (in €$_{2003}$)

Description of costs	Estimated annual costs
Cost of hydraulic pumping and treatment of the water	300,000 €/yr
Cost of monitoring groundwater quality downstream of the site	12,000 €/yr
Decontamination and cleaning up of schoolyards	400 €/yr
Total defensive costs (DC)	**312,400 €/yr**

3.3.5.5 Non-use value costs (NC)

Although some of the experts interviewed agree that soil contamination has caused a loss of non-use value, it was not possible to economically assess this loss. It could be done using the results of contingent valuation studies conducted in other contexts.

3.3.5.6 Summary of cost estimation

All the types of cost, except non-use value costs (NC), are identified in this case. As shown above, the costs related to soil deterioration due to contamination are substantial and are not easily borne by the various actors.

Table 15. Type of costs - Summary for the contamination case (€/year)

PC	MC	SC	DC	NC
Reclamation of the site within the redevelopment project, done by private investor. Monitoring impact.	Demolition of contaminated buildings. Soil decontamination and treatment. Acquisition of contaminated land (>250 ppm Pb) and afforestation. Monitoring impact.	Human health impact (costs of disease, inaptitude for work, etc.). Agricultural impact (loss of income). Urban impact (decrease in real estate prices).	Hydraulic pumping in the aquifer to limit propagation of the pollution plume. Monitoring of groundwater quality. Decontamination of schoolyards.	Loss of non-use value for local population.
Included in MC	947,800 €/yr	4,429,647 €/yr	312,400 €/yr	Not estimated

The estimated total annual cost of the contamination case study is about 5.7 M€. The total cost of off-site measures (SC + DC) outweighs on-site costs (PC + MC) by a factor of 5. These cost figures might be underestimated because they do not take into account former soil contamination damage and the cost of measures implemented before the Metaleurop plant closed down.

3.3.5.7 Who bears the costs?

All levels of the decision-making process are involved in the management of this contaminated site:

- At the local level, the surrounding towns and the new owner in charge of reclamation and redevelopment of the site.
- At the regional level, the Regional Council, the department and all regional authorities in charge of monitoring public health, industry and the environment, animal production, etc.
- At the national level, the Ministry for Environment and ADEME.

The off-site costs for prevention, damage suffered, monitoring and reclamation are borne for the most part by the government (local authorities and ADEME).

In particular, ADEME is fulfilling some of the environmental requirements not done by the company. Its current mission is due to end in June 2004. Discussions are now being held with the Ministry for Environment, local authorities and the affected sectors to extend this deadline by one year and also extend the scope of certain tasks (clean-up of additional school playgrounds, etc.). In particular, an evaluation of possible alternative crops (with high added-value) will be done in order to revitalize agriculture in the area.

A private investor, SITA (Suez group), will remediate the site as part of a redevelopment project (waste treatment plant). The various actors have agreed on this at the local level. Not all costs related to the site remediation of this contamination case study are currently available, in particular those closely related to:

- the definition and design of the redevelopment project now under discussion between the private investor and the various levels of authorities; the Site Contract (involving the State, the Regional Council, two Departmental Councils, three urban agglomerates and the private investor) has several objectives: redevelopment of activities with the creation of 1,000 new jobs within a period of four years, training and environmental reclamation.
- the monitoring of groundwater quality.
- the choice of remedial options for the contaminated soils located in the vicinity of the site. Due to the size of the contaminated area, the feasibility of several different technical options is currently are being assessed.

These costs will be borne by:

(i) The private investor, for on-site soil reclamation within the redevelopment project

(ii) Public funds allocated by the Regional Council, the Departmental Council (funded by taxes collected at the local level for employment measures)

(iii) The European Regional Development Fund– ERDF (for demolition and part of the site remedation)

(iv) The French Government for remediation costs around the site (off-site costs)

The breakdown of the costs is not known in detail but it appears to be clear that the public sector will bear the largest share.

3.3.6 Conclusion

The costs related to soil deterioration due to contamination are significant and not easily bearable for the various actors. This situation is encountered in many megasites. All countries facing this type of situation are now adopting precautionary measures to prevent their repetition.

Moreover, the various actors, in particular the public authorities who must manage the orphan sites, are currently reviewing their remediation approach using a cost-benefit analysis (for public health or the entire ecosystem). The options are:

(i) The "do nothing" or "status quo" option: negative impacts are closely monitored, and maintained at a level considered to be acceptable.

(ii) Remediation for a specific use, pre-determined by local actors: the benefits can then be estimated (increase of land value, farming incomes, etc.).

Concerning the structure of the costs, the private PC costs are not really relevant and should be included in the on-site cost of remediation. In most cases of point-source contamination, the economic activity that caused the pollution may not even be affected by it.

The estimated social cost is based on the possible development of human diseases not yet observed in the population. It should be considered to be a maximum expenditure if a no-action approach is chosen. The consequences of on-going actions cannot be assessed at this time.

The distinction between on- and off-site impacts is essential in the case of point-source contamination, taking into account the fact that damage effects both the polluted site and spatially remote areas (off-site impacts). For soil contamination, the off-site cost of soil contamination tends to be higher than the on-site cost (roughly by a factor 5).

In addition, off-site effects can occur over a long period of time. The on-site effects are more obviously the consequences of soil degradation, as these directly affect soil use at the site.

3.4 SALINISATION / SPAIN CENTRAL EBRO AREA

Salinisation is the accumulation in soil of soluble sodium, magnesium, and calcium salts to the point that soil fertility is severely reduced. The salinisation can have natural origins (such as particular geological conditions, floods of fluvial waters derived from rich geological strata, or wind) or anthropogenic origins (irrigation using water rich in salt, use of fertilisers and additives, etc.). Salinisation is often associated with irrigation, as the water used systematically contains variable amounts of salts in particular in regions where low rainfall, high evapotranspiration rates or soil textural characteristics impede the washing out of the salts, which subsequently build-up in the shallow soil layers.

High sodium content and alkalinity nearly always accompany salinisation. Sodication (alkalisation) consists of an excessive increase in sodium, with respect to calcium and magnesium, in the exchange complex. Excessive saturation of exchange capacity with sodium provokes clay deflocculation and consequently destruction of the soil structure that, with low permeability conditions, may become irreversible. Alkalinity consists in an excessive increase of pH to exceed the value of 8.6 (pH buffer by carbonate). In this situation, due to degradation of the soil structure, most agricultural and forest plants cannot survive.

Non-point-source pollution by nitrates or pesticides can also be combined with salinisation and sodication due to intensive agriculture activities in the same area. Salinity (cationic concentration) affects crop productivity and yield and farmers sometimes use excessive quantities of nutrients to combat this. Salinisation and sodication also affect the structural and hydraulic characteristics of soil, water transport in the vadose zone, water available for crops and evapotranspiration. They can also lead to additional threats such as erosion.

3.4.1 Presentation of the case study

Spain is the country with the largest irrigated area (3.4 million ha) in Western Europe (FAO, 1994). Aragón contains the central Ebro Valley, the most arid inland region of Europe. It is a semi-arid bioclimatic zone subject to salinisation and sodication (evapotranspiration of 1,406 mm, annual precipitation of 337 mm, annual mean daily temperature of 14.9°C).

The Aragón area is bordered by the Alcanardre and Flumen rivers and by the Flumen Canal. The irrigated area of Aragón has grown over the last 2000 years and now comprises 413,100 ha, with an additional 404,600 ha that are likely to be irrigated in the future. The principal irrigated crops are alfalfa, winter cereals (barley and wheat), maize, sunflower, deciduous fruit trees, horticultural crops and rice. Agricultural production from these lands is an important component of the regional economy. Winter cereals are the only feasible crops that can be grown on the non-irrigated lands, and crop production is often low or nil. Poor production years have an impact on the whole society and successive Spanish authorities have responded by increasing the area of irrigated land (Figure 6).

Figure 6. Location of the studied area for the Spanish salinisation case

3.4.1.1 Local conditions

The central Ebro area is an agricultural zone, with a low population density (rural population with temporary manpower employed for seasonal tasks). It is for the most part flat, has an average rainfall of 400 to 500 mm/year, and a potential evapotranspiration of 1,300 to 1,400 mm/year.

Water for surface irrigation in Aragón is drawn mainly from surface water resources. The old irrigation systems tapped the rivers by means of small diversion dams. Since the end of the 19th century, a system of large reservoirs has been built along the Pyrenean rivers. A network of concrete canals, which distribute water to irrigation districts, connects these reservoirs. More recently, pumping stations have been built to raise the water from downstream in the Ebro River to irrigate new areas above the local river level.

Before the 1940s, water was delivered by unlined canals to small, relatively flat fields, meaning that only slight levelling was required. In the following decades, concrete was used extensively to build canals and additional land was cultivated for agricultural production, which mechanically levelled the land for surface gravity flow irrigation.

The origin of the salt in these soils is the 100-m deep Tertiary deposits in the central Ebro Valley, exposed during levelling of irrigated land in the new districts for flood irrigation. The original (natural) thin topsoil layer was destroyed exposing the deeper layers and saline marls.

Major problems with salt-affected soils developed as a result of some of these extensive levelling works. In the 1970s, new technologies such as sprinkler and drip irrigation (in particular for fruit plantations) were introduced, enabling irrigation without major earth movement. The use of these modern irrigation systems enables the application of small volumes of water with higher frequencies than flood irrigation, decreasing the risk of a rise in the water level and evapoconcentration of deep salts in the root zone.

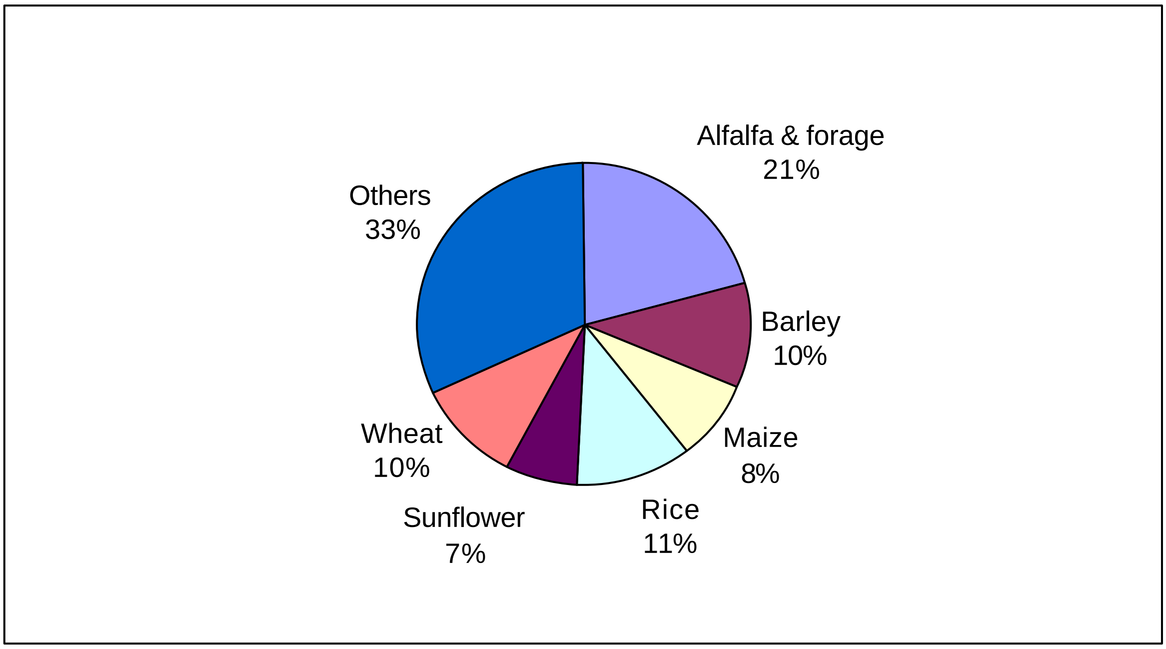


Figure 7. Main crops and their percentage in the studied area (1994)(Noguès et al., 2000).

3.4.1.2 Soils

The central Ebro Valley is typical of aridisols. The soil moisture regime is arid with a xeric fringe. The old irrigated lands have soils (fluvents, orthents and psamments) that, in general, overlie limestone gravel deposits and are well drained.

Salinity is a common problem for irrigated lands. A wide diversity of sources and differences in the solubility of minerals, soil hydraulic properties, geomorphology, evapotranspiration rates and precipitation lead to large variations in soil salinity throughout space and time. Salinisation occurs when salts accumulate in a soil and desalinisation is the process whereby salts are removed from the soil. Soil salinity is dynamic rather than static and many measurements are needed to assess the status at any given time (Herrero & Snyder, 1997). Table 16 displays the predominant soils and their proportions in the studied area.

Table 16. Soil map units with their percent distribution over the studied area (Noguès et al., 2000)

Symbol	Land Evaluation Units (LEU)	%
A1.1	Soils of the irrigated structural platforms of sandstone and lutite. Association of Typic Xerorthents and Xeric Torriorthents with inclusions of Lithic Torriorthents.	4
A1.2	Same as A.1.1 but non-irrigated.	<1
A.2.1	Soils of the irrigated residual platforms with coarse detrital sediments. Consociation of Calcixerollic Xerochepts with inclusions of Petrocalcic Xerochrepts, Xeric Haplocalcids and Xeric Petrocalcids.	20
A2.2	Soils of the non-irrigated residual platforms with coarse detrital sediments. Consociation of Calcixerollic Xerochrepts, Xeric Haplocalcids, Xeric Petrocalcids, and Calcic Petrocalcids.	1
B1	Soils of the glacis slopes on fine detrital sediments. Association of Xerofluvents and slightly saline Typic Xerorthents with inclusions of Typic Natrixeralfs and Fluventic Xerochrepts.	11
B2.1	Soils of the other irrigated slopes on fine detrital sediments. Association of moderately saline Typic Xerofluvent, and slightly saline Typic Xerorthent with inclusions of Typic Natrixeralfs, calcixerollic Xerochrepts and slightly saline Xeric Torriorthents.	41
C.1	Soil of the Flumen and Alcanadre river terraces on fine detrital sediments. Association of Typic Xerofluvents and Typic Xerorthents	3
C.2	Soil of the Flumen river terrace, association of Typic Xerofluvents and slightly saline Typic Xerorthents (of the surface)	2
C.3	Soil of the Flument terrace on fine detrital sediments. Strongly saline sodic Xeric Torriorthents.	<1
C.4	Soils of the Flumen terrace. Moderately saline sodic Typic Xerofluvents.	1
D1	Soils of the irrigated bottoms on fine detrital sediments. Association of strongly saline, sodic Typic Xerofluvents, strongly saline sodic Oxyaquic Xerofluvents and strongly saline sodic Typic Xerorthents, with inclusions of strongly saline sodic Typic Natrixeralfs, slightly saline sodic Xeric Torriorthents and moderately saline sodic Aquic Xerochrepts.	14

3.4.1.3 Origin and extent of the problem

Different events are at the origin of the increased salinisation of soils and groundwater resources:

- intensification of agricultural production
- inappropriate irrigation and drainage management
- inappropriate land levelling with soil destruction and burial under geological materials generating salt accumulations underground having a depleting effect on crop yields as its level approaches the crop root zone

Due to the local climatic and soil quality conditions, the vulnerability of the Central Ebro area to salinisation is considered to be very high.

There is a wide diversity of sources and differences in the solubility of minerals, soil hydraulic properties, geomorphology, evapotranspiration rates and precipitation, which lead to large variations in soil salinity throughout space and time.

Spain does not have soil maps at scales useful for agriculture. Therefore, the methods used to detect high soil salinity are on-site salinity monitoring, electromagnetic sensor or remote sensing for indirect detection using crop growth.

Information on soils is fragmentary, at levels that are even problematic for irrigation planning. When available, information is commonly unpublished and apparently difficult to access.

In 1976, the FAO developed a land evaluation system taking into consideration several criteria, such as adequacy of the irrigation water delivery system, chemical fertility, ease of crop establishment, flood risk, growth period, hailstorms and winds, location, mechanisation potential, oxygen availability, pests and diseases, pre- and post-harvest management, rooting depth, salinity, salinisation risk, soil adequacy for trafficability and ploughing, solar radiation, temperature regime, and water availability.

Farmers and local agricultural experts in the study area were surveyed to determine the relative importance of the different land qualities considered and their impact on the final production of each of the six "Land-Use Types" in relation to crops.

The left side of Table 17 displays the average yield levels determined for each suitability level according to this FAO system: from the most suitable (S1) to unsuitable (N). The standard value of relative yield decreases under saline conditions. The right side of Table 17 shows the relationship between the electrical conductivity of the saturation extract of the soil (ECe - Electrical Conductivity) and the suitability levels for the six main crops of the FAO system.

This relationship was determined by comparing the soil analytical data of the evaluation units with their production recorded in the field survey. Soil salinity showed an interaction on the production of the different crops, with important differences between the crops. Therefore, the impacts of salinisation are different for the various crops. The definition of soil salinisation classes should be related to the crop groups and not only to the environmental impacts done by measurements.

Table 17. Variation in crop yield by four suitability levels and relationship between the soil salinity and suitability level for the six main crops*

	Variation in crop yield* by four suitability levels.				Relationship between soil salinity (ECe in dS/m at 25°C) and suitability for the six main crops			
ECe for six crops	S1	S2	S3	N	S1	S2	S3	N
Alfalfa	>15	12 - 15	8 - 12	<8	<8	<8	8 – 16	>16
Barley	>4	3 - 4	2 - 3	<2	<8	8 – 16	8 – 16	>16
Maize	>10	8 - 10	7 - 8	<7	<4	4 – 8	4 – 8	>8
Rice	>5	4 - 5	2 - 4	<2	<16	>16	>16	>16
Sunflower	>3	2 - 3	1 - 2	<1	<4	4 – 8	4 – 8	8 – 16
Wheat	>6.5	4.5 - 6.5	3.0 - 4.5	<3	<4	4 - 8	8 - 16	>16

* Yield in Mg/ha at the allowable relative moisture for each crop yield.

The FAO land evaluation (FAO, 1976) was developed for the studied area (Nogués et al., 2000) to assess and refocus the application of agricultural policies, mainly through subsidies for crops or for agricultural land set-aside, avoiding unwanted effects either on the production or sustainability of the agricultural system. The study deals with salt-affected soils, from both the agricultural productivity and environmental points of view.

Table 18 gives the area and the evaluation of the Land Evaluation Units (LEU) of the studied area. The Numerical Values of Evaluation (NVE) of the FAO system allow the comparison of the potential of each LEU for the crop considered.

Table 18. Index of Productive Potential (IPP) assigned to the LEU, and NVE for the six main crops

LEU	Numerical values of evaluation (NVE)							IPP
	Extent (ha)	Alfalfa	Barley	Maize	Rice	Sunflower	Wheat	For all land uses
C.1	800	75	75	75	50	75	75	70.8
C.2	600	62	75	62	75	75	75	70.8
A.2.1	5,100	75	75	76	25	75	75	66.7
A.1.1	1,200	75	75	37	25	37	75	54.3
B.1	3,000	50	50	44	62	50	50	51.0
B.2.1	10,700	37	56	37	69	37	56	49.0
D.1	3,700	44	50	25	81	31	50	46.9
C.4	300	25	50	25	75	25	50	41.7
C.3	<100	25	50	25	25	25	25	29.2
A.2.2	200	0	50	0	0	50	25	20.8
A.1.2	200	0	50	0	0	37	25	18.7

In 59% of the study area, the IPP is under 50% (low Productive Potential). The lower indices occur in the non-irrigated enclaves, followed by the salt-affected soils.

One land evaluation unit occupies 41.4% of the study area, and its index of productive potential is moderate. It would require a more detailed soil survey in order to draw smaller units with more distinct indices that may be more suitable for decision-making on land set-asides.

This evaluation will be used for the drawing up of the reconnaissance soil survey (to be developed in the low index regions) and the detailed survey of salinisation. This detailed survey will then allow estimation of the benefits of some corrective actions undertaken.

3.4.2 Conservation measures: controlling salinity in irrigated soils

To ensure the beneficial effects of irrigation, soil salinity should not exceed certain values. In the past, various actions have been undertaken to control salinity in the Aragón area. These include:

- Application of low salinity water for soil with good natural or artificial drainage properties
- Drainage of salts by open ditches and subsurface pipes
- Change of crops:
    - rice instead of corn or sunflower (rice needs more water to maintain standing water in the paddies)
    - use of salt-tolerant crops (e.g., barley) (although this entails a loss of profitability depending on the species)
- Reclamation of degraded soils through:

- soil amendments (adding calcium ions that displace sodium ions from the soil exchange complex and so preventing clays from deflocculating), although this requires a minimum of hydraulic conductivity
- modification of the irrigation water (for maintaining an electrolyte level of irrigation above the flocculation values of the soils) avoiding clay dispersion and preserving soil permeability
- breaking up the surface crust induced by surface and sprinkler irrigation
- using soil reclaiming plants, which create porosity or incorporate organic matter and promote microbial and faunal activity
- development of technical specifications in drainage projects

3.4.3 Soil salinisation impact

Soil salinisation negatively affects mainly agricultural yields (crop productivity) and irrigation infrastructure and pumping equipment. Salinisation may also have significant off-site effects:

- Increased salinity in aquifers and downstream rivers: requiring desalinisation for downstream water uses and groundwater treatment
- Impact on landscape values and soil biodiversity: increasing soil salinisation may reduce soil biodiversity

Salinisation is generally reversible. However, above certain thresholds, remediation is very expensive, if not impossible. Most of the severely affected areas are abandoned without any attempt of remediation.

3.4.4 Economic damages and costs

The cost evaluation is fragmental and focuses only on loss of crop productivity, and on remediation costs, by amendments or modifications of the irrigation system. These costs refer to the on-site private costs (PC) category in the cost classification elaborated in the literature review (section 4.6.1).

Concerning the cost of mitigation and repair (MC), no information could be provided on the cost of monitoring the area. Salinisation soil maps are not available at the regional level, except for small areas.

3.4.4.1 On-site costs

Salinisation directly affects crop productivity–crop yield decreases with increasing salinity. The crop yield decrease was estimated for the nine leading crops in the study area (Table 19). These crops are also the most suitable for the region under the present climatic, technical and economical conditions.

Table 19. Estimation of crop yield decrease in relation to increasing salinity

Salinity	ECe	ECe	ECe	Maxi ECe
Wheat	1.4	9,5	13	20
Barley	10	13	18	28
Maize	2.5	3.8	5.9	10
Alfalfa	3.4	5.4	8.8	15.5
Apple	2.3	3.3	4.8	8
Pear	2.3	3.3	4.8	8
Peach	2.2	2.9	4.1	6.5
Apricot	2.0	2.6	3.7	6
Potato	2.5	3.8	5.9	10
Crop yield decrease	10%	25%	50%	

ECe: Salinity of the saturated extract of soil, or Electrical Conductivity, in mmho/cm.

On the basis of the results obtained in this area, up to 10% of crop yields are lost in cases of cases of light salinisation, 10 to 50% of crop yields are lost for moderate salinisation, and 50 to 90% of crop yields are lost in cases of severe salinisation.

The crops have also been classified as either vulnerable (apple, peach, apricot and pear), somewhat vulnerable (maize, alfalfa and potato) or less vulnerable (wheat or barley).

For a given level of salinisation (light, moderate, severe), the total loss of agricultural output related to salinisation in the area studied were then calculated on the basis of the following formula:

Total loss = $GM^{NS} - GM^{S}$

Where GM^{NS} and GM^{S} are the total gross margin without salinisation (NS) and with salinisation (S), respectively.

The total gross margin are estimated from these equations:

Without salinisation : $GM^{NS} = \sum_i \left[p_i y_i - pc_i\right] s_i$

With salinisation : $GM^{S} = \sum_i \left[p_i (1-\gamma) y_i - pc_i\right] s_i$

Where p_i is the product price for crop "i" (in €/tons); y_i the crop yield (in tons/ha); pc_i the production cost (or variable cost) for crop i and s_i the cultivated surface with crop i. The term in bracket gives the agricultural gross margin added per ha and the associated figures for each crop are displayed in Table 20.

Table 20. Unit gross margin for different agricultural productions of the studied area (without salinisation)

	Product prices p_i [€/tons]	Crop yields y_i [tons/ha][1]	Production cost pc_i [€/ha]	Unit gross margin [€/ha][2]
Wheat	122	4.3	235	289
Barley	99	3.6	202	153
Maize	122	9.9	360	852
Alfalfa	61	15.6	395	559
Apple	131	19.1	955	1551
Peer	213	10	1183	957
Peach	304	8.4	847	1709
Apricot	157	10.7	774	898
Potato	720	22.1	105	8593

[1] *Estimated from the mean of crop production (in tons) and cropping pattern in 1988*

[2] *Unit gross margin = price * yield –production cost*

The salinisation level is expressed by parameter γ, which is the percentage of crop yield decrease derived from table 21. The following table displays the cropping pattern observed in 1988 and the estimated total gross margin without salinisation. The total gross margin with salinisation is calculated for different value of γ (10%, 25% and 50%). The calculation assumes that all of the agricultural soils are under the same suitability level system.

Table 21. Total gross margin without and with salinisation for different crops production (M€$_{1988}$)

	Surface in ha (1988)	Total gross margin without salinisation [GM^{NS}]	Total gross margin with salinisation [GM^{S}]		
			g **=10%**	*g* **=25%**	*g* **=50%**
Wheat	4,443	1.29	1.05	0.70	0.12
Barley	939	0.14	0.11	0.06	0.02
Maize	3,700	3.15	2.70	2.03	0.91
Alfalfa	3,645	2.04	1.69	1.17	0.30
Apple	154	0.24	0.20	0.14	0.05
Peer	230	0.22	0.17	0.10	0.03
Peach	317	0.54	0.46	0.34	0.14
Apricot	100	0.09	0.07	0.05	0.01
Potato	87	0.75	0.67	0.56	0.37
Other products	311		-	-	-
Total	13,926	8.46	7.13	5.15	1.84
% of loss			16%	39%	78%

Table 22 gives the gross margin loss for the different crops at the three salinisation levels. Results are also presented in unit gross margin loss for each crop. The total unit loss is calculated by dividing total gross margin loss by the total surface (13,621 ha where the surface of others products are deduced).

Table 22. Gross margin and unit gross margin loss for different crops production

	Gross margin loss [€]			Unit gross margin loss [€/ha]		
Crop yields decrease	*slight 10%*	*moderate 25%*	*severe 50%*	*slight 10%*	*moderate 25%*	*severe 50%*
Wheat	232,971	582,428	1,164,856	52	131	262
Barley	33,304	83,259	166,518	35	89	177
Maize	448,399	1,120,997	2,241,994	121	303	606
Alfalfa	347,712	869,281	1,738,561	95	238	477
Apple	38,599	96,498	192,996	251	627	1253
Peer	49,214	123,034	246,068	214	535	1070
Peach	81,016	202,540	405,080	256	639	1278
Apricot	16,721	41,801	83,603	167	418	836
Potato	75,672	189,180	378,360	870	2174	4349
Other products	-	-	-			
Total loss	1,323,607	3,309,018	6,618,036	97	243	486

We see from this calculation that, on average, 16% of farmers' income is lost in the case of slight salinisation (97 €$_{1988}$ per ha), 39% of income is lost for moderate salinisation (243 €$_{1988}$ per ha) and about 78% of income is lost in the case of severe salinisation (486 €$_{1988}$ per ha).

For the area studied (13,926 ha), the total agricultural income loss (on-site costs) is about 1.32 M€, 3.31 M€ and 6.62 M€, respectively, for slight, moderate and severe salinisation levels. These costs are borne annually by the farmers and might be under-estimated because the additional expenditure on production inputs related to salinisation are not estimated in this study (for example modification of irrigation system). The production cost with and without salinisation is assumed to be the same.

3.4.4.2 Off-site costs

Off-site effects of soil salinisation have not been assessed in this case study. These includes costs of remediation / clean up, etc.:

- Amendment of sodic soils by adding calcium ions that displace sodium from the soil exchange complex and thereby prevent clays from deflocculating.
- Modifications to the irrigation system: no economic estimation has been made of this type of cost.
- Use of soil reclamation plants that resist salinity, sodicity (plants used for grazing): This type of cost was not estimated with economic values.

Non-user value costs (NC) have not been estimated.

3.4.4.3 Who bears the costs?

The main actors involved are the farmers, the water users and re-users within and outside the area (irrigation water from the surroundings) and the Water Basin Authority, in this case, the Confederación Hidrográfica del Ebro.

Farmers and water users bear most of the costs associated with salinisation at the present time:

- farmers for the costs related to crop yield and, in part, those related to the modification of the irrigation systems
- water users for water re-use, modification of irrigation and monitoring

3.4.5 Conclusion

This case study on salinisation is related to extensive irrigation in the Ebro basin. The assessment of the cost of salinisation considers mainly the loss of farmers' income. Based on the results of the case study, the loss in farmers' income is estimated at up to:

- 16% in case of light salinisation (97 €$_{1988}$ / ha)
- 39% in case of moderate salinisation (243 €$_{1988}$ / ha)
- 78% in the case of severe salinisation (243 €$_{1988}$ / ha)

These figures are estimated for a base year 1988. The data availability did not enable us to explicitly take into account the time distribution of costs, different soil types or their vulnerability to salinisation.

No real evaluation of the ecological side effects or long-term revenue losses was done. As for the erosion case, impacts of salinisation have to be evaluated over the short, medium and long term, for several reasons:

- the variation in yield from year to year due to climatic variations
- the accumulated effects of salinity and sodicity on the soil structure
- the effects of remediation / reclamation measures (e.g. new irrigation systems) that appear only after several years

Therefore, the costs of soil deterioration for this salinisation case should be considered as partial.

The absence of detailed data on the extent of salinisation in Europe (see chapter 4), and in particular of salinisation related to irrigation, will cause certain difficulties for the extrapolation of costs at the European level.

3.5 ORGANIC MATTER (OM) LOSS - SWEDEN

At the European scale, three types of configurations for OM loss issues are encountered: i) peat extraction in Northern Europe (Scandinavia - more than 50% of Europe's peat soils are located in Finland, Sweden and Ireland), ii) intensive agriculture and progressive depletion of organic matter content under middle latitudes (e.g. France, Netherlands, Germany), iii) historic and intensive OM losses due to climate, desertification in South Europe. Peat extraction is voluntary and irreversible soil degradation.

The Swedish case studies concern peat cutting and OM extraction, and not really OM loss as defined in this study. Although peat soils cover only a small part of the total land area (about 2.3%), they are estimated to represent as much as 23% of the total organic carbon stock in soils. This case could be considered to be a hotspot of SOM change.

In Sweden, in some areas, mires have been exploited for peat extraction. This is major economic resource. The organic material is removed and older layers (several thousands of years old) form the new soil surface. The main consequences of this are a decrease in the water levels, impacts on hydrology and water quality, additional organic matter decomposition, modification of the biodiversity, and loss of the carbon sink capacity.

The peat-extraction areas can subsequently be used as, for example, forest or wetland. After remediation by rewetting, new conditions often develop, in particular by the leaching of stored chemicals, which affect water quality. Wetlands are then considered as chemical retention areas.

3.5.1 Local conditions

The two areas studied hereafter, the Porla and the Västkärr areas, are peatlands relatively near to each other (10 km apart) in the southwestern part of Sweden where peat has been harvested almost down to the underlying mineral soil and the land converted into wetlands.

A winter period from December to March with snow accumulation, and eventually some snowmelt, influences the climate and hydrology of the region. The main snowmelt occurs in March-April. Snowmelt shapes the hydrological pattern producing high water levels and flow in the spring, which decrease towards the summer when fairly dry conditions may occur. In early autumn, low water is common, although later in the autumn, rainfall produces an excess of water, which freezes again in December. Average annual precipitation is ca. 800 mm, runoff ca. 300 mm and the annual average temperature is +6 ^{o}C.

No one lives in the Porla area.

The Västkärr area has been rewetted as a bird sanctuary. The landowner lives close by.

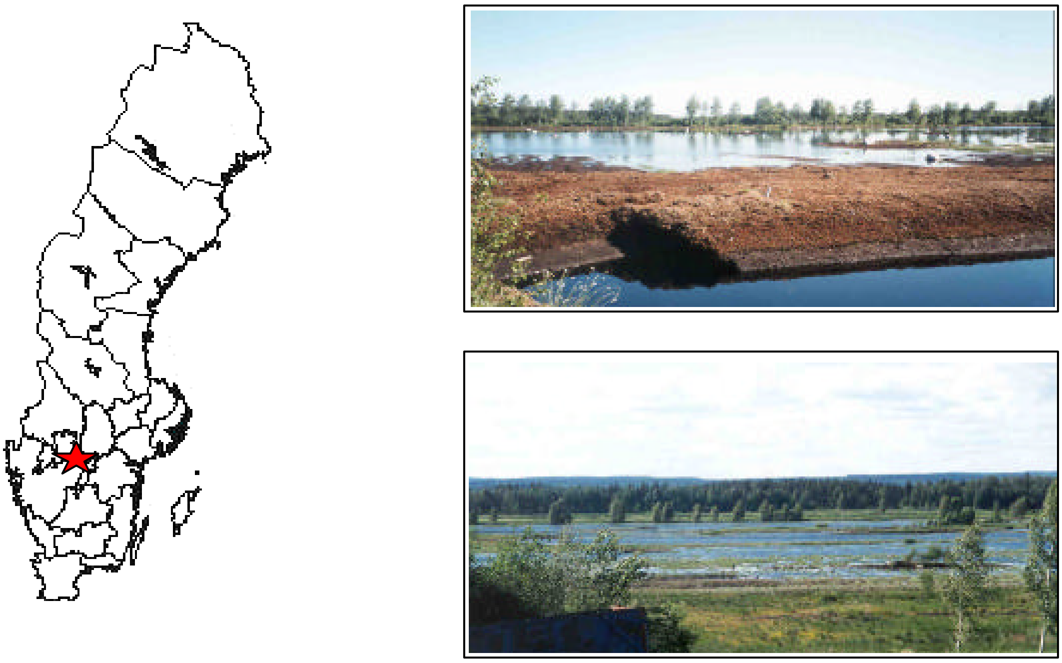


Figure 8. Location of the two areas studied for the Swedish OM loss case

3.5.2 Soils

The Porla site, ca. 20 ha, was a bog from which peat has been extracted for some 100 years. The remaining peat layer varies in thickness from 0 to 2 m (average 0.5 m). This old peat (ca. 7,000 years) is mainly fen peat (carex, scheuzeria mainly, with Sphagum peat in the remaining thick layer). It overlies a coarse till soil (moraine). The site is now rewetted and 0.5 to 1.5 m of water covers the peat and mineral soils.

The Västkärr (West fen) zone is an old lag area close to a large bog, which has since become a nature reserve. Originally, the bog was drained and used for agriculture. Later, the area was used for peat extraction for 20 years. Presently, only 0.2 m of fen peat is left on top of marine clay, which makes the bottom firm and flat.

3.5.3 Origin and extent of the threat

Soil degradation is often linked to the use of land for agricultural purposes. However, forest exploitation activities can also have an effect on organic matter (OM) loss and soil fertility:

- In the most northern part with a climate that is sometimes harsh, forestry has influenced soils with poor OM cover. Remediation of these sites usually fails.
- In the Southwest of Sweden, the burning of thick organic layers has, for centuries, degraded the soil, which has been covered mainly by Calluna, and thus afforestation is hampered.
- In some cases, drainage of wet soils has caused decomposition of the organic cover and only small amounts remain on top of the mineral soil.

Another land use is peat cutting, peat excavation and OM exploitation. When peat cutting activities cease, restoration of the site is often required, in particular to determine a suitable after-use. One such use is the creation of new wetlands, a topic that is currently being studied comprehensively in order to understand the environmental consequences of rewetting.

Peat cutting is performed from the south of Sweden to almost the far north. Apart from the high mountains in the Northwest, peat is cut all over Sweden.

Originally, the Porla mire was a bog with a peat layer over 4 m thick. In the early phase, the targeted product of the peat cutting was *Sphagnum* peat. Later, especially after 1980, fen peat was excavated down to the very uneven and sloping till (mineral soil) base. When peat exploitation ceased, the residual layer of peat varied in thickness from a few decimetres of fen peat to up to 2 m where *Sphagnum* peat still existed. In several places, stones and boulders could be seen on the peat surface. In 1999, the cutover area was prepared for rewetting by precipitation and water inflow from the catchment uplands, which included a poor sedge fen area. Both surface water inflow and groundwater seepage entered into the wetland with a size of ca. 15 ha. The site location in a slightly sloping terrain with low-lying land down slope of the rewetted area constituted a risk for groundwater leaching.

The other area, the Västkärr site, encloses a ca.80 ha peat cutover area originally forming a lag area to the large Skagerhult bog. The area was used for peat excavation in the new peat-cutting era starting around 1980. In 1997, peat cutting ceased leaving ca. 0.2 m of fen peat on top of marine clay with fairly rich nutrients.

3.5.4 Description of damages

The peat cutting areas were converted to wetlands for 1 to 10 years, and then turned into overgrown mires. The impacts affect mainly:

- biodiversity (changed wetland biodiversity)
- groundwater quality
- land values, which increase, in places, after peat cutting

3.5.4.1 Main actors

For this hotspot OM change case study, the main actors are peat companies, landowners, and local authorities.

3.5.5 Cost estimation

Information on costs was received from the peat and energy companies, but included no details.

Due to the specificity of the situation (peat mining is considered an organic matter loss), there is no cost estimation for prevention or monitoring. Even for the Environment Protection authorities, this is not considered to be soil deterioration.

The only costs available for this case study are those related to the restoration of the peat cutting areas to convert them into wetlands and forests. These costs have to be considered as compensatory measure costs, since restoration of OM content in the soil is impossible at the human scale.

3.5.5.1 Costs for compensatory measures

Expenditure of the peat companies to convert the two sites into wetlands has been evaluated at up to:

- ca. 25.000 € for Porla
- ca. 35.000 € for Västkärr

As these are on-site costs borne by the private owners of the land affecting the land use values, they have been assimilated to MC costs.

3.5.5.2 Who bears the costs?

The peat companies bear most of the costs, mainly due to the particular situation presented in this case study, considered as a hotspot of OM change.

3.5.6 Conclusion

This case study related to peat cutting activity should not be considered as soil deterioration as such: this mining activity deliberately uses the peat as a source of energy. It is definitively not a loss of organic matter as defined in the European Soil Protection Strategy. This will influence the way this case is used in the extrapolation task.

In other respects, the different types of cost should be itemised in order to thoroughly assess the situation with, in particular:

- total economic value of the bog that is lost as a consequence of peat extraction
- restoration costs
- compensatory measures
- rewetting benefits (such as increased biodiversity)
- increase of real estate value of the land
- environmental damage costs (related to water quality, reduction of certain biodiversity)

This information is not available at the present time.

4 Information Base for the Empirical Estimation

4.1 EROSION

Two kinds of data are available for extrapolation–those derived from actual measurements and from risk-based modelling where several approaches have been developed. Data from risk-based modelling are highly uncertain at the European level and therefore most of the approaches can only provide a quantitative assessment of the soil erosion risk. Furthermore, it is difficult to evaluate the actual quality of the results at this scale. Extrapolation based on measured data is therefore more suitable, even though it still has significant limitations. For all of the approaches presented, care has been taken to point out the main limitations.

4.1.1 Information based on estimation / predictive modelling

More detailed information about the modelling approaches presented here can be found in Gobin et al., 2003.

4.1.1.1 Qualitative risk-based modelling of soil erosion

<u>The De Ploey map</u> (De Ploey, 1989): This is a soil erosion risk map of Western Europe, produced by various experts who delineated areas where, according to their judgement, there is significant erosion. It, therefore, represents areas of potential risk. A limitation of this approach is that the author does not give a clear-cut definition of the criteria according to which areas were delineated (Yassoglou et al., 1998).

<u>The 'hot-spot' map</u> (EEA, 2000): The hot-spot map aims to present a kind of 'spatial indicator' that would enable the identification of priorities of intervention and the visualisation of data gaps. The map was developed from earlier maps (e.g. De Ploey, 1989), based on local empirical data. In the hot-spot approach, broad zones are first identified for which the erosion processes are roughly similar (actual erosion risk). Hot spots are then highlighted within each zone and associated with the best estimates, from the literature, of erosion rates in these hot-spot areas. Although there are advantages in concentrating on measured empirical data where these are abundant, and interpolation can be meaningful, the sporadic distribution and episodic occurrence of soil erosion makes it very ill-suited to this approach. It is also clear that sites of high erosion identified on this map are definitely areas of high impact, but that there is no reliable way to extrapolate these local results, even to their surrounding area.

<u>The GLASOD map:</u> The aim was to provide a world map of soil degradation. It is based on responses to a questionnaire sent to recognised experts in all countries (Oldeman et al., 1991). It thus shares with the hot-spot approach a dependence on a set of expert judgements, but can provide very little control or objectivity in comparing the standards applied by different experts for different areas. The Glasod map identifies areas with a subjectively similar severity of erosion, irrespective of the conditions that produced the erosion. The Glasod map is still widely used and quoted, although its authors and critics alike recognise the need for a more detailed and more quantitative assessment. Given that there are now improved methodologies, based on more quantitative analysis, it is unquestionably timely to abandon this approach, whilst not rejecting the use of data from local erosion sites to calibrate more quantitative models. A similar project, SOVEUR (Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe), uses a slightly modified GLASOD methodology with special focus on non-point-source pollution.

<u>The USLE map</u> (Van der Knijff (1999, 2000)): Van der Knijff et al. (1999, 2000) used the universal soil loss equation (USLE, Wischmeier and Smith, 1978) to estimate the

risk of rill and interrill erosion in Europe. USLE is one of the least data demanding erosion models that has been developed. It is a simple empirical model, based on regression analyses of soil loss rates on erosion plots in the USA. The model is designed to estimate long-term annual erosion rates on agricultural fields. In this assessment, soil erosion risk seems to be underestimated for most of Northern Europe and overestimated for mountainous areas and for already eroded areas.

The CORINE map (Corine, 1992): The Corine soil erosion methodology produced soil erosion risk maps for southern Europe, excluding northern Europe. The methodology used was based on a simplification of the universal soil loss equation. The Corine map seem to place too great an importance on climatic factors in determining erosion risk, with relatively little weight given to important factors such as erodibility and land cover. Both Van der Knijff (1999, 2000) and Corine used the USLE on account of its simple structure, although it lacks a sound physical basis and compatibility with higher resolution models and therefore cannot be recommended as the best basis for estimation of erosion risk.

The INRA map: The aim of this work is to develop pedotransfer rules based on the best available expert knowledge of erosion processes using soil parameters available in the European Soil Geographical Database for the assessment of erosion parameters (soil erodibility and crusting). The resulting map is not suitable for extrapolation of quantitative figures for soil erosion but is suitable for relative comparison of different European regions

4.1.1.2 Quantitative risk-based modelling of soil erosion

The PESERA map: The pan-European soil erosion risk assessment project (process modelling to assess regional soil erosion), has developed a physically based and spatially distributed model to quantify soil erosion in a nested strategy of focusing on environmentally sensitive areas relevant on a European scale. The model produces a quantitative forecast of soil erosion and plant growth, and therefore has the potential to respond explicitly and rationally to changes in climate or land use, offering great promise for scenario analysis and impact assessment. Set against this advantage, the model can only incorporate the impact of past erosion where this has been measured and thus requires numerous and good data sets needed for testing. The model simplifies the set of processes operating and may therefore not be appropriate under particular local circumstances. The Pesera model is currently being calibrated and validated at different resolutions and across different agro-ecological zones.

The PESERA model is described as the most conceptually appropriate (and the most physically based approach). However, in order to produce reliable quantitative estimations at the European level, it needs a lot of data. These input data are not currently available at the European scale. Therefore, at present, it is best to use the model to give relative trends, or discriminate at-risk-areas (see the PESERA final poster map, European Communities, 2004).

4.1.2 Information based on real data

4.1.2.1 The plot database

This database gives information on erosion processes ranging from sheet (or interrill) erosion to rill erosion (Glossary of Soil Science Terms http://www.soils.org/sssagloss). The former consists of the removal of a fairly uniform layer of soil by raindrop splash and sheet flow. The latter results in the formation of numerous and randomly occurring small channels only several centimetres deep under the action of small, intermittent water courses usually also only several centimetres deep. To measure the rates and extent of sheet and rill erosion, both indirect and direct methods have been used.

Indirect methods generally measure soil profile truncation or sediment accumulation relative to a reference soil horizon, to an exposed or buried reference object (exposed or buried roots, foundations…), or to the loss or accumulation of tracers. These methods are more appropriate for studying historical erosion. To assess current sheet and rill erosion rates, direct methods, mainly plot or catchment monitoring and field-based measurements (e.g., mapping of erosion features) are reported. Field-based methods are most effective to answer questions such as, "Where does linear erosion occur", and "Is it a problem?" However, they cannot properly monitor sheet erosion and, more important for this study, their applications have been restricted to very few places in Europe. The best available data to compare soil erosion rates in Europe induced by sheet and rill processes come from plot measurements. These represent relatively well-standardised data, which can give reliable information on slope sensitivity to sheet and rill erosion under a given set of conditions, and they are widespread. Based on a large dataset of soil erosion measurements under natural rainfall at the plot scale, the objective of this tool are: i) to quantify the different sheet and rill erosion rates in various agro-environmental settings throughout Western and Central Europe, ii) to identify the more at-risk situations in terms of land use or physiographic conditions and iii) to assess overall sheet and rill erosion rates for Europe.

Methodology

An extensive database of short- to medium-term (1-10 years) soil loss measurements at the plot scale was compiled from the literature. This database contains 208 entries (each entry corresponds to the combination of one land use, slope, etc. for one experimental site) distributed among 57 experimental sites in 13 countries, standing for a total of 2162 plot-years. Only data from experiments with a direct measurement of soil erosion rates, i.e., with an experimental device to measure erosion during natural rainfall events, were collected (e.g., collecting tanks or tipping buckets with or without automatic samplers). On average, the experiments cover ~10 equivalent (eq.) plot-years with a median of 6 plot-years per entry; the maximum being for cereal plots in Portugal (96 eq. plot-years, Lopes et al., 2002) and in Germany, where bare plots have been monitored for 60 eq. plot-years (Martin, 1988; Auerswald, 1993). As shown in Table 23, the database is composed of sheet and rill erosion rate measurements from Austria, Belgium, Denmark, France, Germany, Greece, Italy, Lithuania, The Netherlands, Portugal, Spain, Switzerland and United Kingdom. The corresponding annual rainfall in the database ranges from <200 mm (Spain) to >1,300 mm (Germany), with a median annual value of 595 mm. No restriction regarding slope length was made when selecting the experimental sites as long as the land use was uniform. However, the median size of the plots is close to the Wischmeier plots with a median slope length of 20 m, a median area of ca. 60 m² and a median slope of 13.2% (94% and 75% of the entries have a slope length >5 and 9 m, respectively, which are two recognised thresholds for rill initiation and development).

To compile the database, data with a similar location, land use, slope, slope length, area and soil texture (5 classes) were aggregated (weighted for plot years of measurements). As a consequence, data were combined even if other parameters influencing the erosion response were different (data showing differences in, for example, soil types or soil surface properties that are not reflected in the textural classification used, tillage systems or direction (parallel or perpendicular to the contour), or slope aspects). Experimental data where a strong evolution with time was reported (e.g., Francia et al., 2002) were not included in the database, as it was difficult to calculate a relevant mean value.

Table 23. Description of the soil erosion plot database

Country	Number of entries*	Total eq. plot-year	Mean eq. plot-year	References
Austria	8	43	5	Klik et al., 2001; Klik, 2003
Belgium	3	31	10	Bollinne, 1982
Denmark	6	16	3	Veihe and Hasholt
France	11	59	5	Viguier, 1993; Messer, 1980; Martin et al., 1997; Lecomte et al., in press; Cerdan et al., 2002; Clauzon and Vaudour, 1971
Germany	41	400	10	Martin, 1988; Auerswald, 1993; Goeck, 1989; Goeck and Geisler, 1989; Dikau, 1986; Voss, 1978; Emde, 1992; Jung and Brechtel, 1980
Greece	8	48	6	Kosmas et al., 1996; Romero-Diaz et al., 1999; Diamantopoulos et al., 1996
Italy	33	433	13	Tropeano, 1983; Zanchi, 1983; 1988; Rivoira et al., 1989; Porqueddu and Roggero, 1994; Careda et al.,1997; Vaccaet al., 2000; Basso, 2002
Lithuania	11	134	12	Jankauskas and Jankauskiene, 2003
The Netherlands	3	35	12	Kwaad, 1991; 1994; Kwaad et al., 1998
Portugal	16	482	30	Roxo, et al. 1996; Figueiredoet al., 1998; Lopes et al., 2002
Spain	48	367	8	Andreu et al., 1994 cited by Cerdà 2001; Bautista et al., 1996; Bautista, 1999 cited by Cerdà, 2001; Andreu et al., 1998a & b; Andreu et al., 2001; Sirvent et al., 1997; La Roca, 1984 cited by Cerdà 2001; Castillo et al., 1997; Puigdefabregas et al., 1996; Padron et al., 1998; Romero-Diaz et al., 1999; Lopez-Bermudez et al., 1991; 1998; Canton et al., 2001; Nicolau et al., 2002
Switzerland	2	9	5	Schmidt, 1979
United Kingdom	18	104	6	Fullen and Reed, 1986; Fullen, 1991; 1992; Quinton, 1994

*Each entry corresponds to the combination of one land use, slope, etc. for one experimental site

Discussion

The mean sheet and rill erosion rates are presented in Tables 24 and 25. The erosion responses between the different land use classes differ significantly (Kruskal-Wallis test statistics = 79.1 with probability <0.0001). If we rank (in descending order) the land use classes with at least 25 eq. plot-years of measurement according to the observed sheet and rill erosion rates, we obtain: bare soil, vineyard, maize, spring crops, cereal, post fire, forage, shrubs, grassland and forest. Bare soil is the most represented class with 563 eq. plot-years, and bare soil and the vineyard class have the highest mean rates (23.4 and 20 ton/ha/year, respectively). Maize and spring crops also show very high rates, i.e., more than 10 ton/ha/year. Interestingly, spring crops have the highest mean yearly rainfall (749 mm) and a relatively low mean yearly runoff (~16 mm), which also imply high sediment concentration.

Table 24. Description of the soil erosion database aggregated according to land use.

Land use	Number of entries*	Equivalent plot-year	Mean area [m²]	Mean slope [%]	Mean rainfall [mm/year]	Mean slope length [m]	Mean runoff [mm/year]	Mean erosion [ton /ha/year]
Bare soil	54	563	60.0	15.9	674	14.4	91.7	23.40
Vineyard	10	113	100.3	19.3	629	52.3	80.8	19.97
Maize	6	27	38.1	9.9	676	12.9	63.7	13.95
Spring crop**	13	62	375.8	11.0	749	43.4	16.1	10.64
Maize + cover	3	21	21.2	8.7	560	10.9	19.9	2.65
Cereal	36	335	1641.2	12.7	629	37.7	19.3	2.10
Post fire	8	112	1859.0	28.7	466	11.3	40.2	1.54
Forage	9	192	500.2	17.3	661	34.7	27.6	1.35
Vineyard + grass	5	12	102.5	24.0	598	62.7	17.1	0.78
Arable crops	6	139	16.0	10.8	862	8.0	42.2	0.53
Shrubs	34	283	65.3	22.1	411	16.2	9.5	0.50
Grassland	16	231	179.5	15.9	623	31.5	15.2	0.29
Barley + cover	1	3	66.3	10.0	665	22.1	-	0.28
Forest	6	51	48.7	19.9	483	11.8	6.0	0.10
Orchard	1	18	30.0	19.0	467	10.0	0.7	0.05
Total/Mean	208	2162	466	16.4	609	25.7	41.0	8.76

*Each entry corresponds to the combination of one land use, slope, etc. for one experimental site

**Except maize, maize + cover and barley + cover classes

Cereal, post fire and forage have moderate rates ~1.5 ton/ha/year. Despite relatively steep slopes, the classes shrubs, grassland and forest have the lowest rates, i.e. <1 ton/ha/year and have relatively high mean yearly runoff volumes, which, inversely to spring crops, imply very low sediment concentration. In fact, land uses with the highest percentage of bare soil, either spatially (wide interrow length and low leaf cover, e.g., vineyard or maize) or temporally (long intercrop duration, e.g., maize or spring crop) have the highest rates. The assemblage of these plot data in a database allows comparison of the impact of very different land uses in a common framework and thus confirm ideas that were commonly assumed about the sensitivity of certain crops (e.g., maize, spring crops, etc.) to sheet and rill erosion. However, as always with results directly deduced from an experimental dataset, the limits concerning the representativity of this database should be examined. Two types of limits can be highlighted.

4.1.2.2 Limitations

Limits related to spatial representativity

Even if the database is rather comprehensive, good quality long-term plot data are not available for every agro-ecological zone in Europe. For example values up to 200 ton/ha per rainfall event were observed in Southwest France for high intensity storms on agricultural areas with low vegetation density (Le Bissonnais et al., 2003), but no long-term plot studies have ever been conducted in Southwest France (and some possibly high-risk crops such as hops and vegetables are also missing from the plot database). Some plot studies are set up systematically according to predefined large monitoring schemes (e.g., Wischmeier plots with different soil types, tillage systems or crop rotations) independent from the erosion risk. Hence, these studies are rather objective. On the other hand, other plot studies might focus on a high-risk area. In this case, extrapolation of results without careful attention being paid to the specificity of the site can lead to an overestimation of the problem.

Limits related to the representativity of the of sheet and rill erosion processes

Erosion is a scale-dependent process–depending on the size of the monitoring schemes, results differ. One reason for this is the influence of slope length, topography and the spatial variability in soil surface conditions on both sediment transport and deposition. Plot studies, being limited in space, will therefore not reflect everything about what is happening in the landscape in terms of sheet and rill erosion. The results should be understood as a comparison of the sensitivity of given slopes to sheet and rill erosion in a given set of conditions. But whether the observed soil losses will actually leave the field or catchment where they originate or will be deposited, needs to be addressed through further investigations.

Table 25. Description of the soil erosion database aggregated according to land use and per countries.

	Land use	Austria	Belgium	Denmark	France	Germany	Greece	Italy	Lithuania	Netherlands	Portugal	Spain	Switzerland	United Kingdom
Number of plot/month	Arable land	516	284	116	30	1818	72	2112	648	315	2737	316		384
	Bare		92	36	48	2670		481		102	1740	683	108	792
	Forest					60		528				24		
	Grassland			36	48			816	960		644	192		72
	Orchard						216							
	Post fire				84			636				621		
	Shrubs					90	72	592			68	2569		
	Vineyard				432	96	216	7			600			
	Vineyard + Grass				60	64		21						
Mean Erosion	Arable land	8.93	8.50	0.64	2.03	1.32	0.58	1.33	19.38	6.76	0.59	0.30		2.09
	Bare		30.90	0.42	22.22	16.27		34.55		16.67	5.67	45.29	19.33	19.21
	Forest					0.00		0.20				0.00		
	Grassland			0.03	0.01			0.28	0.01		0.04	0.84		0.01
	Orchard						0.05							
	Post fire				5.41			0.04				0.46		
	Shrubs					0.13	1.17	0.06			0.40	0.52		
	Vineyard				11.09	33.23	0.41	54.86			0.36			
	Vineyard + Grass				0.66	0.00		2.57						

4.1.2.3 Geographical distribution of soil losses

Numerous observations have been made in the Mediterranean zone, 1382 eq. plot-years data for 113 entries vs. 780 plot-years for 95 entries for the rest of Europe (Table 26). Overall, the sheet and rill erosion rates for the Mediterranean zone (MZ) are similar to those of the rest of Europe.

Table 26. Description of the soil erosion database aggregated according to location and land use.

Zone	Land use	Number of entries	Equivalent plot-year	Mean area [m²]	Mean slope length [m]	Mean slope [%]	Mean rainfall [mm/year]	Mean runoff [mm/year]	Mean erosion [ton /ha/year]
Mediterranean	Bare soil	23	246	113.9	21.0	18.0	559	90.6	31.62
	Vineyard	6	101	99.4	32.2	16.4	640	116.4	16.64
	Vineyard + grass	2	6	100.0	41.8	23.5	582	33.3	1.92
	Post fire	8	112	1859.0	11.3	28.7	466	40.2	1.54
	Forage	9	192	500.2	34.7	17.3	661	27.6	1.35
	Cereal	18	244	222.6	22.8	13.8	520	24.7	0.66
	Shrubs	31	275	70.1	17.0	22.1	375	9.4	0.54
	Grassland	11	142	180.8	22.9	15.6	564	16.9	0.42
	Forest	4	46	65.0	13.8	19.9	334	8.6	0.15
	Orchard	1	18	30.0	10.0	19.0	467	0.7	0.05
	Total/Mean	113	1382	281.2	21.7	18.7	500	39.8	7.87
Other	Vineyard	4	12	105.0	82.5	23.8	612	21.4	24.96
	Bare soil	31	317	21.7	10.1	14.4	760	93.2	17.30
	Maize	6	27	38.1	12.9	9.9	676	63.7	13.95
	Spring crop**	13	62	375.8	43.4	11.0	749	16.1	10.64
	Cereal	18	91	3059.9	52.6	11.6	739	11.6	3.53
	Maize + cover	3	21	21.2	10.9	8.7	560	19.9	2.65
	Arable crops	6	139	16.0	8.0	10.8	862	42.2	0.53
	Barley + cover	1	3	66.3	22.1	10.0	665	-	0.28
	Shrubs	3	8	16.0	8.0	-	780	10.8	0.13
	Vineyard + grass	3	6	105.0	76.7	24.3	608	1.0	0.02
	Grassland	5	89	176.7	50.4	16.3	751	0.7	0.01
	Forest	2	5	16.0	8.0	-	780	0.7	0.003
	Total/Mean	95	780	691.8	30.1	13.4	738	43.0	9.83
Grand Total		208	2162	466	25.7	16.4	609	41.0	8.76

**Except maize, maize + cover and barley + cover classes

In the MZ, rates are higher for bare soils (~32 ton/ha/year for the MZ vs. 17.3 for the rest of Europe) but lower for most of the crop types, although the slopes are steeper. One possible explanation for these differences in the mean sheet and rill erosion rates for crops (e.g., 0.7 ton/ha/year for cereals in the MZ vs. 3.5 ton/ha/year for cereals in the rest of Europe) is the high rock fragment content found in MZ soils (e.g., Poesen and Lavee, 1994; Puigdefabregas et al., 1996). The influence of surface stoniness on the decrease of sheet and rill erosion rates has been described in many studies (see, for example, the references for Spain in Table 25) and percentage of stone covers of 30-50% are regularly observed. Rates are also higher in the MZ for permanent cover such as grasslands, forests or shrubs, probably due to differences in vegetation density for these land uses in the two zones, natural or perennial vegetation being less dense and with species having lower leaf cover in the MZ.

4.1.2.4 Extrapolation of experimental data to Europe

Mean sheet and rill erosion rates differ significantly according to land use. It is therefore interesting to calculate the spatial extent of the different land uses to assess sheet and rill erosion rates for Europe. Land cover can be estimated for Europe from the CORINE database. To homogenise the land use classes between the CORINE database and the soil loss database, both databases were reclassified. Figure 11 presents the extent of the reclassified CORINE land covers classes used in this study (the area where the slopes are <2 % are omitted as corresponding soil losses are usually very small) and Table 27 presents the soil loss database aggregated according to the reclassified CORINE land covers.

Table 27. Description of the soil erosion database aggregated according to the reclassified CORINE land covers.

Land use	Number of entries	Equivalent plot-year	Mean area [m²]	Mean slope length [m]	Mean slope [%]	Mean rainfall [mm/year]	Mean runoff [mm/year]	Mean erosion [ton /ha/year]
Bare soil	54	563	60	14.4	15.9	674	91.7	23.40
Vineyard	10	113	100	52.3	19.3	629	80.8	19.97
Arable land	74	779	931	32.6	12.4	674	25.9	4.34
Post fire	8	112	1859	11.3	28.7	466	40.2	1.54
Vineyard + grass	5	12	102	62.7	24.0	598	17.1	0.78
Shrubs	34	283	65	16.2	22.1	411	9.5	0.50
Grassland	16	231	179	31.5	15.8	623	15.2	0.29
Forest	6	51	49	11.8	19.9	483	6.0	0.10
Orchard	1	18	30	10.0	19.0	467	0.7	0.05
Total/Mean	208	2162	466	25.7	16.4	609	41.0	8.76

Table 26 presents the potential mean sheet and rill erosion per land use according to its extent and erosion rate. It is interesting to note that arable lands produce ~70% of total soil loss. The mean calculated sheet and rill erosion rates for Europe are ~1 ton/ha/year for the total area and ~1.6 ton/ha/year for the erodible areas (i.e., in Table 25, land uses with a sheet and rill erosion rate >0). These mean values are however, not an indicator of the significance of soil erosion in Europe as they average out spatial variability. For arable land in general and more specifically for vineyards (~20 ton/ha/year) and spring crops (~12 ton/ha/year), the average rates are well above acceptable rates of soil erosion (i.e., rates of erosion exceeds rates of soil production). From our calculations, it appears that at least 16.7% of the total area covered by CORINE suffers from significant soil erosion problems. These figures are only indicative and should not be taken as absolute values. Furthermore, in addition to the approximation related to the extrapolation of plot data, the mean sheet and rill erosion rates should be corrected for mean slope, particularly for arable land (12.4% for the plot database vs. an estimated 6.7% for CORINE).

New data should be received from Romania, Bulgaria, Hungary, Czech Republic and Poland. However, from a first approximation, the figures seem to be similar to those presented here.

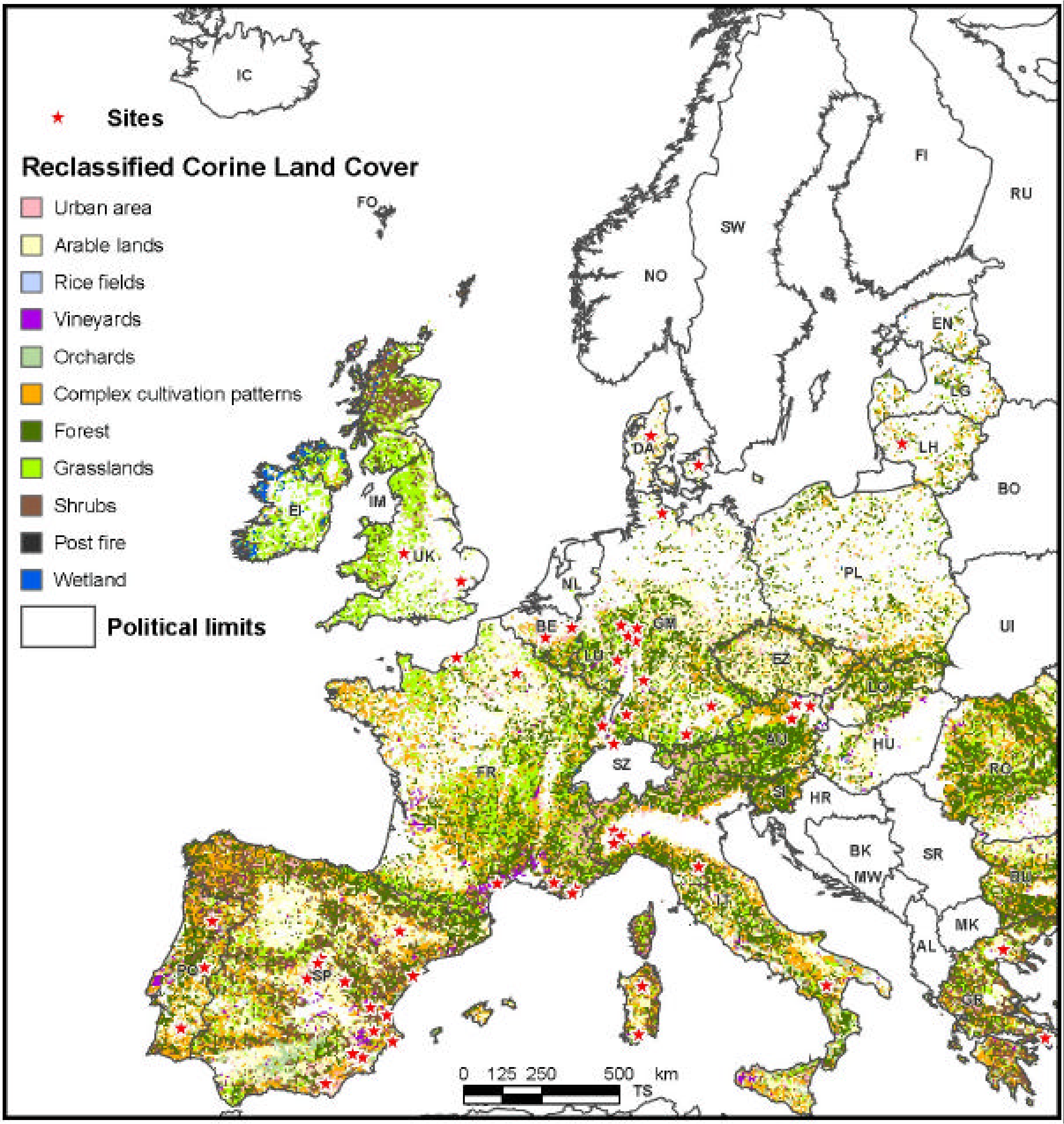


Figure 9. Extent of the reclassified CORINE land cover classes used in this study

In figure 9, areas with slopes below 2% or outside of the scope of CORINE are represented in white.

The first extrapolation carried out here was undertaken for countries for which we have spatial information on land use (i.e. the countries covered by Corine: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, United Kingdom). For the remaining European countries (i.e. Cyprus, Finland, Malta, Slovakia and Sweden), the extrapolation can be done on the basis of the figures presented in the following table. Romania and Bulgaria are not Member States but are included in Corine and are, therefore, also presented.

Table 28. Statistical information on land use

Land cover (1000Ha)		Bulgaria	Cyprus	Finland	Malta	Romania	Slovakia	Sweden
Land Area	2001	11055	924	30459	32	23034	4808	41162
Agricultural Area	2001	6251	117	2219	10	14852	2450	3144
Arable Land	2001	4424	72	2191	9	9402	1450	2694
Permanent Crops	2001	212	41	8	1	519	126	3
Permanent Pasture	2001	1615	4	20		4931	874	447
Forests And Woodland	1994	3348	123	23186		6680	1989	28025

(Source: FAOSTAT data, 2004, http://faostat.fao.org/faostat)

Table 29. Mean sheet and rill erosion amounts and rates for the reclassified CORINE land covers (Cerdan et al., 2003)

Land use	Area (ha)	Mean sheet and rill erosion rates (ton /ha/year)	Mean sheet and rill erosion (10^4 ton /year)	Mean slope (area <2% excluded)	Mean slope %
No soil	14,100	0	0.0	21.7	13.9
Arable land	55,150	4.337	23919	6.7	3.9
Rice fields	70,000	0	0.0	4.7	1.1
Vineyards	2,920,000	19.97	5832	9.4	7.5
Orchards	5,180,000	0.052	27	15.3	13.6
Complex cultivation pattern	36,170,000	0.502	1816	11.4	8.6
Forest	64,980,000	0.1	650	20.6	15.8
Grassland	32,120,000	0.289	928	15.6	10.6
Shrubs	24,150,000	0.502	1212	23.1	21.1
Post fire	220,000	1.541	35	20.8	20.3
Wetland	1,270,000	0	0.0	12.2	6.4
Slope <2%	113,510,000	0	0.0	<2	<2
Total	349,830,000	-	34418		

Mean erosion rate: for the total surface ca. 1 ton/ha/year, for the erodible areas 1.6 ton/ha/year

4.1.3 Conclusion

Two kinds of data are available–from **actual measurements** and from **risk-based modelling** where several approaches have been developed. Data from risk-based modelling are highly uncertain at the European level. Soil erosion is a complex phenomenon, which shows very high spatial and temporal variability and a non-linear response to climatic and anthropogenic pressures. It is therefore difficult to design a modelling approach that is able to describe all the erosion sub-processes occurring in the different agro-ecological zones in Europe. Hence, most of the approaches use simple modelling frameworks that only give qualitative assessment of soil erosion risk, which is not suitable for this extrapolation objective. Another major limitation is the data availability at the European scale. More detailed digital elevation data, better representation of rainfall erosivity (i.e., more detailed rainfall measurements), and satellite data that have better spectral and geometric characteristics than the data that are currently available (NOAA-AVHRR) would be needed. Ideally, multi-temporal satellite images should be used in order to account for the interaction between vegetation growth and senescence over the year, and rainfall. Finally, more detailed soil data are required (especially soil depth, stone volume and surface texture).

Extrapolation based on measured data is therefore more appropriate, even though it still presents significant limitations (very high spatial and temporal variations) that could be assessed with a comprehensive monitoring system.

4.2 CONTAMINATION

4.2.1 Local point sources

The principal sources of national data are the EIONET (European Environmental Information and Observation Network) priority data flow (last updated in December 2003) of the European Environment Agency and the national ministries for environment. The data background is mainly generated by the EEA on the basis of the indicator fact sheets, regularly updated and developed with the support of the European Topic Centre on Terrestrial Environment and some previous studies on comparison of data from several years. National data were obtained from data update requests for EEA countries.

All data are given by the National Ministries of Environment, the National Environmental Protection Agencies or the EIONET National Reference Centres for Contaminated sites, who collect data from various national sources. National information is updated with different periodicity in the Member States: in France, the data is updated every three months (the number of known contaminated sites in March 2004 was 3,723) in most other Member States, updating is done annually.

The largest and most heavily affected areas in Europe are concentrated around the most industrialised regions in Northern and Western Europe:

- Nord-Pas de Calais and Rhône-Alpes regions in France
- Rhein-Ruhr, Saar regions in Germany
- The Po area in Italy
- The so-called "black triangle" region located at the corner of Poland, the Czech Republic and the Slovak Republic
- Belgium and the Netherlands

4.2.1.1 Estimation of number of sites

The European Environment Agency has estimated the number of contaminated sites. The European Countries currently conduct different types of inventories. Estimations are related to potentially contaminated sites or known contaminated sites in relation with industrial, waste treatment or military activities. Table 30 shows the situation in 2000.

Table 30. Estimation of potentially and known contaminated sites in European countries as of August 1999 (EEA, 2000)

	Industrial sites		Waste sites		Military sites	Potentially contaminated		Contaminated sites	
	abandoned	operating	abandoned	operating		identified	Estimated total	identified	Estimated total
Austria	x	x	x	x	x	28,000	-80,000	135	-1,500
Belgium [1)]	x	x	x	x	x	7,728	14,000	8,020	n.i.
Denmark[2)]	x	x	x		x	37,000	-40,000	3,673	-14,000
Finland	x	x	x	x	x	10,396	25,000	1,200	n.i.
France	x	x	x	x	x	n.i.	700,000 – 800,000	896	n.i.
Germany[3)]	x	x	x		x	202,880	- 240,000	n.i.	n.i.
Greece						n.i.	n.i.	n.i.	n.i.
Iceland	x	x	x	x		n.i.	300 - 400	2	n.i.
Ireland	x	x	x	x		n.i.	-2,000	n.i.	n.i.
Italy	x	x	x	x		8,873	n.i.	1,251	n.i.
Luxemburg			x	x		616	n.i.	175	n.i.
The Netherlands	X	x	x	x	x	n.i.	110,000 – 120,000	n.i.	n.i.
Norway	x	x	x	x	x	2,121	n.i.	n.i.	n.i.
Portugal						n.i.	n.i.	n.i.	n.i.
Spain	x	x	x	x		4,902	n.i.	370	n.i.
Sweden	x	x	x	x	x	7,000	n.i.	2,000	n.i.
Switzerland	x	x	x	x	x	35,000	50,000	-3,500	n.i.
UK						n.i.	- 100,000	n.i.	-10,000

n.i. = no information available

[1)] PCS identified: 5,528/Flanders + 2,200/Wallonia, PCS estimated: 9,000/Flanders + 5,000/ Wallonia; CS identified: 7,870/Flanders + 150/Wallonia. Figures for Flanders concern contamination generated before 1994 and refer to plots, one site can consist of several plots or 'cadastral lots'.

[2)] Includes contamination generated before the mid 1970s.

[3)] Military sites are not included in this figure.

Important differences are identified due to:

- the types of activities inventoried (all three categories, or only one)
- former or existing activities

- the size of the industrial activities taken into consideration (those covered by the IPPC – considered as highly risky sites, smaller sites, etc.)

4.2.1.2 Surface estimation

As previously stated, all countries do not create inventories for the same type of site surface. For instance, in France, the surface area recorded in the national inventory is area of the source of contamination (table 31). This information is not available for all the sites in BASOL due to the different levels of knowledge on the site quality (from first level - initial diagnosis to in-depth diagnosis and reclamation levels).

Table 31. Estimation of contaminated surface area on contaminated sites

Number of sites in BASOL / March 2004	3795
Number of sites with references to contaminated soil surface	928
Total surface (in hectares)	60,723
Average surface (in hectares)	65.5
Surface maxi - largest surface (in hectares)	24,000
Surface maxi - second largest surface (in hectares)	11,000
Surface mini (in hectares)	0.0003

This data can be broken down as follows:

Table 32. Distribution of contamination surfaces (France)

Surface class [ha]	Number of sites with that amount of contaminated area	Total surface (ha)	Average surface [ha] for this class
0 to 01	148	7.1	0,05
0.1 to 1	331	196.8	0,59
1 to 5	260	685.8	2,64
5 to 10	71	522.9	7,37
10 to 100	98	3071.4	31,34
100 to 1000	14	5139.0	367,07
>1000	6	51100.0	8516,67
	928	60723	

In the Netherlands, data are available on the surface of the contaminated sites that had been remediated in 2003. The average surface of the 39 sites that had been remediated with public funds is 2 ha. The surface of the other 896 remediated sites is 0.2 ha. The total volume of remediated groundwater is 2.19 million m^3. The total surface of the remediated sites in 2003 in the Netherlands is 232 ha.

There is no agreed protocol for classifying sites in small, large and megasites depending on their surface area. The definition currently used for megasites is “large scale contaminated sites, that pose a large potential or actual risk to deterioration of groundwater, sediment, soil and surface water quality” (Rijnaarts et al, 2003).

For France, few sites are considered to be megasites. The average number of megasites per European country is approximately 10 to 20 sites. Differences between small and large sites is sometimes related to the type of activity (in general, smelters are large whereas gasworks are small). For other categories like petroleum and petrochemistry, it is more difficult because this class covers refineries (megasites), storage installations (large) and gasworks (small). In France, there are 10 refineries, 100 storage installations and 20,000 gasworks in operation. An additional 19,000 gasworks have already been shut down.

4.2.1.3 Typology of activities

Point-source soil contamination often originates in industrial plants no longer in operation, industrial and transport accidents and improper municipal and industrial waste disposal.

Effects of industrial activities that pose a risk to soil and groundwater and the spectrum of the various polluting activities vary between countries. However, in the countries analysed, there is a broad common picture of the main soil-polluting activities. A direct quantification of hazardous substance input into soil is, however, almost impossible.

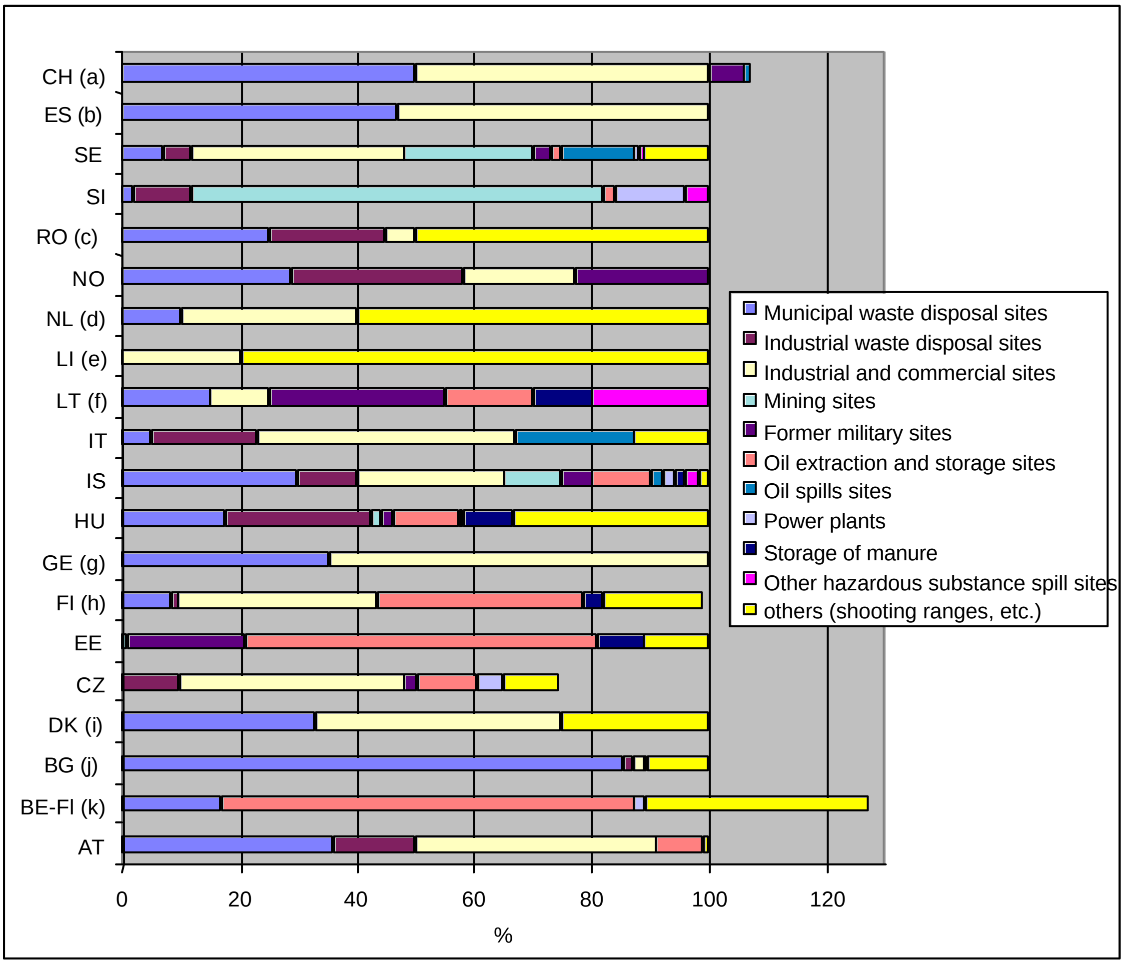


Figure 10. Breakdown of point-source soil-polluting activities

Source: EIONET priority data flow; September 2003. For DK, GE, LI, NL, ES: Pilot EIONET data flow; January 2002; for RO: data request new EEA member countries, February 2002. **NB: 2003 data not yet published, subject to validation**

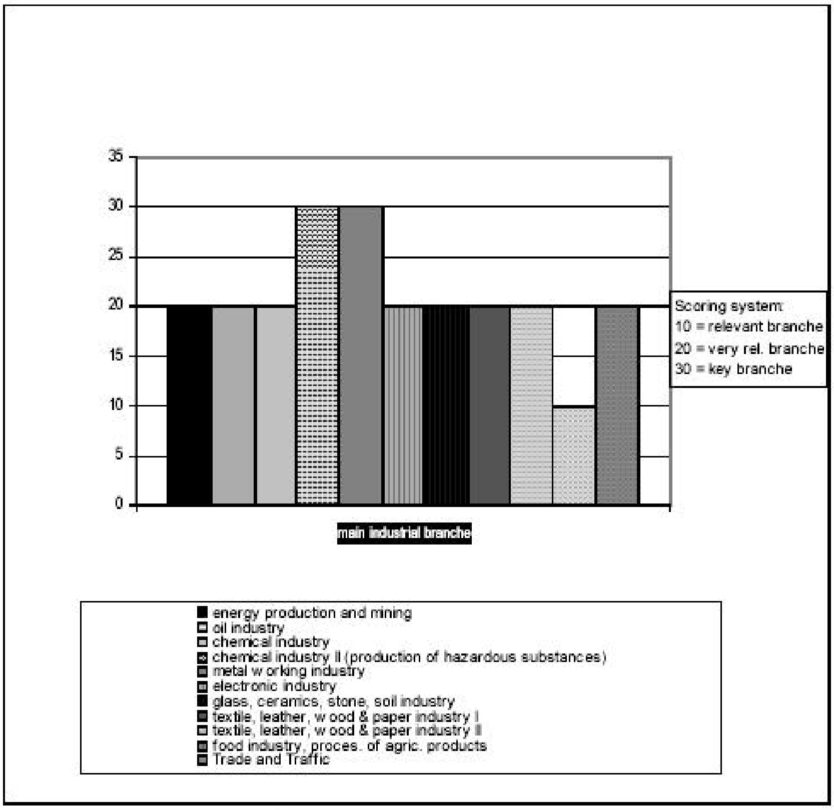
Notes:
(a) Switzerland: 'Municipal waste disposal' also includes 'Industrial waste disposal'; 'former military sites' also include active military sites and shooting ranges.
(b) Spain: 'Municipal waste disposal' also includes 'Industrial waste disposal'

(c) Romania: 'others' also includes accidents
(d) Netherlands: 'others' also includes accidents
(e) Liechtenstein: 'others' only refers to major accidents; minor accidents are not included.
(f) Lithuania: petrol stations are included in 'oil extraction'; pesticide storage facilities are included in 'other hazardous substance spill sites'
(g) Germany: 'Industrial activities' also includes accidents and 'other'; 'Municipal waste disposal' also includes 'Industrial waste disposal'
(h) Finland: service stations, large fuel and heating oil storage facilities included in 'oil extraction'
(i) Denmark: 'Municipal waste disposal' also includes 'Industrial waste disposal'
(j) Bulgaria: 'others' includes storage facilities for forbidden (obsolete) pesticides
(k) Belgium-Flanders: 'oil extraction and storage sites' also includes 'oil spill sites'
several activities can occur together on 1 site (127%)

For DK, GE, LI, NL, ES and RO the category 'Industrial activities' was used instead of the term 'industrial and commercial sites' used here.

The main activities identified as main sources of local pollution are:

- Waste deposits
- Industrial activities, in particular, petroleum & gas, chemical, ferrous and non-ferrous industries
- Commercial activities such as cleaning sites



NB: Assessment of relevance to soil and groundwater contamination of 41 industrial activities based on expert judgment. Average scores deriving from nine test regions, scoring system: 30 = very relevant; – 10 = currently not regarded or included.

Figure 11. Estimated main industrial branches causing point-source soil contamination in selected European regions (EEA, 2002)

Source: Second technical workshop on contaminated sites (Dublin, November 1999) – results published in EEA, 2002.

At the national level, some small differences can be identified, such as in France. But the main activities remain (figure 12).

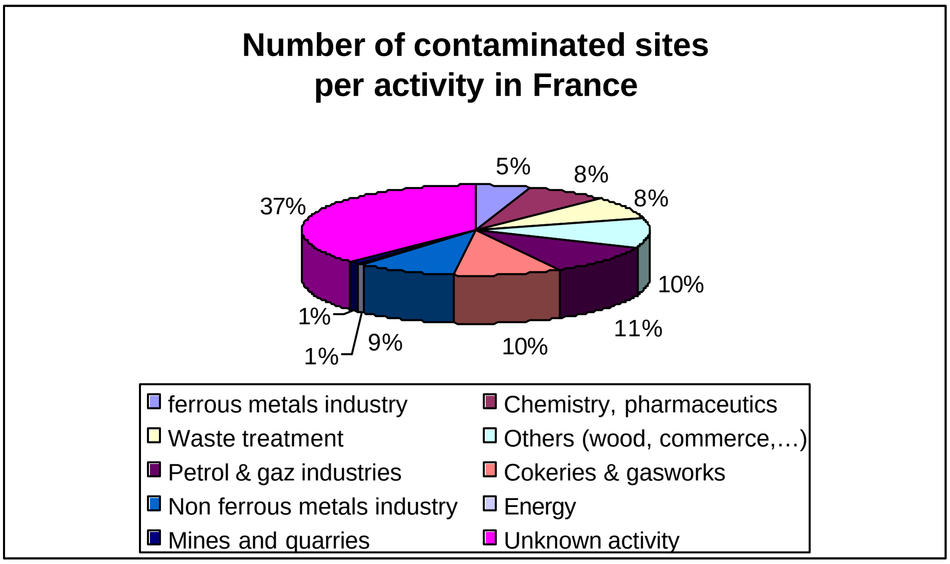


Figure 12. Breakdown of industrial branches causing soil contamination in France

4.2.1.4 Progress in the clean-up of contaminated land

The progress in the management of contaminated land is one of the three indicators developed at the European level (EEA, 2000).

Management of contaminated sites is a long-term and tiered process. Remediation (the final step of the approach) is much more costly, in both time and money, than site investigations (first steps). Due to different legal requirements (at national levels), the progress in management of contaminated sites varies considerably from country to country.

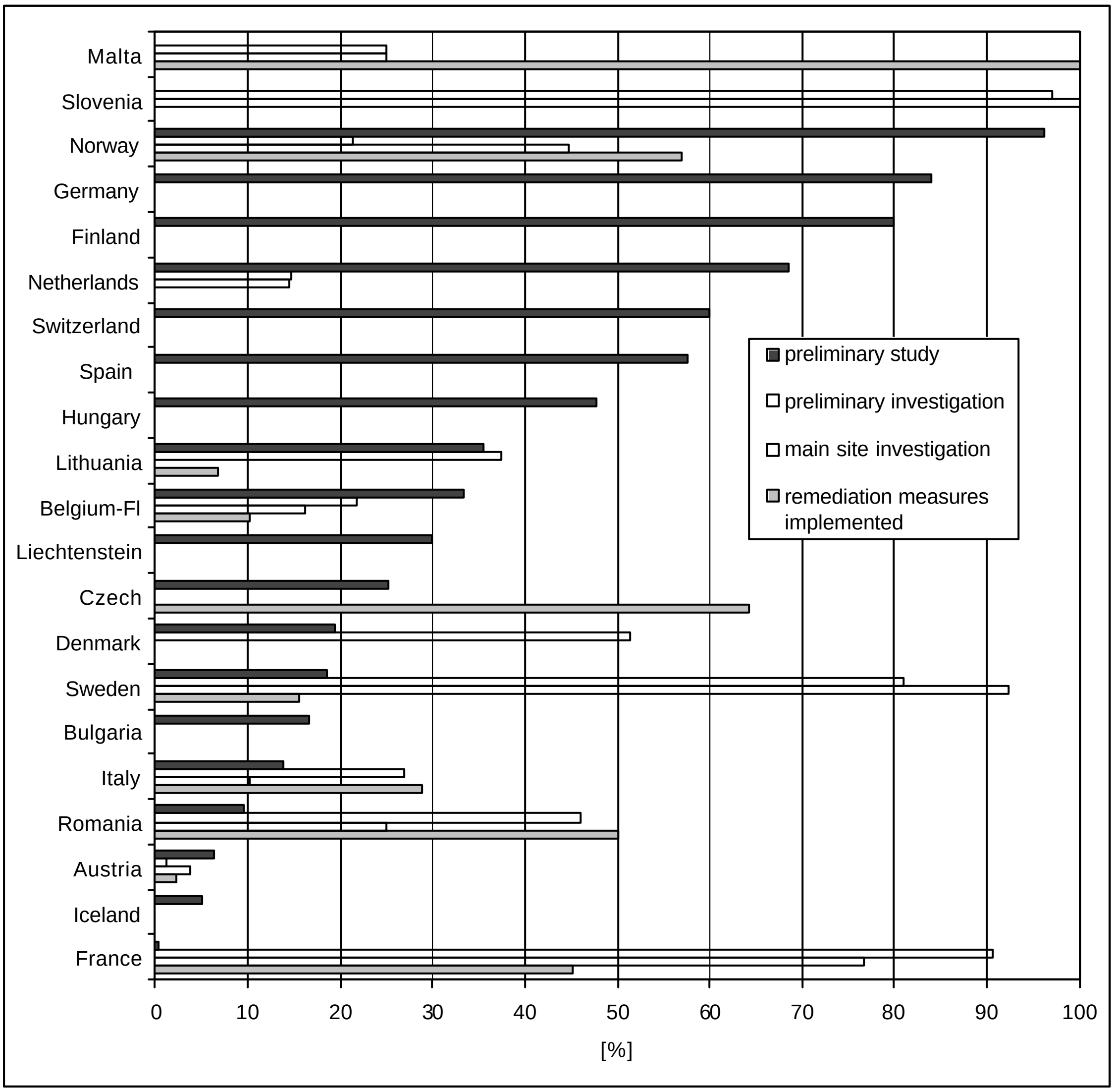


Figure 13. Management of contaminated sites in European Countries

4.2.1.5 Annual expenditure on soil remediation

Data on actual expenditure are very limited. Two surveys conducted by the EEA (in 2001 and 2003) refer to an average annual expenditure of 10 € per capita in European Countries with a high GDP.

Table 33. Average annual expenditure for soil remediation in European Countries

	Expenditure per year (M€)			Gross Domestic Product (M€)			Population
Country	**1999**	**2000**	**2002**	**GDP 1999**	**GDP 2000**	**GDP 2002**	**Inhabitants (M)**
Austria	67	75	120	198,340,887	204,210,287	208,850,304	8.1
Belgium-Fl	114.1	120	180.7	109,000,000			5.9
Bulgaria	36.9	50		9,116,809	9,609,116		7.9
Denmark	90	80	89	152,491,467	157,101,702	161,320,838	5.4
Estonia (a)			16.49	3235,62	3,466,272	3,641,009	1.4
Finland		30	60	119,837,501	127,157,507	130,079,661	5.2
France	239	290	635	1,306,383,740	1,355,789,286	1,403,314,940	59.2

	Expenditure per year (M€)			Gross Domestic Product (M€)			Population
Country	**1999**	**2000**	**2002**	**GDP 1999**	**GDP 2000**	**GDP 2002**	**Inhabitants (M)**
Germany (b)	57			1,998,678,517	2,055,774,671	2,084,939,722	82.3
Hungary	40	39	30	39,494,847	41,545,225		10.2
Liechtenstein	0.33			2,300,000			0.03
Netherlands	550	304	270	367,425,651	380,166,534	390,234,902	16.0
Norway			0.4625	127,429,818	130,324,911	135,654,614	4.5
Romania (c)	0.8	1.5		24,900,314	25,341,744		22.4
Slovenia (d)	0.1		0.092	16,954,688	17,736,448		2.0
Spain	15	20	33.54	517,374,634	538,573,024	565,230,937	41.1
Sweden	23	25	96	205,053,879	212,455,569	218,606,526	8.9
United Kingdom	1,450	1,179	1,239.9	970,950,625	1,000,878,636	1,040,235,146	58.8

Notes: (a) Estonia: GDP for 1999, 2000 and 2001
(b) Germany: projection from estimates of expenditure from some of the "Länder"
(c) Romania: expenditures for 1997 and 2000
(d) Slovenia: expenditures for 1999 and 2001

Source: 2002 data: EIONET priority data flow; September 2003. 1999 and 2000 data: For EU member states and Liechtenstein, pilot EIONET data flow; January 2002; for candidate countries, data request new EEA member states, February 2002; Eurostat Yearbook 2001 and 2002, Eurostat international statistics (Recent demographic developments in Europe 2000.); estimated total costs from EEA Topic Report No 13/1999. NB: 2003 data not yet published, subject to validation

Although the polluter pays principle (PPP) is generally applied, a huge sum of public money - on average 25% of total expenses - has to be provided to fund necessary remediation activities, which is a common factor across Europe. Annual expenditure has varied from 35 to less than 2 € per capita in the various countries over the past 4 years.

Data on expenditure includes public and private funds, but not for all countries. This will probably be better assessed in the coming years. Moreover, for the countries for which EEA has information on private expenditure, data may be incomplete.

The contributions from the public and the private sectors to the costs of remediation of contaminated sites vary from country to country (table 34).

Table 34. Breakdown of public and private remediation costs 2002 in selected European countries

Country	**public**	**private**
	[%]	
Austria	58	42
Denmark	45	55
Finland	5	95
France	7	93
Hungary	100	no data
Netherlands	50	50
Sweden	50	50

Source: EIONET priority data flow; September 2003.

These annual costs can be separated for the different steps in the management of contaminated sites (table 35).

Table 35. Breakdown of costs of soil reclamation in selected countries (M€)

Country	Site investigation	Remediation measures	After-care measures	Redevelop ment	Total
Austria	15	95	5	5	120
Belgium-Fl	58.7	122			180.7
Estonia	0.4				16.49
Finland		50-60			60
France	534	101			635
Netherlands	22	251			270
Norway	0.03	0.44			0.46
Slovenia (a)	0.092				0.092
Sweden	15	70	1	10	96
United Kingdom	458.8	781.1			1,239.9

Note: (a) Slovenia: data from 2001
Source: EIONET priority data flow; September 2003.

Annual remediation expenditure in the various countries has remained almost constant in the years 1999–2000. In some countries where this indicator has been monitored for 20 years, it can be concluded that public expenditure in this field remains constant. In the Netherlands, the total amount spent in remediation of contaminated sites has been around 300 M€ per year for the last 10 years. In recent years, the number of contaminated sites remediated annually with that amount of money has been multiplied by 10. Major reductions have been done on:

- diagnosis costs, in particular introducing several principles such as the proportionality principle and the “fit for use” concept (not necessarily for a multifunctional use that would include the most vulnerable such as school or recreational use involving children)
- treatment costs have become increasingly cost-effective

There is very little data on average costs for specific site classes (French data – discussion Darmendrail with petrochemistry industry):

- gas works: around 90,000 € per site
- refineries: around 100 M€ per site
- megasite with off-site effects (i.e., Metaleurop Noyelles-Godault site): between 300 and 500 M€

In France, there are 10 operating and former refineries, 100 storage installations and 20,000 gasworks in operation and 19,000 former ones (total number of potential contaminated sites). On these 39,310 operating and former sites in this industrial branch, ca. 340 are known to be contaminated. This class of site activity represents 11% of the known contaminated sites in France.

In the Netherlands, new estimates have been made of the total expected costs for soil remediation. The total amount is 20 billion €, of which 4.6 billion is for sediments, 1.6 billion for railways, gas factories and state property, 2.3 billion for asbestos and 11.5 billion for the remaining categories.

Data on expenditure available on the EEA database have the following characteristics:

Strengths:

- Cost estimations are available in numerous European countries.
- Extrapolation of representative regional data to national scale is possible.
- Clearer definitions have been introduced for expenditure, enabling classification of the costs in different categories (investigation costs, remediation costs, redevelopment costs etc.).
- It is possible to differentiate between public and private expenditure.

Limitations:

- There is a high dependence on cost estimations (no exact data available).
- Access to real data is often impossible (e.g., regarding private investments).

4.2.1.6 Population Exposure

There is no comprehensive data on the exposure of the population. However, contaminated areas exist around most major cities (for historical reasons) and there are some contaminated sites in low populated areas (EEA-UNEP, 2000).

There is a French study on this particular point related to an account of the number of potentially exposed people living near active industrial sites (lead smelters and battery recycling plants) that generate off-site effects (mainly due to atmospheric emissions) in the Centre Region in France.

Table 36. Estimation of the number of people exposed to point-source contamination (France)

	0 to 500 meters		500 to 1000 meters		1000 to 1500 meters	
Department	Total number of people	0-6 year olds	Total number of people	0-6 year olds	Total number of people	0-6 year olds
Cher	5,110	247	13,949	695	22,773	1,192
Eure and Loir	6,896	480	21,423	1,546	27,585	1,898
Loir and Cher	2,391	107	7,461	346	11,787	601
Loiret	6,404	405	16,453	1,065	24,786	1,421
Total	20,801	1,239	59,286	3,652	86,931	5,112

Currently, scientific discussion focuses on the distance to be taken into account in order to establish the number of people exposed to soil contamination. Probably for these types of site, which generate soil contamination by atmospheric emissions, the number of people considered to be exposed should be the ones present within a distance of at least 500 to 1,000 m.

4.2.1.7 Consequences

The main force driving the remediation of contaminated sites in urban areas is urban development rather than the presence of an impact on public health. This is true all over Europe for urban areas. The remediation costs are now taken into consideration in the overall cost of urban redevelopment projects (see the “Ceramique information sheet – NL” in chapter 8.1.8). Some countries such as the Netherlands are now promoting private – public partnerships (PPP) in order to enhance the redevelopment of contaminated sites and brownfields (derelict sites) that might not be contaminated but are perceived to be contaminated.

4.2.2 Non-point-source contamination

The main sources of non-point-source soil contamination are atmospheric deposition of acidifying and eutrophying compounds or potentially harmful chemicals, deposition of contaminants from flowing water or the eroded soil itself, and the direct application of substances such as pesticides, sewage sludge, fertilisers, and manure, all of which may contain heavy metals.

Two situations are generally labelled as non-point-source contamination:

1. Contamination that may arise from current agricultural practices and related soil uses such as forestry, managed nature reserves, gardens and parks where the user of the land modifies ecological processes in soil with additions of nutrients, exogenic organic matter and pesticides to increase productivity or to protect the current state of the land.
2. Contamination that enters the soil system by natural pathways likes atmospheric deposition and sedimentation from surface waters (in the case of sediments).

4.2.2.1 The SOTER database

The International Soil Reference and Information centre (ISRIC), in co-operation with the United Nations Food and Agriculture Organisation (FAO), United Nations Environment Programme (UNEP), and the International Union for Soil Science (IUSS), has developed a uniform system for handling SOil and TERrain data (SOTER database), initially for use at a global scale. This internationally recognised methodology is now operational in many countries worldwide at different scales, from national to continental.

ISRIC's mission is to:

- collect data and information on the world’s soil sources
- maintain the collected data and information
- improve the accessibility and dissemination of the information
- function as a portal for the soils through the World Wide Web

The SOVEUR project (mapping soil and terrain vulnerability in Central and Eastern countries) was implemented at ISRIC in 1997, under contract with FAO. The project encompassed collaboration with specialists from thirteen countries in Central and Eastern Countries, who collated the primary data using uniform criteria and guidelines developed at ISRIC. The project area covers Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldavia, Poland, Romania, Russian Federation (west of the Urals), Slovakia, and the Ukraine.

The aims of the SOVEUR project are to strengthen regional awareness of the significant role soils play in protecting food and water supplies, and demonstrate the need for environmental protection, by preparing soil degradation and vulnerability maps that will focus attention upon the areas most at risk (scale 1:2,500,000). This has been achieved by: (a) developing a digital soil and terrain (SOTER) database, (b) mapping the current status of soil degradation, and (c) assessing the soil's vulnerability to selected categories of pollutants. The final product was delivered to FAO in 2000 and published as volume 10 in FAO's Land and Water Digital Media Series.

The type of soil degradation refers to the nature of the degradation process (displacement of soil material by water and wind, in-situ deterioration by physical, chemical and biological processes). Types of soil degradation are represented by a code, the first letter (uppercase) indicating the major degradation type, the second letter(s) (lowercase) referring to the subtype. Most of the codes are the same as those used for the GLASOD map (see Erosion), but some additional codes have been added and some definitions have been changed slightly, in particular for pollution. In the context of the SOVEUR project, pollution has been treated as a separate main degradation type and the assessment criteria for pollution have been modified accordingly. The other types of degradation include various subtypes of water erosion, wind erosion, chemical deterioration (other than pollution), and physical deterioration.

The extent of soil degradation refers to the percentage of the area within a (map) polygon affected by the given type of degradation or by an association of several types. Several types of degradation often overlap and in some cases even interact.

4.2.2.2 Limitations of the SOTER database

- Most criteria are not quantitative (based on expert judgement, even using uniform standards and criteria).
- The 1:2.5 M scale of assessment does not enable detailed conclusions to be drawn.
- Varying data availability and quality may have led to local or regional under-representation of certain degradation types.
- Different interpretations of the criteria (e.g., risk versus status of degradation) have been used. It's clear that the risk rather than the status has been evaluated for some countries.
- Area calculations are based on the GIS data. Due to differences in projection, data gaps and some other inaccuracies, total areas shown may deviate somewhat from those in other data sources.
- Some records have incomplete or missing data.

4.2.2.3 Breakdown of degradation types

The results of the assessment is shown in the following table. 67% of the total area, about 385 Mha, is not affected by degradation. Soil compaction is the most predominant type of degradation (62 Mha, 11% of the total area and 21.7% of all degradation). Water erosion ranks second and pollution ranks third. This data is, however, incomplete, partly due to a reported lack of existing data (e.g., for Russia). Some countries also report only local occurrence for certain pollution types, while others provide extensive spatial data. This disturbs the general picture that should be taken into consideration when studying the results of the pollution assessment.

Table 37. Breakdown of soil deterioration categories at the European level (SOTER database)

Type		Negligible	Light	Moderate	Strong	Extreme	Total of SOVEUR area
Pc	Compaction	4.4%	13.6%	30.0%	26.8%	25.2%	10.9%
Wt	Water Erosion (topsoil)	8.0%	20.6%	33.0%	2.7%	35.7%	7.9%
Cn	Fertility decline	0.4%	25.6%	69.5%	4.5%	0%	5.5%
Pk	Crusting	5.8%	30.4%	62.9%	1.0%	0%	4.8%
Pd	Aridification	0.0%	0.4%	3.1%	25.4%	71.1%	4.2%
Cpa	Acidification	5.1%	24.5%	69.1%	1.3%	0%	4.3%
Et	Wind Erosion (topsoil)	11.4%	11.6%	33.4%	6.9%	36.7%	3.1%
Cpp	Pesticide pollution	7.7%	26.7%	64.0%	1.6%	0.0%	1.9%
Pw	Waterlogging	17.0%	20.3%	41.4%	14.7%	6.7%	1.5%
Cph	Heavy metal pollution	20.4%	24.0%	52.4%	3.2%	0.0%	1.4%
Cpr	Radio-active contamination	47.1%	29.3%	23.4%	0.2%	0.0%	1.1%
Cs	Salinisation	4.7%	13.8%	45.8%	27.0%	8.7%	0.9%
Wd	Water erosion (terrain deformation)	1.0%	17.9%	22.1%	57.4%	1.6%	0.9%
	Others*						**0.9%**
	Non degraded						67.4%
	* Other						
Wo	Water erosion (off-site effects)						0.4%
Ed	Wind erosion (terrain deformation)						0.3%
Pu	Land conversion						0.1%
Ps	Subsidence						0.1%
Cpn	Eutrophication						+
Eo	Wind erosion (off-site effects)						+

Total Soveur area (Central and Eastern countries involved in the SOVEUR project): 568,656 Mha.

The soil deterioration due to contamination is covered by four categories in this database:

- acidification: 4.3% of the Soveur Area, with 98.8% of the area classified under negligible, light and moderate impacts
- pesticide pollution: 1.9% of the total area

- heavy metal pollution: 1.4%
- Radioactive contamination: 1.1%, 99.8% of which is classified under the three lower impact levels

For each type of pollution, detailed information is given for some of the Central and Eastern countries (tables 38, 39, 40 and 41). The situation varies a lot from country to country.

Table 38. Percentage of country area affected by acidification

Country	Negligible	Light	Moderate	Strong	Total
Czech rep.	0.0	0.0	0.0	1.6	1.6
Estonia	0.4	0.2	0.0	0.0	0.6
Hungary	0.0	6.0	11.6	2.0	19.6
Latvia	17.6	0.0	0.0	0.0	17.6
Lithuania	1.1	24.4	0.3	0.0	25.8
Poland	0.0	0.1	34.8	0.0	34.9
Romania	0.0	3.3	0.2	0.0	3.6
Slovakia	0.8	0.2	0.1	0.1	1.2

Table 39. Percentage of country area affected by heavy metal pollution

Country	Negligible	Light	Moderate	Strong	Total
Belarus	0.0	0.0	0.0	0.0	0.0
Bulgaria	0.0	0.0	0.0	0.0	0.0
Czech rep.	2.5	0.0	0.0	0.0	2.5
Estonia	0.0	2.5	0.3	0.0	2.8
Latvia	0.0	0.0	0.0	0.0	0.0
Lithuania	19.5	22.8	0.0	0.0	42.2
Poland	0.0	0.0	0.6	0.0	0.6
Romania	0.0	0.0	0.0	0.0	0.0
Slovakia	0.0	0.0	0.1	0.0	0.1

Table 40. Percentage of country area affected by pesticide pollution

Country	Negligible	Light	Moderate	Strong	Total
Bulgaria	0.0	0.0	0.0	0.0	0.0
Czech rep.	1.9	0.0	0.0	0.0	1.9
Estonia	0.1	0.0	0.0	0.0	0.1
Lithuania	0.0	0.0	0.0	0.0	0.0
Poland	2.4	0.0	0.0	0.0	2.4
Romania	0.0	6.6	12.7	0.0	19.3
Slovakia	0.3	0.0	0.0	0.0	0.3

Table 41. Percentage of country area affected by radio-nuclear pollution

Country	Negligible	Light	Moderate	Strong	Total
Bulgaria	0.0	0.0	0.0	0.0	0.0
Estonia	0.0	0.0	0.0	0.0	0.0
Ukraine	5.2	3.2	2.6	0.0	11.0

Acidification is the most widespread type of pollution in Central and Eastern European Countries, in particular in Poland and Ukraine. This data is not available for the Western European Countries.

4.2.3 Conclusion

Point sources of contamination are currently taken into consideration in most European countries. Therefore, accurate data are available both on environmental and economic impacts. Even incomplete (in some countries, for some specific parameters that could be of interest for the extrapolation - e.g., surfaces), some extrapolation should be possible.

This is, however, not the case for non-point-source pollution, which is a more complex issue due to the origin of this type of threat. A strategic approach is recognised as needed for giving some indication how to weight the different inputs, how to consider accumulation of hazardous substances in soil and the associated risks for public health or ecosystems. However, there is no consensus on this strategic approach (WG contamination final report), and the economic impacts of this pollution threat are not currently being studied.

4.3 SALINISATION

4.3.1 The SOTER database

As seen in the chapter on Contamination, the SOTER database also provides information on salinisation (table 37). This threat affects 0.9% of the SOVEUR area.

Salinisation is reported to be significant in Ukraine (2.5 Mha or 4.3% of the total surface area), Russia (1.6 Mha or 0.4%) and Hungary (0.7 Mha or 8%). In Hungary, the degree is negligible and the impact is light to moderate. In Russia, the degree is light to moderate and the impact is strong. In Ukraine, both the degree and impact are mostly moderate.

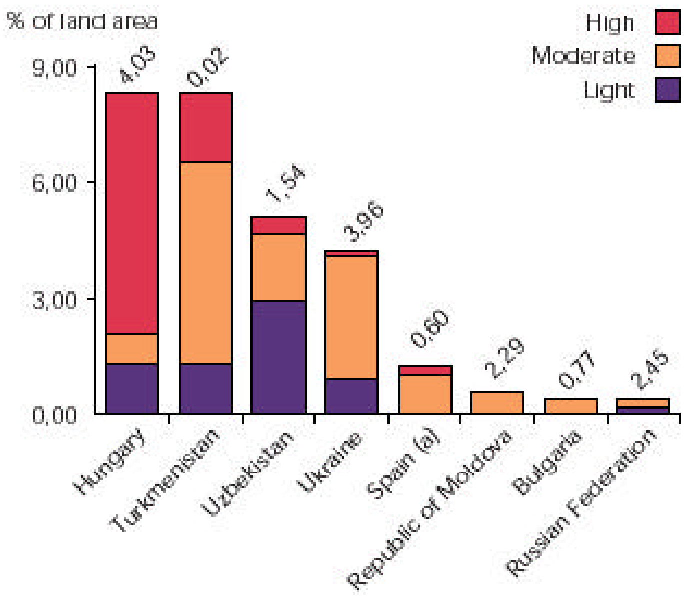


Figure 14. Area affected by Salinisation (EEA, 2001)

4.3.2 The UNEP Database

The country values represent averages of the station-level values for the three-year period 1994-96, except where data were only available for an earlier time period (1988-1993). The number of stations per country varies depending on country size, number of water bodies, and level of participation in the GEMS monitoring system.

Table 42 shows the European countries identified in the UNEP among the 100 countries affected by salinisation.

This situation is based on measurements at field stations. At this time, there is no indication of the number of stations in each country and, therefore, it is unknown whether or not these measurements are representative of the situation in the entire country or extent.

Table 42. Average salinisation values (UNEP database)

Country	Electrical Conductivity [micro-siemens/cm]	**Estimation**
Belgium	2626.19	
Greece	2259.13	x
Bulgaria	1743.52	x
FYROM (Former Yugoslav Republic of Macedonia)	1619.25	x
Germany	1566.07	
Bosnia and Herzegovina	1248.06	x
Belarus	1124.68	x
Turkey	1105.28	x
Poland	1043.77	
Spain	927.14	x
Slovakia	918.85	x
Italy	915.42	x
Slovenia	908.82	x
Austria	811.60	x
Ireland	723.43	x
Croatia	700.79	x
Netherlands	623.12	x
Czech Republic	592.77	x
Hungary	579.26	
Ukraine	557.81	x
Romania	438.87	x
Denmark	422.19	x
Latvia	371.55	x

The other European countries are not reported by UNEP to be affected by this type of soil deterioration.

4.3.3 Personal communication on salinisation

According to Guiseppina Crescimanno (Universita di Palermo), considering the *global scale*, most of the water in the hydrosphere is salty. Of all cultivated land, about $0.34*10^{9}$ ha (23%) is salty and another $0.56*10^{9}$ ha (37%) is sodic. Saline and sodic soils cover about 10% of all arable land and exist in over 100 countries. Furthermore, saline and sodic soils, although mostly affecting arid and semi-arid regions, are not limited to these regions. According to estimates, 10 million ha of irrigated land are abandoned yearly as a consequence of the adverse effect of irrigation, mainly secondary salinisation and sodication (Szabolcs, 1989).

Table 43. Levels of desertification in relation to salinisation rates

Desertification	Plant Cover	Salinisation of irrigated land ECe x 10^3 [mmhos]	Crop yield
Slight	Excellent to good range conditions	<4	Crop yield reduced by less than 10 %
Moderate	Fair range conditions	4-8	Crop yield reduced by 10-50 %
Severe	Poor range conditions	8-15	Crop yield reduced by 50-90 %
Very severe	Land essentially stripped of vegetation	Salt efflorescence on the surface	Crop yield reduced by more than 90 %

This clearly shows that all the degrees of desertification are associated with a certain degree of salinisation, and that a positive correlation exists between the extent of desertification and salinisation. But, as shown in the Spanish case study, the economic impact depends on the crop. Some of the reclamation solutions are based on the change of crops with the use of salt tolerant crops (e.g., barley).

4.3.4 Conclusion

In order to extrapolate to the European level, the following actions are necessary:

- Updated and reliable information on the status of salinisation and sodication in Europe must be collected.
- Areas threatened by salinisation and sodication in different countries must be identified by measuring the suggested indicators (EC, ESP/SAR, critical ground water depth and critical ground water salinity).
- Models predicting transport of water and solutes and those used to select management strategy scenarios (i.e., alternative irrigation methods and scheduling, calculation of leaching requirement, conjunctive use of different irrigation waters, amendments, etc) or alternative land uses taking into account the social and economic consequences of land degradation must be validated/calibrated.
- All major agriculture production in each country that could be affected by salinisation must be identified.

4.4 ORGANIC MATTER LOSS

The Soil Organic Matter Working Group of the EU Soil Thematic Strategy has done a review of the status and distribution of soil organic matter in Europe (Jones et al, 2004). Their conclusions are:

- The European Soil Database, at 1:1,000,000 scale, is the only source of data on the soils of Europe harmonised according to a standard international classification (FAO).
- Available as part of this database, is a Soil Profile Database for Europe (SPADE) containing data on organic carbon in the topsoil (0-30 cm) for major soil types.

- These data are not comprehensive geographically and have poor replication. Consequently, an expanded database for Europe (SPADE 2) is currently in the advanced stage of compilation and will provide (after 2004) many more measured values of Organic Content (OC) for European soils.
- OC data for soils in Europe are available from other sources: National Soil Survey archives, the ISRIC–WISE database, the ICP Forest Survey, the FOREGS Geochemical Baseline Mapping and the Baltic Survey.
- With the exception of national soil survey archives, it is not possible to produce distribution maps of soil OC from any of these databases that would be accurate enough for policy support in Europe.
- However, national data are not generally available for use outside the country of origin, the ICP forest survey is limited to forested land, the Foregs database is based on only 5 samples per 160 km x 160 km, and the Baltic Survey covers only northern countries.

Estimated organic carbon level in the topsoil has been derived from the European Soil Database using four classes:

H(igh): >6%

M(edium): 2.1 – 6.0%

L(ow): 1.1 – 2.0%

V(ery) L(ow): <1%

Table 44 shows the distribution of Soil OC classes in Europe.

Table 44. Proportion of Europe estimated to fall into the different OC classes

Hectares (ha)	OC class	OC [%]	Area [%]
66,558,238	V	<1	13
163,967,166	L	1 - 2	32
232,325,106	M	2 – 6	45
22,173,470	H	> 6	5

A study of the distribution of peat and peaty topped soils in Europe has recently been conducted by the Joint Research Centre (Montanarella et al, 2004) using the European Soil Database (v1.0). The results highlight the contrast in topsoil organic carbon content between northern and southern Europe (see table 45).

Table 45. Area of peat and peaty topped soils, within country (estimated from a) the European Soil Database, and b) the map of Organic Carbon in the Topsoils of Europe using thresholds of 20 and 25% of OC)

Country	Area of Peat[1] in SMUs of European Soil Database		Area of peat and peaty-topped soils from Map of OC in Topsoils of Europe[2]			
			OC>20%		OC>25%	
	[km²]	[%]	[km²]	[%]	[km²]	[%]
Albania	44	0.2	41	0.1	0	0.0
Austria	276	0.3	1,262	1.5	134	0.2
Bosnia Herzegovina	170	0.3	86	0.2	32	0.1
Belgium	240	0.8	96	0.3	95	0.3
Bulgaria	53	0.5	1	0.0	0	0.0
Switzerland	183	0.5	4,762	11.9	836	2.1
Czech Republic	687	0.9	1,449	1.9	251	0.3
Denmark	1091	2.6	249	0.6	66	0.2
Estonia	9,353	21.7	8,196	19.0	6,889	16.0
Spain	360	0.1	196	0.0	184	0.0
Finland	88,908	29.5	10,0440	33.3	98,353	32.6
Faeroe Islands	201	15.0	111	8.3	92	6.9
France	3,157	0.6	5,417	1.0	775	0.1
Germany	15,276	4.3	17,846	5.0	6,279	1.8
Greece	554	0.4	0	0.0	0	0.0
Croatia	41	0.1	0	0.0	0	0.0
Hungary	2,738	3.0	1,018	1.1	401	0.4
Ireland	11,392	16.5	13,014	18.9	12,725	18.5
Italy	292	0.1	3	0.0	1	0.0
Liechtenstein	0	0.0	0	0.0	0	0.0
Lithuania	2,433	3.8	1,850	2.9	1,489	2.3
Luxembourg	3	0.1	0	0.0	0	0.0
Latvia	7,385	11.7	4,017	6.3	3,382	5.3
Monaco	0	0.0	0	0.0	0	0.0
FYROM[3]	0	0.0	18	0.1	0	0.0
Malta	0	0.0	0	0.0	0	0.0
Netherlands	5,392	15.6	3,209	9.3	2,022	5.9
Norway	18,685	6.0	28,380	9.2	18,798	6.1
Poland	29,720	9.7	15,043	4.9	4,677	1.5
Portugal	271	0.3	0	0.0	0	0.0
Romania	95	0.0	585	0.2	39	0.0
Sweden	65,859	15.6	105,025	24.9	90,785	21.5
Slovenia	78	0.4	180	0.9	0	0.0

Country	Area of Peat[1] in SMUs of European Soil Database		Area of peat and peaty-topped soils from Map of OC in Topsoils of Europe[2]			
			OC>20%		OC>25%	
	[km²]	[%]	[km²]	[%]	[km²]	[%]
Slovakia	35	0.1	555	1.1	1	0.0
United Kingdom	26,519	10.9	54,957	22.6	44,411	18.3
Yugoslavia[4]	110	0.1	3	0.0	0	0.0

[1] Peat as defined by the pedotransfer rule
[2] S.P.I.04.72, Jones *et al*.(2004)
[3] FYROM – Former Yugoslav Republic of Macedonia
[4] Yugoslavia – Serbia and Kosovo

Using both databases, almost a third of the peat and peaty–topped soils in Europe are shown to be in Finland and more than a quarter in Sweden, with the remainder found in Poland, UK, Norway, Germany, Ireland, Estonia, Latvia, Netherlands, and France. There are also small areas of peat and peaty–topped soils in Lithuania, Hungary, Denmark and Czech Republic.

In the Southern countries, the OC content in topsoil is quite low (table 46).

Table 46. Estimation of the OC content in topsoil in Southern Europe

Country	Total area	Very low to low (OC <= 2%)		Medium to high (OC >2%)	
	[km²]	[km²]	[%]	[km²]	[%]
Albania	28,704.567	21,575.076	75.2	6,788.233	23.6
Bosnia	51,524.030	34,453.723	66.9	16,898.412	32.8
Croatia	56,191.096	28,030.731	49.9	26,903.652	47.9
France (S of 45°N)	196,550.777	116,603.968	59.3	78,371.704	39.9
Greece	133,007.789	126,841.043	95.4	4,868.798	3.7
Italy	300,453.890	259,601.949	86.4	37,341.722	12.4
Montenegro	13,792.171	7,012.719	50.8	6,531.899	47.4
Portugal	89,335.536	51,026.010	57.1	37,944.766	42.5
Slovenia	20,235.843	11,615.170	57.4	8,375.443	41.4
Spain	498,914.695	378,630.678	75.9	117,451.853	23.5
Southern Europe	1,388,710.394	1,035,391.069	74.6	341,476.480	24.6

Source: Jones et al. Review and analysis of existing studies aimed at assessing soil organic matter at national scales (Belgium, Denmark, Finland, France, Italy, Spain, Switzerland and UK).

These data can be considered as the baseline for determining the volume of carbon stocks in topsoil in Europe and, in the future, for an estimation of the potential Organic Matter Loss.

4.5 FLOODING

The causes of flooding are climatological (rain, snowmelt, icemelt), partly climatological (estuarine interactions between streamflow and tidal conditions, coastal storm surges), and other phenomena (earthquakes, landslides, rupturing of dams and other flood control structures). Flood-intensifying conditions include basin characteristics (area, slope, altitude, soil type, vegetation cover, etc.), network characteristics (surface storage, channel length, etc.) and channel characteristics (slope, flood control, storage, etc.). It is, therefore, extremely difficult to identify the part of flooding erosion related only to soil degradation and find harmonised data allowing comparison and extrapolation.

5 Conclusion

The difficulties encountered in identifying and assessing the impacts of the various causes of soil deterioration reflect the late awareness of the actors concerning the true economic issues of the main threats to soil. Existing studies are limited.

All of the case studies presented in this report are more or less representative of the European situation summarised below.

The extensive British study on ***erosion*** covers 17 communities in England and Wales (typical Atlantic climate) since the early 1980s. The cost evaluation was made essentially to estimate on- and off-farm impacts in the short- and medium-term. Although the figures are given as a combined value, somewhat imprecise, they enable comparisons to be made of the impacts of erosion.

The soil ***contamination*** case is representative of this major category of point-source contamination at a derelict industrial megasite. Among the millions of contaminated sites identified in Europe, megasites represent just a few hundred or so. In most cases, they are the only ones with off-site effects, generating different types of cost.

Erosion and contamination constitute threats that are studied both in terms of environmental and economic issues. For the other threats identified in the European Communication on Soil Protection, information is lacking.

The ***salinisation*** case study is located in one of the European regions most affected by this threat, Spain, and is related to extensive irrigation. Unfortunately, there is no detailed study of the extent of the salinisation problem in Europe and the assessment of the economic impacts has been limited to the consequences of the use (and non-use) of irrigation in agriculture.

For ***Organic Matter loss***, the case studies presented from Sweden are related to peat cutting and OM extraction, and not really to OM loss as initially required in this study. The Working Group on Soil Organic Matter stated that data on soil fauna and flora, organic matter and heavy metals are inadequate at the European level and that it is extremely difficult to assess OM content (and therefore OM losses) at anything broader than the local level. Although peat soils only cover a minor part of the total land area (about 2.3%), they are estimated to represent as much as 23% of the total organic carbon stock in soils. This case, OM change, could be considered as a hotspot.

The last detailed case study is related to ***flooding*** in Italy, in relation to a major climatic event that occurred in 2000. Establishing the part that soil played in the flooding is difficult and highly uncertain. The extent, frequency and severity of the damage are closely related to the actual climatic event. Unfortunately, no figures could be found to evaluate financially the different impacts. No statistics were found that would enable placing a cost on the different impacts, and no evaluation of the extent of such threats exists at the European level.

For the cost estimation of each detailed case study, the cost components (on-site private costs of damage – PC, on-site private costs of mitigation and repair – MC, off-site social costs – SC, defensive costs – DC and non-user value costs – NC) have been highlighted (in blue for each overview). As discussed and agreed in Brussels on February 11, 2004, the study did not asses the potential benefits that could be made by a direct approach of the costs that soil users would have to bear if the soil quality decreased (in relation to risks) and the damage costs that could be avoided (i.e., public health threats or degradation of ecosystems).

Due to the fact that for certain threats (e.g., erosion, salinisation and, to some extent, contamination) effects vary from year to year, the impacts of soil degradation have to be evaluated over the short, medium and long term. This was not done in all of the cases studied.

Economic study results are also site specific, which implies certain important limitations, hence the precautionary approach suggested.

The environmental and economic indicators elaborated on the basis of the results of the literature review (Volume I of this report) proposed a direct and logical link between the two types of indicators. For erosion, contamination and salinisation, environmental indicators can be partly developed with the publicly accessible information. Unfortunately, some of the data necessary to establish the environmental indicators are not yet available on synthetic data sources at the European level.

The current work done under the Soil Thematic Strategy will probably lead to proposals of criteria and classes of judgement that could differ from those presented in this report.

Soil quality is commonly seen as all current positive or negative properties (biological, chemical and physical) with regards to soil functions and soil services/potentials/uses (WG Research of the Soil Thematic Strategy). Soil quality is commonly recognized for its ability to perform certain productivity, environmental, and health functions and is closely associated with the notion of resilience, which indicates the ability of a soil to resist adverse changes and to return to its original equilibrium after disturbance. Its assessment is achieved through the identification and measurement of chemical, physical and biological indicators, which are usually connected by simple empirical functions. Soil quality is often seen in relation to the absence or presence of contaminants. However, soil quality is much more significant if we consider salinisation, erosion, organic matter accumulation, sealing, compaction, etc. Therefore, the criteria for defining a good soil status will vary depending on the threats and the uses of the soil.

In some cases, such as the hotspot OM case, the benefits generated by the restoration of the area (wetlands) should be considered. Decisions made concerning the reclamation of the area take into account the environmental or societal desirability of the remediation of the soil quality.

6 Acknowledgements

The authors would like to thank their contacts in the different countries for providing all of the environmental and economic information, and in particular:

1) the Ministries for Environment / Environment Agencies of:

- Belgium: Victor Dries and Griet van Gestel
- Finland: Anna-Maija Pajukallio
- France: Emmanuel Teys (ADEME Nord-Pas de Calais)
- Germany: Andreas Bieber (Ministry of Environment)
- Ireland: Jane Brogan and Margaret Keegan
- Italy: Francesca Quercia and Leonello Serva (APAT)
- Netherlands: Onno van Sannick
- UK: Peter Redfern

2) the following experts:

- in France, Yves le Bissonnais, INRA Ardon, Charles Di Luca, DRIRE Nord-Pas de Calais, Emmanuel Teys, ADEME Nord-Pas de Calais, Bertrand Zuindeau, IFRESI
- in Italy, Luca Guerrieri and Irene Rischia, APAT (Italian Environment Protection Agency), Prof. Guiseppina Crescimanno, University of Palermo
- in Spain, Juan Herrero-Isern, Agri-research Center of the Goverment of Aragon
- in Sweden, Lars Lüdin, Swedish University of Agricultural Sciences, and Hjordis Hofroth, Swedish Geotechnical institute
- in UK, Robert Evans, Anglia Polytechnic University, Mark Kibblewhite, University of Cranfield

and also:

- at the DG Environment, Claudia Olazabal, Benilde Bujarrabal, for the identification of relevant contacts in several countries and the review of earlier versions of this report
- at the European Environment Agency, Ana Rita Gentile, for the updated information on contamination
- at the Food and Agriculture Organisation of the United Nations, Maryse Finka
- some of the Soil Thematic Strategy Working Group members, in particular: Stephen Northcliff (UK), B. James (France), T. Breure (Netherlands), G. Prokop (Austria), for updating information and providing access to other relevant contacts
- Members of the Common Forum

7 Bibliography

Albiac, J., and Martínez, Y. 2004. Agricultural pollution control under Spanish and European environmental policies. Paper presented at the Thirteenth EAERE Conference. Budapest. Hungary.

Arnalds, O. and Barkarson B.H., 2003 – Soil erosion and land use policy in Iceland in relation to sheep grazing and government subsidies. Environmental Sciences & Policy, 6, 105 – 113.

CEC, 1985 - Explanatory text and map sheets of the 1: 1.000.000 soil map of the European Communities. Directorate-General for Agriculture. Office for official publications of the European Communities, Luxembourg, Luxembourg.

Cerdan O., Poesen J., Govers G., Saby N., Le Bissonnais Y., Gobin A., Vacca A., Quinton J., Auerswald K., Klik A., Kwaad F.J.P.M., Roxo M.J. 2003. Sheet and rill erosion rates in Europe. In: Boardman, J., Poesen, J. (eds), Soil erosion in Europe. Wiley, Chichester, U.K. in press.

Cerdan O., Poesen J., Govers G., Saby N., Le Bissonnais Y., Vacca A., Quinton J., Auerswald K., Klik A., Kwaad F.J.P.M., Roxo M.J., 2003 - Sheet and rill erosion rates in Europe. GCTE Soil Erosion Network meeting « Soil Erosion under Climate Change: Rates, Implications, and Feedbacks », Tucson, Arizona, USA. November 17-19, 2003. [Oral presentation]

Cerdan O., Gobin A., Govers G., Kirkby M., Le Bissonnais Y., Vacca A., Quinton J., Klik A., Kwaad F.J.P.M., Roxo M.J., Dikau R., 2003 - Long-term soil erosion plot data to evaluate the PESERA (Pan-European Soil Erosion Risk Assessment) approach. EGS-AGU-EUG Joint Assembly Nice, France, 06 - 11 April 2003. [Poster].

Corine (1992). *Corine soil erosion risk and important land resources in the southern regions of the European Community*, Publication EUR 13233 EN, Luxembourg, 97 pp. + maps.

De Ploey, J., 1989 - *A soil erosion map for western Europe*. Catena Verlag.

EEA, 1995 - Europe’s environment: The Dobris assessment, European Environment Agency, Copenhagen, Denmark. 676 pp.

EEA, 1998. Europe Environment: the Second Assessment. European Environment Agency. Office for Official Publications of the European Communities; Elsevier Science Ltd.

EEA, 1999. Management of Contaminated Sites in Western Europe. Topic Report n°13/99. European Environment Agency, Copenhagen, Denmark.

EEA, 2001. Europe Environment: the Third Assessment. Environmental Assessment Report n°10. European Environment Agency. Office for Official Publications of the European Communities.

EEA, 2002. Second technical workshop on contaminated sites. Workshop proceedings and follow-up Technical report No 76. European Environment Agency

EEA, 2003 – EIONET questionnaire on contaminated sites. To be published in 2004 on the EIONET website.

EEA-UNEP, 2000. Down to earth: Soil degradation and sustainable development in Europe. A challenge for the 21st century. Environmental issues Series No 6. EEA, UNEP, Luxembourg.

England and Wales Environment Agency, 2002 – Agriculture and natural resources : benefits, costs and potential solutions. May 2002, 85 pages.

European Commission, 2002 – Towards a Thematic Strategy for Soil Protection. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, COM(2002) 179 final, 16.4.2002.

Evans, R., 2002 - An alternative way to assess water erosion of cultivated land - field-based measurements: and analysis of some results. Applied Geography 22, 187-208.

Evans R., 1995a - Assessing costs to farmers, both cumulative and in terms of risk management; downstream costs off-farm. In Oram, T. (ed) Soils, Land Use and Sustainable Development. Proceedings Paper No 2 of the East Anglian Sustainable Agriculture and Rural Development Working Group. Norwich: Farmers' Link, p 19-26.

Evans R., 1990 – Soils at risk of accelerated erosion in England and Wales- Soil use and Management, september 1990, vol.6, n°3, p. 131.

FAO, 1994 – Production yearbook 1993. FAO statistics series n°117, Roma: FAO. 295p.

FAO, 1976 – A framework for land evaluation. FAO Soils Bulletin 32. Rome, 66 pp.

Feijóo, M., Calvo, E. y Albiac, J. 2000. Economic and environmental policy analysis of the Flumen-Monegros irrigation system in Huesca, Spain. Geographical Analysis 32: 5-41.

Ferguson C., Darmendrail D., Freier .K, Jensen B.K., Kasamas H., Urzelai A., Vegter J., 1999 – Risk Assessment for Contaminated Sites in Europe, Vol. 2: Policy Framework – LQM Press, Nottingham, 1999.

Gobin A., Govers G., Jones R., Kirkby M., Kosmas C., 2003 - Assessment and report on soil erosion. Background and workshop report Technical report 94. European Environmental Agency, Copenhagen.

Görlach B., Landgrebe-Trinkunaite R. Intervies E., 2004 - Assessing Economic Impacts of Soil Deterioration: A Review of the Literature. Study Contract ENV.B.1 / ETU / 2003 / 0024.

Greenland, D. J. and Szabolcs, I., 1994 - Proceedings of the Soil Resilience and Sustainable Land Use Symposium. Greenland, D. J. and Szabolcs, I. (eds), CAB International, 1994.

Herrero, J. y Snyder, R.L. 1997. Aridity and irrigation in Aragon, Spain. Journal of Arid Environments 35: 535-547.

Irish Enviromental Protection Agency – Towards setting environmental quality objectives for soil: developing a soil protection strategy for Ireland; a discussion paper. 2002, ISBN 1-84095-092-7.

Jankauskas B., Jankauskiene G., 2003 – Erosion-preventive crop rotations for landscape ecological stability in upland regions of Lithuania. Agriculture, Ecosystems and Environment 95, 129-142.

Jones R.J.A., Yli-Halla M., Demetriades A., Leifeld J., Robert M., 2004, The status and distribution of soil organic matter in Europe, European Commission, available on the CIRCA website.

Jones, R.J.A., Hiederer, R., Rusco, E., Loveland, P.J. and Montanarella, L. (2004). The map of organic carbon in topsoils in Europe, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.72 (S.P.I.04.72). European Soil Bureau Research Report No.17.

Le Bissonnais Y. and Daroussin J., 2001 - A pedotransfer rules database to interpret the soil geographical database of Europe for environmental purposes. Proceedings of the workshop on the use of pedotransfer in soil hydrology research in Europe, Orléans, France, 10–12 October 1996.

Le Bissonnais Y., Cerdan O., Léonard J. 2003. Pan-European soil erodibility assessment. In: Boardman, J., Poesen, J. (eds), Soil erosion in Europe. Wiley, Chichester, U.K. in press.

Le Bissonnais Y, Bruno J-F, Cerdan O, Couturier A, Elyakime B, Fox D, Lebrun P, Martin P, Morschel J, Papy F, Souchère V. 2003. Maîtrise de l'érosion hydrique des sols cultivés : phénomènes physiques et dispositifs d'action. Programme GESSOL, rapport final, Mars 2003.

Ludin L., Lode E. 2004 – Wetland after peat cutting: impacts on water chemistry. Personal communication.

Montanarella L., Jones R.J.A., Heiderer R., 2004 - Distribution of peat and peaty topped soils in Europe. Submitted to International Peat Journal, June 2004.

NL Ministry for Housing, Spatial Planning and Environment – Urban brownfields.

Nogués J., Herrero J., Rodriguez-Ochoa R., Boixadera J. 2000 – Land evaluation in a salt-affected irrigated district using an Index of Productive Potential. Environmental Management, 2000, vol. 25, n°2, p. 143-152.

Oldeman L. R., Hakkeling R. T. A. and Sombroek W. G., 1991 - Glasod world map of the status of human-induced soil degradation (second revised edition), ISRIC, Wageningen, UNEP, Nairobi.

Rijnaarts H., Hoogeveen N., Ter Meer J., Bien J., Wallace S. (2003). *Risk Based Management approaches for contaminated Megasites*, NICOLE Workshop, Lille, October 2003.

Riksen M.J.M., De Graaff J., 2001 – On-site and off-site effects of wind erosion on European Light soils, Land degradation & development, 12, 1-11.

Van Lynden G. W. J., 1995 - European soil resources, Nature and Environment, No 71. Council of Europe, Strasbourg.

Van Lynden G.W., 2000 - Soil degradation in Central and Eastern Europe: The assessment of the status of human-induced soil degradation. FAO-ISRIC, Rome.

Van der Knijff, J. M., Jones, R. J. A. and Montanarella, L. (1999). *Soil erosion risk assessment in Italy,* EUR 19044 EN, 52 pp.

Van der Knijff, J. M., Jones, R. J. A. and Montanarella, L. (2000). *Soil erosion risk assessment in Europe*, EUR 19044 EN, 34 pp.

Veile A., Hasholt B., Schiotz I.G., 2003. Soil Erosion in Denmark: processes and politics. Enviromental Science & Policy, 6, 37 – 50.

Wischmeier W. H. and Smith D. D., 1978 - Predicting rainfall erosion losses — A guide for conservation planning, Agriculture Handbook 537, US Department of Agriculture.

Yassoglou N., Montanarella L., Govers G., Van Lynden G., Jones R. J. A., Zdruli P., Kirkby M., Giordano A., Le Bissonnais Y., Daroussin J. and King D., 1998 - Soil erosion in Europe. European Soil Bureau.

8 APPENDICES

8.1 APPENDIX 1: INFORMATION SHEETS FOR POSSIBLE CASE STUDIES

8.1.1 Case Study / Belgium Contamination

8.1.1.1 Name

Kempen, Belgium-Netherlands border

Contamination Case study

8.1.1.2 Contact co-ordinates

Wendy Van Dijck (wvdijck@ovam.be)

Raf Engels (raf.engels@ovam.be)

Griet van Gestel (griet.van.gestel@ovam.be)

Eric Kessels (Ekessels@abdk.nl)

8.1.1.3 Information

8.1.1.3.1 General

Name: Kempen, Belgium-Netherlands border

Location (lat long; map)

Size of the area: 700 km²

Type of threats DPSIR: Contamination/ local pollution affecting a large area

Main actors involved: all possible at local (municipality, industry,…), regional (province of Antwerp and Limburg (FL), Province of Brabant and Limburg (Nl), regional authorities in charge of Human Health, Industry and Environment,….), international (Ministers of Environment Flanders and Nederlands,…)

8.1.1.3.2 Environmental criteria

Pre-dominant use(s) of area, population density: agriculture, dispersed habitat (340 inhabitants per km²)

Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall): flat, cold to moderate climate with mild, moist winters, 750 mm/year

Conservation measures (typology, efficiency):

1) restriction of use (information of the populations on the behaviours to be avoided)
2) pilot projects for phytoremediation and immobilisation

Comprehensive description of damages (level of impacts – local, regional, national, time scale):

- contamination impact on soils and on groundwater: soil (Flanders): 280 km² above soil background values, 75 km² above soil standard values (cadmium >3 ppm), 31 km² where cadmium concentration is above 6 ppm and 10 km² above 12 ppm. Several industrial and residential areas are situated in these areas. There are also a huge number of parcels of agricultural land and private gardens.
- For groundwater contamination it can be assumed that at least the same areas are contaminated. Rivers, streams,…have a poor bottom quality in this area.
- Consequences on human health in the population: The maximum permitted load from WHO for Cd is 400-500 µg/person/week. The weekly Cd load in the contaminated area can easily exceed this maximum. Even when the people follow the use restrictions the threshold value of the WHO guideline is easily reached. The EU average of 300 mg is always exceeded. Studies state that the Cd load of the human body of people living in the contaminated area is 30% higher than people of

who are living in reference areas. This can lead to kidney problems, problems with the Cd metabolism and osteoporosis.

Description of event generating the threats:

1) atmospheric emission from the industrial Zn production since the second half of the nineteenth century. Cd, Zn and Pb were spread in huge amounts to the environment.

2) Use of slags for paving roads and drives

Vulnerability of area: medium for the groundwater resources in the area (secondary contamination). Important for soils.

8.1.1.3.3 Economics

Costs of preventive measures:

Immobilisation of contamination in the schoolyard with Berengiet,…

Costs of suffered damages:

Impact of the contamination on the real estate values in proximity,…(-10% as an average).

Costs of monitoring:

Medical follow-up of the population (Cadmibel, Pheecad = finished projects)

Survey of the agriculture productions (kidney and muscles of the animals (meat) = project is still going on, vegetables = finished project, …).

Costs of remediation / clean up, etc (protective measures):

Detailed risk assessment on the site (impact on groundwater and human health)

Detailed risk assessment in the surroundings of the site.

Methodology for costs estimation, «non-used values», link between soil impact and economic uses?

Sources of information: see references.

Who bears the costs (affected sectors)

Industry co-operates with the relevant authorities for the prevention, recovery of suffered damages, monitoring and reclamation, off-site costs. Industry also co-finances investigations on contaminated land management options.

In other cases the owner, e.g. the Zn industry covers the costs, for the investigations on their sites

8.1.1.3.4 References / Bibliography

Lauwerys R., Amery A., Bernard A. Et al (1990) Health effects of environmental exposure to cadmium: objectives, design, and organisation of the Cadmibel Study: a cross-sectional morbidity in workers exposed to cadmium, Environ Health Perspect.

Draye A., Thewys T. Et Al. (2000) Economic benefits of soil remediation, Department Economy and Law, LUC.

8.1.2 Case Study / Finland Contamination

8.1.2.1 Name

Arabianranta (Arabia waterfront) -project, Helsinki

8.1.2.2 Contact coordinates

Heikki Somervuo, City Council of Helsinki

Eija Kivilaakso, City Planning Department of Helsinki

Anni Bäckman, City of Helsinki, Real Estate Department

Antti Salla, Environment Centre of Helsinki City

Anna-Maija Pajukallio, the Ministry of Environment

8.1.2.3 Information

8.1.2.3.1 General

Name: Arabia waterfront

Location (lat long, map): city of Helsinki, Arabianranta (Arabia waterfront), residential development area near the city centre (about 5 km).

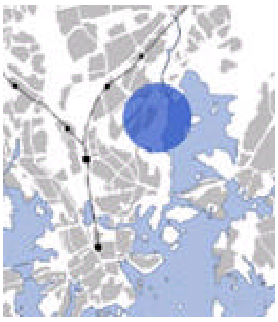


Figure 15. Location of Arabianranta

Size of the area: The size of the total project area is about 85 ha. The area where remediation actions have to be considered is about 55 ha.
Arabianranta is going to be one of the most important new residential areas of Helsinki. Arabiaranta's construction project started in the year 2000 and the whole area is estimated to be ready by 2010. Geotechnical matters and contaminated soil issues have made this project especially demanding.

Type of threats DPSIR: contamination. Point source.

Main actors involved: The city of Helsinki is the main landowner of the Arabianranta project area. The project was there fore adopted by the City Council of Helsinki in order to develop Arabianranta within a few years as a residential neighbourhood, by co-ordinating the area's planning and building. The inner co-operative organisations are the city leadership and almost all the city offices and institutes, particularly Helsinki City Office, City Planning Department and Public Works Department. Other notable collaborators are residents, future residents, developers with lot reservations, contractors, planners, different governing agencies and media. Arabianranta project also works closely together with Art and Design City Oy, University of Art and Design and some private companies and with community organisations in the area.

8.1.2.3.2 Environmental criteria

Pre-dominant use(s) of area, population density: industrial area with ceramic factory, stockholding businesses, timber yard, transport companies etc. The contamination is however mainly related to the dumping of heterogeneous soil material when the area was reclaimed from the sea by filling.

Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall): flat area at the seashore (land reclaimed some decades ago from the sea), Nordic climate

Conservation measures (typology, efficiency): Part of the project-area is relict area (idle land), part has still industrial land use. Remediation is required before land use is changed. Remediation of the area has partly been already finished; partly it is still under planning. Some of the residential houses have already been built.

Comprehensive description of damages (level of impacts – local, regional, national, time scale), [cf. list of pre-selected indicators]: contamination by heavy metals (mainly Zn and Pb), PAHs and mineral oils. No contamination of the groundwater resources (groundwater is under a clay layer which has prevented the contamination).

Description of event generating the threats: see above

Vulnerability of area: high due to the new residential land-use

8.1.2.3.3 Economics

Costs of preventive measures: -

Costs of suffered damages: -

Costs of monitoring: - (mainly only basic surveys)

Costs of remediation / clean up, etc (protective measures):

Overall cost of the redevelopment project (investments) is about 120 M€.

The overall cost of remediation and pre-construction of the area is estimated to be about 42 M€. It's somewhat difficult to estimate the portion of remediation, because remediation and pre-construction actions are closely linked and there are some overlaps, but it is estimated to be about 20 – 30 %.

Remediation was and will be based on site-specific risk analysis:

- Soil contaminated with organic compounds has been/will be excavated.
- Soil contaminated with heavy metals is /will be mainly covered with 0,5 - 1 m layer of clean soil or it is isolated with concrete slap. Some hot spot areas are excavated. Concrete slap is not used because of the contamination but because of the geotechnical reasons, but it serves also as an isolation method.

Costs for purchasing the site at the end of the activity: the City of Helsinki is going partly to rent and partly to sell the remediated and geotechnically pre-constructed areas.

Estimated income for the city for renting the real estates is going to be about 3,5 M€ / year (16 €/gross floor m^2/year for residential buildings) end for selling the real estates about 25 M€ (550 - 1000 €/gross floor m^2)

Methodology for costs estimation, «non used values», link between soil impact and economic uses: A special study about economic assessment (including also the remediation costs) of the Arabianranta was made by the Technical Research Centre of Finland.

Sources of information:

Who bears the costs (affected sectors):

The city of Helsinki will pay most of the redevelopment costs including soil remediation. The sum collected form the former polluters will be in this case minor.

The future gross floor area is almost 500,000 m^2 including housing and business buildings. The number of inhabitants is going to be about 7,000.

Figure 16. Future Arabianranta

8.1.2.3.4 References / Bibliography

Many reports produced by the city of Helsinki, published only in Finnish. Further information can be gathered from above-mentioned contacts.

8.1.3 Case Study / Finland Contamination

8.1.3.1 Name

Old petrol station – Juankoski – County of Eastern Finland - Finland

8.1.3.2 Contact co-ordinates

SOILI-programme / Kati Valkama, Oil industry service centre and Merja Huhtala, Oil Pollution Fund

8.1.3.3 Information

8.1.3.3.1 General

Name: Old petrol station – Juankoski – County of Eastern Finland - Finland

Location (lat long; map): x = 6 996 680, y = 3 567 500, address is Juankoskentie 14; The town of Juankoski is situated 450 km northeast from Helsinki

Size of the area: 5000 m^2

Type of threats (DPSIR): contamination

Main actors involved:

SOILI-programme / Kati Valkama, Oil industry service centre and Merja Huhtala, Oil Pollution Fund

North Savo Regional Environment Centre, Lea Koponen

Town of Juankoski, Hemmo Kauppinen

8.1.3.3.2 Environmental criteria

Pre-dominant use(s) of area, population density: There was a petrol station from 1970's to 1990's and a shop. The petrol station had three underground storage tanks and one above the ground. Also there was a place for washing cars and a service pit (I'm not sure what is a correct translation, I mean a hole / excavation in the ground and you can drive your car above it and repair it). As far as is known, there have been no oil accidents in the area of this real estate.

Currently the area is a parking place and there is also a collecting place for different kinds of re-usable wastes. The area is in the middle of a densely populated area of Juankoski. Juankoski is a town of nearly 6,000 inhabitants. The total area of Juankoski is 580 km^2, of which 120 km^2 is covered by the waterways. In the town of Juankoski there are three densely populated areas: Juankoski, Muuruvesi and Säyneinen.

Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall): flat, soil type is sand, inland, Nordic conditions.

Conservation measures (typology, efficiency): -

Comprehensive description of damages (level of impacts – local, regional, national, time scale):

Soils were excavated in the area of 308 m^2 and total amount of soils was 810 m^3, it was calculated that the excavated soils contained around 700 kg petroleum hydrocarbons, mainly diesel and lubricating oil, highest concentration that was measured during the remediation was 5600 mg/ kg,

1) Consequences on human health in the population: -

2) Consequences on workers human health / Number marked inaptitutes with work -

Description of event generating the threats: soil was contaminated during the operation of the petrol station

Vulnerability of area: The real estate is situated in middle of densely populated area, the nearest house is only 20 m away from the border line of the real estate, soil type is sand, 150 m East from the estate is small pond, no groundwater was found in the depth of 6,5 meters (ground water monitoring well)

8.1.3.3.3 Economics

Costs of preventive measures: -

Costs of suffered damages: -

Costs of monitoring: -

Costs of remediation / clean up, etc (protective measures): total amount of remediation cost is 53,680 € (44,000 € + value-added tax 22%). This amount doesn't contain administrative costs. There has been sometimes used a calculated estimate that is 8% of the total amount of remediation costs.

Methodology for costs estimation, «non-used values», link between soil impact and economic uses: -

Sources of information: -

Who bears the costs (affected sectors): Oil Pollution Fund pays all the costs.

SOILI-programme is a remediation programme that aims to remediate soil and groundwater in the estates of the former petrol stations.

The programme takes care of the whole remediation project. The programme is constituted on the agreement that is made between Oil Industry Service Centre, oil companies, Ministry of the Environment and Association of Finnish Local and Regional Authorities. Period for applying in to the programme continues until the end of year 2005. This programme remediates two kinds of sites:

- The real estates that belong to the companies that are involved in SOILI-programme. The action has ended or will end within a year after the estate has been accepted in the programme.
- Ownerless estates are those where it is not possible to say who is the polluter or otherwise liable to remediate the site or if the liable one is unable to pay the remediation or the remediation cost are unjust / unfair to present owner. Ownerless estate remediation is paid by the Oil Pollution Fund. This fund is taken care be the Ministry of the Environment and it is not included in the state budget. The funds are gathered by collecting a fee / charge from all the oil transportation that are imported or transported trough Finland. The fee is 0.60 € per ton of oil.

So far SOILI-programme has received 498 remediation applications and 233 of them are ownerless sites. Remediation measures have been completed on around 200 sites.

8.1.3.3.4 References / Bibliography

Many reports produced by the city of Helsinki, published only in Finnish. If you like to have more information, please make contact to above-mentioned persons.

8.1.4 Case Study / Central Italy Flooding

8.1.4.1 Name

Elba Island, September 2002 Flood

8.1.4.2 Contact co-ordinates

Irene RISCHIA, APAT

e-mail: rischia@apat.it

8.1.4.3 Information

8.1.4.3.1 General

Location (lat long; map)

UTM 32: X between 590,200 and 617,770; Y: between 4,730,000 and 4,750,000

Co-ordinates are projected in the UTM system.

Size of the area: about 265 km^2

Type of threats DPSIR

Driving Forces and Pressures:

Intense rainfall, intense linear erosion, high value of rivers discharges, increased urbanisation and high density of tourist structures in high-risk areas

State: floods, landslides (blocks flow, slides, soil slip), intense linear erosion, soil erosion

Impacts: destruction of buildings, infrastructures, and agricultural areas;

Responses: Emergency measures aimed at a first aid affected population and a fast reconstruction of primary infrastructures; Planning measures to prevent future catastrophic events.

Main actors involved:

Civil Protection Department of Italy; Regional Authorities of Tuscany; Firemen; Local Authorities (Municipalities); Comunità Montana dell'Isola d'Elba (Elba Island authority for the management of mountain/forest areas and environmental resources); Italian Agency for the Environmental Protection and Technical Services and Regional Environmental Agencies

8.1.4.3.2 Environmental criteria

Pre-dominant use(s) of area:

Tourist structures and buildings, agriculture, breeding, forests, urban areas

Population density: 111 per km^2

This value is the average population density over the Communes affected by the flood

Geographical/Topographical Slope aspect:

A large part of the island is a hilly area, excepted Capanne mountain (1,019 m). Generally, morphology is characterised by alternation of low slope areas and rough mountain ridges increases of slopes and deep and narrow valleys. In correspondence of the two main river basins, Fosso della Madonnina and Fosso della Galea-Pila, there are flat areas. Along the cost subvertical cliff and sandy shores are alternated.

Orientation: River drainage networks has not a specific orientation

Soil category:

All soils are typical of humid Mediterranean climates. In particular, there is a large amount of granular and silty debris on the lithic substratum.

Climate: Mediterranean humid

Average rainfall:

Average annual rainfall is about 1,000 mm/year. Rainfall that triggered the flooding event is about 215-230 mm (over 20 mm/hour)

Conservation measures (typology, efficiency):

Structural measures (engineering works): rather dams along some main rivers.

Comprehensive description of damages (level of impacts – local, regional, national, time scale):

High impact on tourist structure and main roads that have been destroyed. A large part of the stream rivers overflowed. The level of impact is regional.

Description of event generating the threats:

On 4th and 10th September 2002 intense rainfall hit the northwestern Tyrrenian Basin, and in particular the Elba Island (up to 200 mm in 10 hours). As a result, in the mountainous and hilly areas gravitational phenomena occurred (debris flows, mud flows, translational slide, soils slips), related to increase of linear erosion along the stream rivers. In the alluvial plains the major rivers overflowed and inundated wide areas where tourist buildings (camping, hotel, etc.) and beaches are located.

Vulnerability of area:

Vulnerability of the area is mainly related to the presence of a great number of tourist structures and buildings, especially along the coast. High vulnerability is also related to the roads and to the agricultural and pastoral activities.

8.1.4.3.3 Economics

Costs of preventive measures:

After the alluvial flood of September 2002, the Ministry for the Environment, on the basis of laws 183/89 and 198/98, financed structural works in order to realise preventive measures and ordinary maintenance at the scale of the river basins of the Elba Island. In particular, works regard hydraulic and forest works, adaptation of hydraulic sections of the rivers and stabilisation of riversides. These works will be realised in the localities of Rio dell'Elba, Marciana, Porto Azzurro and Porto Ferraio for a total amount of 14.3 M€.

Costs of suffered damages:

Following the alluvial flood of September 2002, the Ministry for the Environment emanated the decrees DEC/DT/2002/0242 and D.M. 23/12/2002, in order to support costs for reconstruction works: for a total amount of over 10 M€. These works consist of hydraulic and forestall engineering structure adaptation of hydraulic sections of rivers and stabilisation of riversides and slides and interested a large part of the localities and of the territory of the island.

Costs of monitoring: Not available data

Costs of remediation/clean up, etc (protective measures): Not available data in detail. This is an institutional task of Civil Protection Department of Italy

Methodology for costs estimation, «non used values», link between soil impact and economic uses: Not available data

Sources of information:

Department of Soil Defence, Ministry for the Environment and Territory, Department of Civil Protection

Who bears the costs (affected sectors):

- Emergency measures: Civil Protection Department of Italy, under Emergency Government Provision, supplies Regions with needed funds.
- Preventive measures: Civil Protection Department of Italy, under specific Dispositions; Ministry for the Environment and Territory, which co-ordinates the planning for the reduction of flood phenomena in agreement with River Basin Authorities and supports specific programs for structural works.

8.1.4.3.4 References / Bibliography

Le attività emergenziali APAT in seguito ad eventi alluvionali e sismici, rapporti APAT 35/2003

8.1.5 Case Study / Italy Salinisation

8.1.5.1 Name

Delia Nivolelli Salinisation Case

8.1.5.2 Contact coordinates

Prof. Dr. Giuseppina Crescimanno

Università di Palermo

Dipartimento ITAF-Sezione Idraulica

Viale delle Scienze 13- 90128 Palermo, Italy

e-mail: gcrescim@unipa.it

8.1.5.3 Information

8.1.5.3.1 General

Name : Delia Nivolelli Irrigated Area in Delia-Nivolelli Catchment

Location (lat long; map): Mazara del Vallo (Sicily) about 37° 40' 00'' N – 12° 40' 00'' E

Size of the area: about 6000 ha (60 Km^2)

Type of threats DPSIR**:** Soil salinisation due to irrigation with saline waters

Main actors involved**:** farmers, association of farmers; Consorzio irriguo Trapani 1

8.1.5.3.2 Environmental criteria

Pre-dominant use(s) of area, population density: Agriculture, resident population: less than 15 persons per km^2, working people: more than 100 persons per km^2

Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall): average slope: less than 10%; hilly; soil (USDA 1999): Lithic Xerothens, Typic Chromoxerert, Vertic Xerichrept, Vertic Xerofluvent; climate: xeric-Mediterranean: average rainfall: less than 600 mm/year

Conservation measures (typology, efficiency): No conservation or remediation measures are adopted

Comprehensive description of damages (level of impacts – local, regional, national, time scale):

Reduction in crop yields with considerable economic lost and social impact on local communities.

Description of event generating the threats: geological characteristics of soil, high salinity of irrigation water, mismanagement of irrigation and lack of drainage systems in clay soils

Vulnerability of area: high (during three-year monitoring desertification of some lands and abandonment of many cultivated fields was observed in the study area)

8.1.5.3.3 Economics

Costs of preventive measures: proper irrigation systems and drainage systems: 6,000 €/ha;

Costs of suffered damages: reduction of crop production ranging between 10% and 30%

Costs of monitoring: 75 €/ha*year

Costs of remediation / clean up, etc (protective measures): drainage systems and strategies for salt-leaching: 4,500 €/ha

Methodology for costs estimation, «non used values», link between soil impact and economic uses?

Sources of information?

Who bears the costs (affected sectors):

The farmers should bear the costs, sometimes with subsidies from Assessorato Agricoltura e Foreste (Regione Siciliana)

8.1.5.3.4 References / Bibliography

Crescimanno, G. - An integrated approach for sustainable management of irrigated lands susceptible to degradation/desertification. Final Report ENV7-CT97-0681. April 2001.

8.1.6 Case Study / Netherlands Contamination

8.1.6.1 Name

Ceramique Maastricht

8.1.6.2 Contact co-ordinates

Onno Von Sannick, NL Ministry for Housing, Spatial Planning and Environment

J. Notten, Project Bureau at the Maastricht Municipality

8.1.6.3 Information

8.1.6.3.1 General

Name: Ceramique Maastricht

Location (lat long; map): city of Maastricht, at the edge of the downtown Maastricht (between the historic quarter of Wyck and the new Randwyck commercial centre).

Size of the area: 23 ha

Type of threats DPSIR: contamination

Main actors involved: NL Ministry for Housing, Spatial Planning and Environment, Municipality, Province of South Lindburg, Ministry for Interior.

8.1.6.3.2 Environmental criteria

Pre-dominant use(s) of area, population density: Urban area,

Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall): flat area.

Conservation measures (typology, efficiency): /

Comprehensive description of damages (level of impacts – local, regional, national, time scale), [cf. list of pre-selected indicators]: contamination by heavy metals bounded to the glazing of the fragments of ceramic mixed to soil (constituting the surface of the Ceramique Site). No contamination of the groundwater resources (not leaching of the heavy metals from the ceramic fragments).

Description of event generating the threats: mixture of ceramic fragments and soil. Industrial activity since the middle of the last century, up to 1990.

Vulnerability of area: high due to the urban planning projects in the area.

8.1.6.3.3 Economics

Costs of preventive measures:

Costs of suffered damages:

Costs of monitoring:

After care plan still needs to be detailed?

Costs of remediation / clean up, etc (protective measures):

Overall cost of the redevelopment project: 900 MNLG = 408.4 M€.

Costs for purchasing the site at the end of the activity:

Costs for clean-up using a function-oriented approach: 6.8 M€

- presence of a buffer layer between the contaminated soil and human activity – 1,40 m in depth laid on public spaces:
- remediation of soil to an acceptable level which safeguards public health for the soil under buildings and car parks.

Methodology for costs estimation, «non used values», link between soil impact and economic uses:

Sources of information: See references.

Existence of Government grants for urban regeneration:

- BELSTATO urban renewal fund = approximately 363 M€ per year available over the period 1990 – 2005
- Intrafonds of the Ministry of Transport, Public Works and Water Management, and the VINEX covenants = approximately 408.4 M€ budgeted for 1995 – 2005 for contaminated land.
- Soil Protection Act including provisions relating to the costs of the cleaning up contaminated land, around 227 M€ / year.

Who bears the costs (affected sectors):

Public (grants, landfilling support, construction of buildings) and private in relation with the project of redevelopment of the site including:

- 1,600 homes,
- 70,000 m^2 (gross floor area) office and other establishments,
- 20,000 m^2 hotel accommodation,
- 20,000 m^2 for cultural and other non-commercial purposes,
- 5,000 m^2 for catering and retail,
- 4,400 parking spaces (the majority underground/covered),
- supra-local facilities, such as a bridge over the river Maas for pedestrians and cyclists, a market hall and various traffic access schemes.

Using the ABP pension fund, in consultation with the municipality of Maastricht, with three property developers.

A public-private-partnership (PPP), sharing financial risks associated with the project, has been set. Its main features are as follows:

- acquisition of the necessary land and premises,
- agreements relating to the legal aspects of the project,
- establishment of the financial framework for the exploitation of the site,
- laying the necessary building site infrastructure,
- execution of the construction work,
- agreements on the apportionment of risks and responsibilities.

Distribution of funding:

- Central government: 9 M€ for subsiding large-scale construction projects,
- Province: 6.8 M€ for restructuring / redevelopment,
- Ministry of the Interior: 5 M€ in the framework of the 1994 employment initiative.
- Municipality of Maastricht: 9.4 M€ + 22.7 M€ for the construction of the library and municipal buildings.

8.1.6.3.4 References / Bibliography

NL Ministry for Housing, Spatial Planning and Environment – Department for Urban brownfields;

8.1.7 Case Study / Sweden Landslides

8.1.7.1 Name

Landslide in Vagnhärad, Sweden

8.1.7.2 Contact

Hjördis Löfroth

Swedish Geotechnical Institute

SE-581 93 Linköping, Sweden

Phone: +46 13 20 18 00

E-mail: hjordis.lofroth@swedgeo.se

8.1.7.3 Information

8.1.7.3.1 General

Name*:* Landslide in soft clay at Vagnhärad, Sweden.

Location: In the community of Vagnhärad (Trosa), province of Sörmland, about 70 km southwest of Stockholm.

Size of the area*:* The slide covered a 200 m stretch along the river and reached 60 m up the bank.

Type of threats DPSIR*:* Landslide. The need for development of new residential areas led to use of land not fully suitable for this purpose. After the slide, 29 properties in the risk zone were demolished, the slide area was reinforced and to four of the properties in the risk zone families could return.

Main actors involved*:* The community of Trosa (incl. Vagnhärad), The Fire and Rescue Services Agency, The Swedish Geotechnical Institute, and others as insurance companies, consulting companies, construction companies etc.

8.1.7.3.2 Environmental criteria

Pre-dominant use(s) of area, population density, Geographical/Topographical (slope aspect, curvature, orientation; soil category, climate, average rainfall), Conservation measures (typology, efficiency), Comprehensive description of damages (level of impacts – local, regional, national, time scale), [cf. list of pre-selected indicators], Description of event generating the threats, Vulnerability of area. See description below:

The residential area of Vagnhärad known as Ödesby was developed in the mid-70s. The plan for building for Ödesby, recommended that the area should be built by one-family houses. In the plan for building it was suggested that the area should be built with 45 one-family houses and that the houses should only be built as one-storey houses.

During the night of 22/23 May 1997, a landslide occurred in this area. The landslide was the largest in a populated area in Sweden since the mid-70s. The landslide took place in a clay slope and covered a 200 m stretch along the river and reached 60 m up the bank. It displaced the course of the river by 15 m, raised the ground surface at the original position of the river by two metres and lowered the surface along the upper edge of the slide by five metres. The slide followed a smaller movement within a limited area along the river. No one was severely injured, but three houses were destroyed and several others damaged or undermined. A total of 33 properties were judged to be in the risk zone for further slides and the railway on the other side of the Trosa river was temporarily closed. Nearly 100 persons were evacuated after the slide.

The slide area consisted of a long slope with soft clay leading down to the river. The total difference in height between the top of the slope and the ground surface at the toe of the slope was approximately 15 m. The depth of the river increased the difference by a further two metres. Within the populated part of the area, the natural ground surface prior to development had had an inclination of 1:12. On the steepest sections between the houses on the road closest to the river and the river, the inclination was, however, 1:5. The thickness of the clay varied from about 1 m in the upper part of the slope to 10-14 m on the lowest parts. The clay lay on top of a layer of friction soil. Higher areas of rock and sandy gravel in the surroundings act as infiltration zones, i.e. areas where rainwater can penetrate beneath the clay. In the slide area and adjacent areas, the clay formed an impervious lid over the friction soil.

The period before the slide, there was unusually heavy rain for the season. A comparison with a normal year show that the accumulated precipitation during the period 1st January to 31st May 1997 was 180 mm compared to 159 mm a normal year. Measurements indicate that the water pressure in the lower parts of the slope was artesian. The groundwater levels were also higher than normal for the particular period. The pressure level in the friction soil was about two metres above the ground surface by the river.

A study (Andersson et al., 1998) concludes that the main cause of the slide was that the slope was so stressed that even very small changes in the conditions could result in a slide. The factors that triggered the slide at just that point in time may have been:

- Heavy rain for the season, which increased pore pressures
- Erosion and small, local slides along the river
- Large and repeated ground movements, which reduced strength
- Low water level in the river over a period of time
- Increased pore pressures due to heavy rain in combination with water leakage

The most probable cause is a combination of two or more factors.

8.1.7.3.3 Economics

<u>Costs of preventive measures. Costs of suffered damages. Costs of monitoring. Costs of remediation / clean up, etc (protective measures). Methodology for costs estimation, «non used values», link between soil impact and economic uses.</u>

It has not been possible to receive the costs for the whole landslide incident exactly in the way presented above. The presentation is made the way the information has been obtained.

- Costs during the ”Rescue service phase”: 3.3 MSEK (approximately 0.36 M€).
- Costs of remediation / clean up, etc (protective measures): 26.0 MSEK (approx. 2.83 M€).
- Costs of redemption of properties: About 46.8 MSEK for a total of 29 properties (approx. 5.08 M€)
- Sources of information: The Community of Trosa (incl. Vagnhärad), The Swedish Rescue Services Agency, Trygg Hansa (Insurance Company)
- Who bears the costs (affected sectors): The Swedish Rescue Services Agency, The Community of Trosa (incl. Vagnhärad) and Insurance companies.

8.1.7.3.4 References / Bibliography

Andersson H, Bengtsson P-E, Berglund C, Larsson R, Sällfors G and Öberg-Högsta A-L (1998). The landslide at Vagnhärad. (Skredet i Vagnhärad, Teknisk/vetenskaplig utredning om skredets orsaker) Report No. 56, Swedish Geotechnical Institute, Linköping, Sweden (125 p) (in Swedish).

Andersson, H, Bengtsson, PE, Berglund, C, Larsson, R, Sällfors, G, Öberg-Högsta, AL (2000). Landslide at Vagnhärad in Sweden, International symposium on landslides, 8, Cardiff, Proceedings, vol. 1 (6 p).

Löfroth, H and Kjellberg, U. (2003). The May 1997 landslide in soft clay at Vagnhärad, Sweden. NEDIES Project - Lessons Learnt from Landslide Disasters in Europe. Report € 20558 EN. Ispra, Italy. (8 p)

Swedish Rescue Services Agency. (1998). Large accidents – The Landslide at Vagnhärad 23 May 1997, observation report (Stora olyckor – Skredet i Vagnhärad 23 maj 1997). Karlstad, Sweden (31 p) (in Swedish).

8.1.8 Case Study / Northern Italy Flooding

This case study deals with the flooding of large areas of northern Italy in October 2000.

8.1.8.1 Case study description - local conditions

In October 2000, a serious climatic event hit the northwestern part of Italy. Numerous landslides from the Alps generated floods in the valleys, in particular in the sector bounded by the Ticino River, the first part of the Po River and the whole of the Valle d'Aosta (basins of Toce, Sesia, Orco, Stura di Lanzo, Dora Baltea, Dora Riparia and Pellice).

The rainfall event that triggered the flood was of the order of 400 - 700 mm in 80 hours (average annual rainfall range between 1,000 mm/year in the lower areas and 1,600 mm/year in the mountainous areas). This was coupled with an increase in temperature leading to substantial snow melting.

The effects on this area, used essentially for human activities, have been totally devastating, recalling the necessity of reviewing the relationship between human activities and its environment, in particular the urban area management plans and emergency intervention plans.

In Italy, this type of event is well known. The country has regularly faced events of similar magnitude:

- in 1994 in Piemonte,
- in 1996 in Versilia,
- in 1998 in Sarno,
- in 1999 in Cervinara and Calabria.

8.1.8.2 Soils

The October 2000 flood affected a huge area of northern Italy (see Figure 8) that is characterised by a wide variety of geological and geomorphologic types and, as a consequence, by a great number of different soil types.

In order to describe roughly the main types of soil affected by the flood it is necessary to distinguish two major environments:

- **Alluvial plains of the Po River and tributaries** (primarily in Piemonte, Lombardia): flat areas widely inundated, with peak discharges lasting for a number of days, but relatively slow rising water levels. Topsoils, generally very young (Entisoils), are developed on unconsolidated gravels, sands, silts and clays in fluvial and subordinately lacustrine facies. On the contrary, more developed soils (for example Cambic soils) located on terraced surfaces have not been affected by the flood.
- **Upstream sectors of the Po River and tributary drainage networks** (primarily in Valle d'Aosta and Piemonte, locally in Liguria and Lombardia): in this mountainous environment, characterised by narrow valleys and steep slopes, numerous landslides were reactivated and new gravitational phenomena occurred. Landslides occurred along steep slopes in the surface weathered portion of metamorphic bedrock, breccias and conglomerates in morenic and colluvial facies. Along lateral stream networks this unstable material has been in part remobilised by debris flows and mud flows, which became mixed with unconsolidated gravely and fine-grained fluvial sediments. These phenomena have killed 26 people due to their extreme rapidity, which limits the efficiency of warning procedures and emergency actions. It is important to outline the presence of ancient deposits relating to previous debris flows (alluvial fans), demonstrating the repeated occurrence of these events in this area in the past.

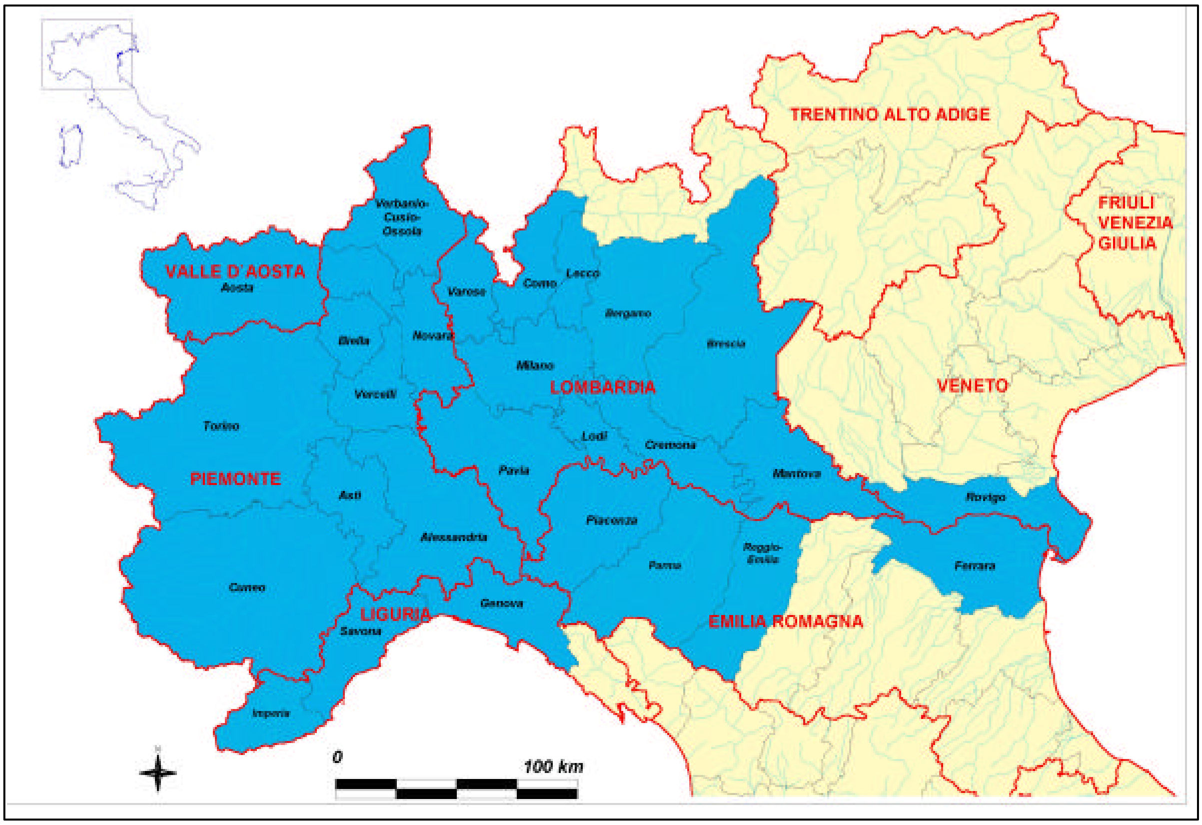


Figure 17. The Italian provinces, including the areas affected by flooding (source: Mattinali di Protezione Civile, 23.10.2000)

8.1.8.3 Extent of the threat

In the period 13-16 October 2000, intense rainfall hit the northwestern part of Italy, and in particular the sector bound by the Ticino River, the first part of the Po River and the whole of the Valle d'Aosta region (up to 600 mm in 80 hours). In the mountainous and hilly areas, gravitational processes occurred (debris flows, mud flows, rock falls, soil slips). In the alluvial plains, the major rivers overflowed and flooded extensive areas.

The observed threats were mainly:

- flooding,
- landslides,
- excessive and rapid mud flow, containing variably coarse blocks,
- solifluction,
- heavy erosion of the soils.

Buildings and infrastructures (mainly bridges of railways and highways) located in the flooded areas were totally destroyed. Agricultural, industrial and tourist activities suffered huge damages. In all, 26 deaths were recorded for the October 2000 event.

The problems encountered during management of the crisis were mainly due to the intensity of the climatic conditions and to the breakdown of communication networks, leading to difficulties in organising and reaching the affected areas.

The main impacts were:

- loss of human life (26 casualties);

- damage to buildings and infrastructures (bridges, railways, roads), some being totally destroyed;
- loss of soil and yield for the agricultural sector;
- loss of industrial production;
- reduced tourist activity;

8.1.8.4 Conservation measures

There are two types of conservation measures:

- ***Structural measures*** (engineering works): dams, reservoir and retarding basins, channel and catchment modifications, levee-banks, flood proofing. Where these measures are widely applied, the impact of flooding can be significantly reduced. However, structural measures can be very costly and have a significant impact on the environment.
- ***Non-structural measures*** are any procedure altering the exposure of lives and properties to flooding, such as flood forecasting and warning, flooding insurance, planning controls, public information and education, etc.

Most of the funding necessary for the structural measures are covered by the national budget, mainly by the Civil Protection Department of Italy.

8.1.8.5 Committed actions by ANPA (now APAT)

During the crisis, the Italian Agency for Environmental Protection (ANPA) intervened within the framework of its institutional competencies, in co-operation with the local Civil Safety Operational centres in the Valle d'Aosta and Piemonte regions to support technically and scientifically the Civil Protection Authorities with:

- prioritisation of the most affected areas;
- identification of the areas presenting high technological risks;
- mapping of the landslide zones, with identification of the causes, mechanisms and assessment of the results, by individualising the situation at the residual risks.

8.1.8.6 Economic damages and costs

Again, this was a specific situation due to the severe climatic conditions leading to landslides and flooding. It was not possible to separate the costs related to individual threats.

Most of the costs for prevention measures, monitoring and interventions during the critical phase were covered by the Civil Protection Department of Italy (institutional task funded by the national budget).

Some of the costs have been identified but not quantified during the study, due to the huge number of actors (industries, municipalities, population, insurance companies). For this particular type of threat, all types of cost have to be accounted for, but are not available in a separate calculation.

8.1.8.6.1 Costs of preventive measures

The main part of the annual government investment to prevent flooding is provided by the Civil Protection Department (these data are not available).

Moreover, the Ministry for the Environment supports structural works coupled with preventive measures at the scale of the river basin (River Basin Plans (law 183/89 and 267/98). The amount of these investments changes every year. Recent national programmes of investments for the mitigation of flooding and landslide risk are reported in the following table 47:

Table 47. Recent programmes of investment for the mitigation of flooding and landslide risk supported by the Ministry for the Environment

Programme of Investments	Year	Amount of investment
Emergency programme [a)]	1998	57 M€
Emergency programme [a)]	1999-2000	420 M€
Integration programmes [b)]	1999-2000	131 M€
Provisory programmes [c)]	2002-2003	349 M€

a) Programma Interventi Urgenti (legal basis/reference DPCM 12/01/1999 and DPCM 30/09/1999)

b) Programmi integrativi (legal basis/reference DL 279/2000)

c) Programmi stralcio (legal basis/reference various DM)

The elaboration of land planning now allows the introduction of additional preventive measures, such as changes in the land use (authorised categories of land use).

8.1.8.6.2 Costs of suffered damages

Several types of cost have been identified: 26 casualties, destruction of buildings, …, borne by numerous actors, both private and public.

The monitoring costs for flooding are included in the preventive measures.

8.1.8.6.3 Costs of remediation / clean-up, etc. (protective measures)

The data are not available in detail. This is an institutional task of the Civil Protection Department of Italy. The Ordinance of Civil Protection no. 3090/00 (about 100 M€) approaches the costs of emergency measures. The complete reconstruction is funded by annual investments (the amount changes yearly).

8.1.8.7 Who bears the costs? (affected sectors)

All the emergency and preventive measures are borne by the public sector.

- Emergency measures: the Civil Protection Department of Italy, under Emergency Government Provision, supplies the Regions with the necessary funds.
- Preventive measures: the Civil Protection Department of Italy, under specific Dispositions; Ministry of the Environment and Territory, which coordinates the planning for the reduction of flood phenomena in agreement with River Basin Authorities and supports specific programmes of structural works.

Depending on the damages suffered, the other costs related to reclamation are born by the owners of the different buildings.

8.1.8.8 Types of cost - synthesis

All the costs have been identified for this type of threat, but in this particular case study, the actual costs were not communicated.

- It was impossible to find out how much of the costs of flooding are actually due to soil degradation processes, and how much due to clomate change or other factors such as regulation of rivers.

8.1.8.8.1 References / Bibliography

- Emergenza Alluvione Ottobre 2000, rapporti ANPA 7/2001

L’alluvione in Piemonte del 13-16 Ottobre 2000. Gli effetti su alcuni siti a significativo impatto ambientale, rapporti ANPA 14/2002

8.2 APPENDIX 2 INFORMATION AT NATIONAL LEVEL

8.2.1 Ireland

The general consensus in Ireland is that soil quality is generally good. However, there is increasing pressure on soils particularly from land use changes, intensification of agriculture, erosion and overgrazing, disposal of organic wastes to soil, afforestation, industry and urbanisation. In addition, untimely or excessive applications of nutrients to soil, in particular phosphorus, has resulted in water quality deterioration. This emphasises the major interactions and connectivity between all environmental media. This is why soil protection is now considered on an equal level with the protection of air and water in Ireland.

A Soil Protection Strategy (Irish Environmental Protection Agency – Towards setting environmental quality objectives for soil: developing a soil protection strategy for Ireland; a discussion paper) has been developed and proposed in 2002, based on the following principles:

- The protection of soil quality may pose some unique difficulties, e.g. most soil resources are in private ownership, soils perform multiple functions.
- Soil quality refers to the status, which will give sustainable support to its multiple properties and functions, within natural or managed ecosystem boundaries, in a sustainable manner.
- The implementation of best management practices should be promoted to protect soil quality,
- The soil strategy must also develop the mechanisms by which changes in soil quality can be measured and the effectiveness of remedial actions assessed: this requires the development of a national soil quality monitoring programme and a selection of a set of indicators which are representative of soil quality.

During the elaboration of this Soil Strategy, an inventory of the sources of information has been elaborated (on soil classification – ten main “Great Soil Groups”, amongst others soil fertility, soil organic content, soil contamination, forestry soil yield). An evaluation of the land use at the national level has been completed using the “Corine Land Cover” information system (69% agriculture, 14% Wetlands, 14% forests and semi-natural areas, 2% of water, 1% of artificial surfaces).

Pressures and impacts on soil resources have been identified. The main pressures on soil in Ireland arise from the following sectors:

- intensive agriculture and organic waste disposal,
- forestry,
- industry,
- peat extraction,
- and urbanisation and infrastructure development.

Those pressures have been qualified, rarely quantified (industrial organic waste disposal, industrial contaminated sites).

The current work is related to:

- a better identification and a review of the existing information in soils in Ireland: they should be assessed in relation to providing information on soil quality and changes over time, e.g. what information is currently available, what does this tell us about soil quality changes over time and under different land uses and pressure, etc.

- the development of a set of key soil quality indicators, these indicators must be capable of informing policy makers, regulators and soil users so that questions such as “what is soil quality like in Ireland? Is it good? Is it bad? How is it changing over time? Good or Bad soil quality has two components, (a) a scientific understanding of the state of soil resources supporting soil functions, and (b) decisions made by society on the intended use for soil.
- the establishment of the soil quality monitoring network,
- the development of a code of good practices for soil management.

Some examples of soil quality indicators have been provided in the strategy document.

Table 48. Soil indicators

Indicator	**Soil property / soil function**
Soil organic carbon content	Biomass production, filtering and buffering soil structure, formation of soil aggregates, soil fertility, ability to retain water, etc.
Cation exchange capacity	filtering and buffering capacities, nutrient reserve
Base saturation	filtering and buffering capacities and indicates reserves left in soil to buffer against acidity
Soil pH	Acidity or alkalinity of soil and influences land use, biomass production and biodiversity
Oisens P or Morgans P	Plant available P, and also indicator of soil fertility status and potential for biomass production. Links to potential for water eutrophication
Microbial biomass	Size of microbial populations and indicates the potential for soil to recycle organic matter and nutrients, relevant to soil fertility and indicates the activity level within a soil. Ability to transform chemical
Soil macro and micro fauna and flora	Biodiversity, soil health, soil fertility
Soil N mineralisation potential	Availability of N reserve, indicates activity of soil microbial biomass, relevant to soil fertility
Soil bulk density	Measure of the porosity and compaction of soil, physical environment for roots and soil organisms
Particle size distribution	Physical environment for roots
Macroporosity and readily available water	Indicates the number of larger pores in the soil which are important for soil aeration and storage of plant – available water
Area of land lost to urbanisation and development	Loss of soil
Sediment load to water courses	Soil erosion and loss of soil functions
Heavy metal concentration in soils	Anthropogenic soil contamination, possible loss of soil functions

No indicator on the economic impact of the soil degradation is currently identified.

All the actions planned are now undertaken in tandem with the developments at the European level.

8.2.2 The Netherlands

In The Netherlands soil cleanup operations started in the early 1980s when an inventory of seriously contaminated sites was drawn up. In particular ongoing local-scale polluting activities were identified as requiring preventive measures. Large-scale diffuse sources also cause soil pollution but in general they do not lead to the creation of seriously contaminated sites. As a result, they do not show up in the inventory of sites for cleanup.

The underlying premise of the "Soil Protection Act", which came into force in 1987, is that pollution of soil is not allowed. If a soil became polluted after the Act came into force then, in principle, the pollution should be removed irrespective of the risks. The ALARA principle (As Low as Reasonably Achievable) and the use of best available techniques are instruments that can be used to control soil pollution. In practice it is seldom possible or feasible to control or prevent all releases to soil. Therefore, the Act states that emissions and the resulting soil pollution can be tolerated as long as the soil quality does not decline (stand-still principle) and that the multi-functionality of the soil is not endangered. For the implementation of this policy, so-called *target values* or criteria related to target values are used. As long as the concentrations of pollutants in soil remain below the target values, the soil is considered *multifunctional*, i.e. fit for any land use, baring in mind any limitations due to the natural composition of the soil.

If soil contamination occurred before 1987, the contamination still has to be managed; and if a site is seriously contaminated then a cleanup might be necessary. For a large number of substances, intervention values have been derived, which represent seriously contaminated soil. Such soil has to be managed before, during, and after the cleanup. The management strategy adopted depends on local circumstances but should always be focused on the prevention of contaminant dispersion, the reduction of site-specific risks, and the improvement of soil quality. Social and economic factors also influence the way soil contamination is managed. In some cases it might be necessary to adapt the end-use of a site.

Current legislation requires that the polluter should pay for the cost of cleanup. If this is not possible then the owner of the contaminated site is responsible. In cases of so-called innocent owners, the authorities using public money pay for the cleanup. At the moment, this process is managed in a way, which gives the owner a more central position in remedial action decisions including more responsibility for the costs.

The Ministry of Housing, Spatial Planning and the Environment (VROM) is responsible for defining general soil policy. The Ministry defines the Soil Protection Act, and instruments based on the Act such as General Administrative Orders, soil quality objectives and procedures for estimating site-specific risks. The local authorities, provinces and municipalities are responsible for applying the Act and associated instruments, and deciding how best deal with specific contaminated sites. The National Institute of Public Health and Environmental Protection (RIVM) provides the scientific basis for soil quality objectives and risk assessment procedures. The Technical Committee on Soil Protection (TCB) advises the Minister on the implementation of technical and scientifically based instruments in soil protection policy. The development of instruments such as quality objectives takes place in close co-operation with all relevant parties to ensure that it will be suitable for use and widely accepted. Because cleanup costs have to be borne primarily by polluters and site owners, special treaties have been developed between the Ministry and specific bodies such as railroad companies and the trade organisation for laundries.

Risk-based soil quality objectives are an important instrument in Dutch soil policy, especially in relation to the cleanup of contaminated soils. Target values and intervention values have been established for about one hundred substances for soil and groundwater, and are related to the percentage of organic matter and clay in the soil. If target values are met, the soil is considered clean or multifunctional. If the *average contaminant concentration* in a minimum soil volume of 25 m^3 exceeds the intervention value, the contamination is classified as serious (in the case of groundwater contamination, a minimum volume of 100 m^3 applies). Target values are not related to a volume criterion at the moment, but this will probably occur in the near future. Recently target values have been re-examined and, for a number of substances, new risk-based values were proposed.

The target and intervention values are part of a general framework of risk-based environmental quality objectives. Exceeding such objectives indicates the potential for risk, assuming that exposure always occurs to its full extent. However, in practice full exposure will not always occur, and it is important to take local circumstances into account when estimating actual risks. For the time being the number of procedures for estimating actual risks is limited. The most advanced procedure developed is that used to determine the urgency for cleanup.

According to the Soil Protection Act the following questions should be answered in relation to the cleanup of contaminated sites:

- Is the site seriously contaminated?
- Is cleanup urgent?
- When should cleanup start?
- What is the cleanup objective?

This last question has been subject to many discussions and debates in recent years. In the past, the strategy has focused on cleanup resulting in a multifunctional soil unless the cleanup caused environmental problems, was impossible for technical reasons, or was too expensive. If a total cleanup appeared to be impossible the site was isolated controlled and monitored (ICM approach). ICM solutions could involve partial soil excavation and could be related either to current or intended use of the soil. A phased approach to remediation was allowed so long as any immediate danger from the site was dealt with as soon as possible. In practice, the distinction between total cleanup and ICM was found to be too rigid and not cost-effective. Therefore other potential solutions were explored. Recently this resulted in a new strategy.

- For new sites (contaminated during and after 1987), a total cleanup should be performed.
- For old sites (contaminated before 1987) and with mobile contaminants, the contamination should be removed as far as possible in a cost effective way.
- For old sites with non-mobile contaminants, the contamination should be removed to the extent necessary, recognising the end-use of the site (function oriented approach).

The general outline of the new approach was adopted by the Dutch Parliament in 1997. Advice on how to deal with certain aspects of this approach (e.g. cost effectiveness, criteria for mobility) has been defined.

The success of the Dutch system partly reflects the organisation of the process. In this context it is useful to summarise some major characteristics.

The distinction between scientific and political aspects. Research projects leading to soil quality objectives or risk assessment procedures are usually divided into scientific and political phases. In the scientific phase, objectives and procedures are derived in an objective manner to the extent possible in the light of scientific knowledge. In the political phase the practical implications for soil policy are discussed including economic, financial and social factors.

Estimation of the consequences of instruments before being enforced.

The acceptance of instruments to manage contamination depends to a large extent on the consequences. In relation to soil cleanup especially, the financial consequences can be very huge. In order to prevent consequences that are unacceptable, it is important that these are anticipated before measures come into force. Usually such an analysis does not change the way that instruments are implemented in soil policy. However, sometimes a phased or alternative approach will be chosen on the basis of estimated consequences.

Development of soil quality objectives and risk assessment procedures in close Cupertino with other ministries, local authorities and other affected parties. In The Netherlands local authorities, provinces and municipalities are largely responsible for the use of instruments like soil quality objectives and risk assessment procedures. Other ministries may also have responsibilities. Therefore representatives from local authorities and other ministries are involved in projects from the beginning. Similarly, a policy will only work if the various parties that will use it or be affected by it accept it. Therefore industry and environmental groups are involved in discussions at an early stage; and, as far as it is reasonable to do so, their interests are taken into account. They are also invited to contribute their scientific expertise.

To increase the redevelopment of brownfield sites, particularly in inner city areas, where potential development is highly strategic (for restructuring the city), but also highly risky (in term of costs), The Netherlands is currently testing a new approach, the Private-Public Partnership (PPP) leading to risk sharing. Linking land and building exploitation may as well help to limit risks in such a way those losses in land exploitation can be offset by positive returns on the buildings. The Ceramique site redevelopment, located in Maastricht (appendix 1), shows the procedure used on a site acting now as a national demonstration project in relation to:

- partnership with a private enterprise,
- its innovative approach to a large construction project,
- the high quality of homes, offices and infrastructures,
- the fast-track planning processes, based on a long-term vision and long-term agreement,
- the intermixing of different functions.

8.2.3 Norway

Some partial data on soil erosion in Norway have been collected. The Vansjø-Hobøl Catchment (in the Morsa region) is one of the two areas selected for pilot studies connected to the Water Framework Directive. The catchment is representative of areas with a cold climate and where most of erosion occurs during the winter due to frozen soil and snow melting periods.

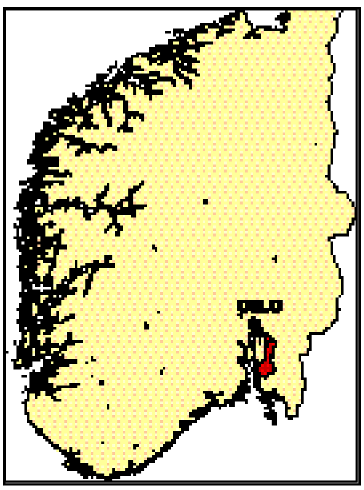


Figure 18. Location of the Morsa Catchment (Southeast Norway)

The catchment area (690 km²) includes seven towns in two counties, and has a population of around 20,000 inhabitants. Agriculture (16%) and forestry (80%) dominate the land use. Most of the catchment is situated below 200 m elevation and is covered by marine sediments deposited during the last glacial period. Mean annual precipitation is about 800 mm. Agricultural soils are typically loamy clay soils (clay content ranging from 20 to 35%). Sandy soils represent less than 20% of the area.

The lower parts of the catchment area near Lake Vansjø typically have a flat agricultural landscape with slope gradients usually below 6%. The remaining area is characterised by a fragmented landscape with a mosaic of agricultural fields and forested areas. Slopes of the agricultural fields are highly variable, but often between 6 and 20%.

The hydrology is characterised by peak runoff events during autumn and winter periods, in particular during the snowmelt, which usually occurs in March and April.

Soil erosion is one of the major contributors to phosphorus losses. Major efforts have been made and active measures taken to reduce soil losses. A huge amount of subsidies are given to reduce erosion such as: reduced tillage, bufferzones, sedimentation ponds, catch crops.

All farmers have to have an Environmental Plan for their farm. Estimates are done for rill and gully erosion, erosion connected to hydrotechnical measures. Soil erosion risk maps exist for each field, calculations are done of actual soil loss with modern farming practices, and estimates are made how much more soil loss can be prevented if more measures are implemented (e.g. high risk classes turned into stubble during autumn and winter period).

During this pilot study and European projects (EUROHARP on diffuse pollution and NOLIMP – Interreg project on local and regional implementation of the Water Framework Directive in the North Sea Region), runoff, nutrient losses, pesticides and soil losses were measured. A field inventory is done on each field after snowmelt. Detailed information from each field about all farming activities will be collected in the next months during these projects.

The Agricultural University of Norway will also use this catchment for economic studies on a field scale using model farms and making scenarios with different farming practices, effect on soil loss and different subsidies. Several options of measures for reducing the agricultural Phosphorous (P) loss will be studied:

- division of the Morsa catchment into smaller and unique sub-catchments
- quantification of the total losses of phosphorus from agriculture and other sources
- identification of the major P loss processes and pathways of P transfer to water
- classification of all agricultural land area into different categories depending on erosion risk
- survey of the current status of land use, crop production
- identification of the possibilities for implementing new or additional measures
- estimating the possible reductions of P loss in relation to the different measures

The most important measures should include:

- conservation tillage
- protection of the surface waterways
- buffer strips
- sedimentation ponds or constructed wetlands

- balanced fertilisation

The results of the pilot project should be available in the following months.

8.2.4 Finland

During the exchanges with the Finnish Ministry for Environment and its experts, some additional information on other threats than contamination was given:

The loss of organic matter and salinisation are not really causing soil degradation in Finland. Erosion is not a major problem (maybe in some southwestern parts of the country were it is harmful chiefly due to its effect on water quality and in Lapland in places where there are too many reindeer) and therefore if economic impacts exist they are minor.

Acid deposition has been shown not to be a significant factor contributing to forest health in Finland, according to the ICP Forest level I defoliation surveys, and to have no noticeable effect on soil acidification. Sulphur (S) deposition declined substantially during the 1990s. Acid deposition on forest production is therefore unlikely.

Levels of heavy metals (e.g. Pd, Cd, Zn and Cu) in the humus layer are below concentrations that would affect microbiological activity and ecosystem functioning, including stand growth, except within the immediate vicinity of a few point sources (e.g. Harjavalta). Emissions of heavy metals from the smelters on the Kola Peninsula do not reach Finland, except for a very limited area in northeastern Finnish Lapland.

8.2.5 Other countries

During this Case Studies identification, some additional information has been collected through the different contacts:

8.2.6 Situation in other countries

- Iceland: soil erosion in relation with sheep grazing (Arnalds & Barkarson, 2003),
- Denmark: soil erosion where the dominant soil erosion processes are wind, sheet, rill, tillage and bank erosion(Veihe et al., 2003).
- England and Wales and agriculture issues (England and Wales Environment Agency, 2002).
- Lithuania: soil erosion (Jankauskas and Jankauskiene, 2003).

8.2.7 Situation on some specific threats

- Wind erosion (Riksen and De Graff, 2001).

Unfortunately, those studies show either the environmental situation or some economic figures. The following contacts with the authors haven't been successful for complementing the literature documents.

8.3 APPENDIX 3 ENVIRONMENTAL INDICATORS AND SOURCES OF DATA

Table 49. Overview of indicators for soil degradation

Degradation type	Soil quality / degradation indicator	Unit	Sources of information
Erosion	**Area affected by erosion (agricultural and non-agricultural) (differentiated by intensity categories)**	ha	**1) CORINE soil erosion risk assessment: Area under risk of erosion in Southern Europe:** 111.4Mha **(22.9 Mha = area with high or extreme risk)** **2) Plot Database (Cerdan et al.): Area potentially under risk of erosion (with very low risk included):** 220 Mha **(58 Mha = area with high risk)**
	Soil loss per year by erosion from agricultural land	t/ha/y	**Plot Database (Cerdan et al.)**
	Area under risk of erosion	%	**1) Plot Database (Cerdan et al.)** **2) EEA, 2001**

Degradation type	Soil quality / degradation indicator	Unit	Sources of information
Contamination	**1) Area affected by contamination (impact cat. 1-3)** **2) N° and av. Size of sites in different impact categories** **3) N° of households / N° of population affected by contamination** **4) Risks of contamination of surface and groundwater from mining dump sites, industrial sites, landfill etc**	ha N° N°	**1) The EEA inventory gives number of sites related to the different levels of impact per country covered. For having the area surface, extrapolation is needed** **2) OK for number of sites (see table send Sunday)** **3) Nothing at European or national level. Some particular studies, like in France. A table in preparation** 4) **Nothing currently at European level. Some indications for some countries such as France (figure in preparation).**

Degradation type	Soil quality / degradation indicator	Unit	Sources of information
	1) Soil polluting activities from localised sources **2) Progress in the clean-up of contaminated land** 3) Total concentrations of heavy metals in agricultural top-soils and sub-soils	% N° / % mg/kg	**1) Existence of information at national level on industrial activities contributing to contaminated soils (i.e. in France. Figure in preparation). Nothing currently at European level.** **2) EEA indicator on their website.** 3) **Several sources to be used : FOREGS report on 'natural' background levels, detailed information in some countries, for 8-10 heavy metals, European Soil Bureau having some information at the European level.**
Floods and landslides	**Area affected by floods (differentiated by intensity categories)**	ha	Close link with climate events…..
	Area affected by landslides (differentiated by intensity categories)	ha	
	Population affected by floods and landslides	N° /y	

Degradation type	Soil quality / degradation indicator	Unit	Sources of information
Salinisation	**Area of soil affected by salinisation (differentiated by intensity categories)**	ha	1) SOTER Database (ISRIC, FAO, UNEP) 2) EEA, 2001
	Salt content in soil (Ca, Mg, Na; Cl, SO_4, HCO_3)	mg/m^3	
	Groundwater salinity	mg/m^3	
Decline in organic matter	**Organic matter content by volume / by mass** (differentiated by intensities / quality categories)	%	
	Loss in organic matter in topsoil calculated according to soil types and land use	t	
	Total carbon (C) contained in soil	t	
(Soil sealing)	**Built-up area as per cent of total land**	%	
	Per cent increase of built-up areas	%	
	Land take by urban sprawl	ha	
(Biodiversity)	Decline in n° of species (Decline in quality / composition of species)	%	

Degradation type	Soil quality / degradation indicator	Unit	Sources of information
(Compaction)	**Area affected by different degrees of compaction**	ha	
	Density of the topsoil	kg/m^3	

BRGM
SERVICE ENVIRONNEMENT INDUSTRIEL ET PROCÉDÉS INNOVANTS
Unité Environnement industriel
BP 6009 - 45060 Orléans cedex 2 - France -Tél.: 33 (0)2 38 64 34 34