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1 Introduction

Soil performs a multitude of functions that are essential to human life. Apart from providing food, biomass and raw materials and serving as a habitat and gene pool, soil also performs storing, filtering and transformation, as well as social and cultural, functions. In this way, soil plays an integral part in the regulation of natural and socio-economic processes that are necessary for human survival, such as the water cycle and the climate system. Because soil forms the basis of many different human activities, it also has a significant economic value. However, this "fundamental" economic value of soil is barely recognised.

Soil *deterioration*, understood as an impairment of these different functions, occurs both naturally, and as a consequence of human influences. This study focuses only on man-made impacts on the soil functions, which are described as soil *degradation.* Like other parts of the environment, soil has come under increasing stress as a consequence of human activities. Intensive agriculture, land consumption for building, the contamination of soil through pollutant emissions and changing climatic conditions are but a few of the man-made pressures on soil. In its Communication “Towards a Thematic Strategy for Soil Protection”, the European Commission (2002) distinguishes between the following eight soil threats:

- Soil erosion,
- Decline in organic matter,
- Soil contamination,
- Soil sealing,
- Soil compaction,
- Decline in soil biodiversity,
- Salinisation, and
- Floods and landslides.

While “healthy soil” can withstand these pressures to a certain degree, the combination and the extent of the stresses has resulted in a slow, but widespread, degradation of soils in many parts of Europe.

Soil degradation has become an important concern for policy makers. The physical, chemical and biological effects of soil degradation on other media of the environment, ecosystems and human populations have been researched to some degree. However, so far, little research has been done about the economic costs that soil degradation imposes both on the users of soil and on society as a whole. The current study was undertaken to address this lack of economic information.

2 Aim and Scope of the Study

The current study was undertaken in order to take stock of the existing knowledge on the economic impacts of soil degradation in Europe and abroad, and to provide initial estimations of the total economic impact of soil degradation in Europe. In the latter task, it is one of the first works of this sort that has been carried out in Europe.

The project has been financed by the European Commission, Directorate General Environment, and was carried out by Ecologic and the BRGM. It was prepared in support of the process leading up to a Thematic Strategy for soil protection in Europe.

The work performed consists of three main components:

- First, a review of the relevant literature, both economic and otherwise, to take stock of the existing information on the economic impacts of soil degradation, and on the basis of this, to develop a methodology for assessing these impacts in Europe;
- Secondly, five case studies from different parts of the EU, addressing different types of soil degradation; and
- Thirdly, an empirical estimation of the Europe-wide economic impacts of soil degradation.

These tasks are documented in separate volumes, which together constitute the final report for the project "Assessing Economic Impacts of Soil Degradation”. This volume summarises the main findings of the three tasks.

However, a general caveat applies for this document. As the literature review (Volume I of this report) and the database research (contained in Volume II of this report) have shown, the data availability on soil degradation is still limited in many respects. Information on the economic impacts of soil degradation is generally scarce, somewhat less for erosion and contamination, much more so for soil biodiversity loss or soil compaction. Likewise, the availability of soil-scientific data on the state of soils in Europe differs markedly between different soil threats and between different regions.

The five case studies that were described as part of this project shed some light on specific impacts and specific regions. Still, they are not sufficient to compensate the shortage of empirical economic data, in order to provide a more comprehensive picture of soil degradation and its impacts in Europe.

Thus, at this stage, on the basis of the available data, a conclusive judgement cannot be made for many of the different types of soil degradation. For those threats with better data availability, the problem remains that many assumptions have to be made in order to arrive at Europe-wide estimates for the economic impacts of soil degradation. Care was taken to make these assumptions and the underlying motivations explicit wherever possible. Nonetheless, these assumptions are sometimes heroic and may be disputed in many cases. In this sense, the current study should be regarded as a first scoping, providing the basis for further discussion and research, rather than as conclusive evidence.

3 Review of the Literature

The economic assessment of soil degradation in Europe has been based on a survey of existing studies and relevant literature assessing the impacts of soil degradation in economic terms. This literature review focused on empirical research and quantitative estimates of soil degradation impacts in Europe and abroad in order to take stock of the existing information, and to give an overview of the relevance of the problem.

The surveyed studies have assessed a variety of impacts associated with soil degradation, both on-site (e.g. yield losses due to compaction or salinisation) and off-site (e.g. the cost of siltation or sedimentation as a consequence of erosion). While the main focus was on the impact of suffered damages, the study also considered the defensive expenditure needed to alleviate impacts of soil degradation, such as the cost of replacing eroded nutrients.

3.1 The Economic Approach to Soil Degradation

Besides its use for agriculture, horticulture and forestry, soil performs a number of different functions that support a variety of human activities. Not all soil functions are of direct and measurable economic relevance: soil also has ecological, cultural and aesthetic functions, for instance as an archive of human and natural history or as a spiritual or religious symbol. Such functions cannot be adequately measured in economic terms, nonetheless, they contribute to the value of soil.

Analytically, the economic valuation of soil *degradation* originates from the economic approach to valuing soil *quality*. Soil degradation is a deterioration of soil quality, which can be understood as a loss of soil functions. Consequently, the process of valuing soil quality can be described as moving

- from *soil functions* (biological and chemical processes that take place in the soil, which are described by ecology)
- to the *uses of soil* (in this context, human uses of soil that are of economic relevance, and thus at the interface between ecology and economics. This also includes indirect uses – i.e. the beneficiaries of ecosystem services provided by soils)
- to the *valuation* of these uses (which is an economic task).

Assessing the economic impact of soil degradation in this framework can be done as follows. First, soil degradation is a process whereby pressures exerted on the soil ecosystem lead to a partial or complete loss of soil ***functions***. This impact on soil functions means that the human ***uses*** of soil are also affected. Uses here include both direct, economic uses, as well as ecosystem services provided by soil. A typology of different uses, and how are affected by degradation is presented below. In the following, the impact of soil degradation on soil uses is ***valued*** in economic terms. To this end, different valuation methods can be applied. A brief discussion of such methods can be found in the literature review (Volume I of this report).

3.2 Typology of the Economic Impacts of Soil Degradation

Soil deterioration makes itself felt in different ways, and there are different methods of classifying the economic impacts of soil degradation. The different impacts can be classified spatially into on-site and off-site effects, distinguished according to the economic values that are affected; they may also be grouped according to causality as direct and indirect impacts.

3.2.1 On-site vs. off-site effects

In the economic context, spatial distinction between on-site and off-site impacts is also of central relevance, taking account of the fact that economic impacts occur both at the site where degradation takes place (**on-site effects**), as well as in spatially remote areas (**off-site effects**). Apart from the spatial criterion, the distinction between on- and off-site effects is also relevant because soil degradation caused by one actor can have negative effects on a third party, thus creating an “externality” in the economic sense. In addition, off-site effects can also occur with a time lag.

On-site effects generally tend to be more manifest and self-evident consequences of soil degradation, as they directly affect the soil uses taking place at the site, like agriculture, forestry or recreational activities. Also, while there may be temporal delays between the degradation and its effects, on-site effects tend to be more immediate than off-site effects. Off-site effects can account for a sizeable proportion of the total economic impact of soil degradation; however, as they are less directly related to soil degradation, it can be difficult to quantify precisely which off-site effect is related to which soil degradation process.

Off-site effects include the following processes:

- **Siltation of dams** as a consequence of erosion;
- **Sedimentation of waterways**, leading to cleaning and maintenance costs;
- **Damage to irrigation infrastructure and pumping equipment**;
- **Contamination of drinking water reserves** and associated health impacts;.
- **Increased frequency of flooding events** through reduced water retention;
- **Increased dust concentrations** leading to health impacts and physical damage;
- **Impact on the aquatic environment**.

It has been argued that, for developed countries, the off-site effects of soil erosion tend to be higher than its on-site costs. This view is supported e.g. by FAO (1999), Furtan (1997), Crosson and Stout (1983), Crosson (1986) and Clark et al. (1985). Pretty et al. (2000) estimate the off-site costs of soil erosion for the UK at £ 14 m per annum (in 1996 prices).

In addition, there are also global effects of soil degradation. Climate change effects arise through the reduced carbon storage in degraded soils: With an estimated storage capacity of 3,200 - 3,500 Petagrammes ($3.2 - 3.5 * 10^{12}$ kg), soil is the third largest global carbon pool (Lal 1999). Furthermore, soil degradation may diminish the biodiversity above and below-ground, reducing the resilience of soil ecosystems when faced with changing land uses or climatic conditions.

3.2.2 Use values and non-use values

A different way to categorise soil degradation is to consider the economic values affected by it. These can either be use values or non-use values. The ***use value*** is impacted if soil functions are currently used in one way or another, and if the capacity of soil to support these uses is diminished by the soil degradation. Uses can be agriculture or forestry, but also housing, tourism or recreational activities.

Within the category of use values, a further subdivision is possible between *direct* and *indirect* use value. Broadly speaking, the **direct use value** relates to the immediate uses of soil, e.g. if soil is used for agriculture. Direct use values are mainly related to the soil function of producing food and biomass. By contrast, **indirect use values** are related to other, ecological functions that soil fulfils, either by itself, or by sustaining other ecosystems. Examples include the filtering and buffering functions of soil, the decomposition of dead organic matter and wastes, and the role that soil plays in the natural carbon, nitrogen and sulphur cycles. These ecological functions performed by soil may be source of significant benefits for economic actors, soil acting as a natural infrastructure. The valuation of such ecological functions from the perspective of human uses is referred to as *ecosystem services* (see Box 1 below). For certain aspects of soil degradation, such as soil biodiversity, it is likely that the impact on indirect use values will exceed that on direct use values.

In opposition to direct and indirect use values, there is also a ***non-use value*** of soil. It is affected if the degradation of soil (and the ecosystems it supports) is experienced as a loss by someone who is not currently using it, nor intends to use it. Non-use values can take the form of *existence values*, based on the conviction that soil should be protected as a valuable resource in its own right, or they can take the form of *bequest values*, if the soil is to be preserved for use by future generations. Non-use values are typically much more difficult to assess economically than use-values. Finally, a category that falls between use values and non-use values is the *option value*. Soil is said to have an option value if it is uncertain whether, and in what form, it will be used at a later stage.

The advantage of classifying soil degradation according to the values affected by it is that the appropriate methods for the economic assessment can be derived more easily: for impacts on use values, market prices can usually be used as a proxy, whereas indirect valuation methods are needed to assess impacts on non-use values.

Box 1: The Ecosystem Services provided by soils

The concept of ecosystem services has attracted much attention in ecological economic research (see e.g. Constanza et al. 1987, Daily et al. 1997). Analytically, ecosystem services form part of the indirect use values: soil is an integral part of many ecosystems and natural processes, including the regulation of the natural water cycle, nutrient cycling, the creation and absorption of biomass, the sustenance of biodiversity, and the natural carbon, sulphur and nitrogen cycles. These functions are of great importance for human survival and for economic activity; however, so far, their value rarely been assessed.

Some ecosystem services were quantified in this study - e.g. the role of soils for flood protection. A broad indication of the value of soils as a pool in the global carbon cycle can be derived from Hartridge and Pearce (2001). They estimate that in the UK, 7.6 million tons of carbon are released annually from cultivated soils, drained peatlands and fenlands, through peat extraction and through the transport of eroded soil to the sea. The annual climate change impact of organic matter released from British soils thus amounts to £$_{1998}$ 226.5 million (€$_{2003}$ 361 million). In a similar estimation, Pretty et al. (2000) value the economic impacts of soil organic matter loss in the UK at GB£ 82.3 m p.a. (€$_{2003}$ 143.3 m).

Along the same lines, Balmford et al. (2002) have reviewed the evidence on the economic value of different ecosystems. They provide evidence from five different ecosystems that were converted to human use (however none of them from Europe). For all the ecosystems considered, they find that the net benefits from conversion are actually negative. For the case of a Canadian wetland, the total economic value decreased by more than 40% as a consequence of conversion (from US$ 8800 to US$ 3700 / ha *y), as the loss of services formerly provided by the wetland is not outweighed by the marginal benefits of conversion. This finding holds despite the fact that some particularly valuable ecosystem services, such as nutrient cycling and the provision of cultural values, were not even quantified.

The FAO Soil Biodiversity Portal (FAO, undated) provides some estimates of the value of ecosystem services provided by soil, based on a study by Pimentel (1997). They investigate the following ecosystem services: waste recycling, soil formation, nitrogen fixation, bioremediation of chemical pollution, biotechnology (genetic resources), biological pest control, pollination and the support of wild animals and ecotourism. The worldwide economic value of these services is estimated at US$ 1.542 billion.

While these results are only indicative, they underline the importance of considering wider environmental and social benefits of soil uses, and show that a focus on the immediate soil uses (such as agriculture) can be misleading. Quite to the contrary: the value of ecosystem services may far exceed the direct use value, e.g. for agriculture. This applies in particular to ecosystems that are rich in species and in biological activity, such as wetlands, floodplains, bogs and forests.

3.3 Typology of Valuation Methods

Different methods have been put forward to assess the economic impact of soil degradation in monetary terms (see van den Bergh 1999 for a general overview). In general, all valuation methods serve to put a price on “environmental quality”, a good which is not traded in the market. Therefore, prices have to be inferred in other ways: either by comparing related products and markets, such as agricultural produce, or by eliciting consumers’ willingness to pay for the conservation of environmental features by means of surveys and questionnaires.

As different valuation methods approach the problem of soil deterioration from different angles, there are no clear-cut rules about which of these methods should be applied in which cases, and how they can best be combined. In addition, not all of the different methods can be applied to all types of soil degradation. Also, some of the different economic impacts mentioned above (on-site vs. off-site, use values vs. non-use values) require the use of particular valuation methods. The multitude of valuation methods brings with it the danger of double counting; likewise, it can be difficult to judge whether a combination of different assessment methods does cover the “true” and full economic impact of soil deterioration.

As a broad-brush classification, the total damage cost of soil degradation can be divided into

- the cost of suffered damage, i.e. damage that is not prevented (**damage cost**), and
- the cost of measures to prevent or alleviate damage (**damage avoidance cost**).

Different valuation methods that can be used to assess these cost categories are discussed in the literature review. The ***damage costs*** can be assessed trough the lost production value, as well as through hedonic pricing or the travel cost approach. By contrast, restoration and replacement cost approaches are methods that are used to estimate the ***avoidance cost***. Stated preference methods can be used for both categories.

The economic impact of soil degradation will normally comprise both cost categories: part of the damage is suffered unmitigated, while other parts of the damage are avoided through mitigation and repair measures. Therefore, in principle, the two can be combined to yield the full cost of soil degradation, under the assumption that the cost of preventing or alleviating damage is at least as large as the damage thereby avoided.

3.4 Methodology for the Economic Assessment of Soil Degradation

Based on the theoretical considerations elaborated above, the next step in the evaluation of soil degradation is to derive a damage function. This function expresses the economic impact of soil degradation (in monetary terms) as a function of the soil degradation processes themselves (expressed in environmental terms).

In principle, establishing a damage function proceeds in three steps:

1. Identify the impacts of soil degradation;
2. Quantify the identified impacts (including the selection of suitable indicators);
3. Estimate or derive coefficients (expressed in $^{€}/_{\text{unit of impact}}$) to value the impacts.

3.4.1 Identification of the impacts of soil degradation

As stated above, the impacts of soil degradation can be divided into different categories:

- the **on-site (private) costs of damage** suffered as a consequence of soil degradation. An example for this are the yield losses that farmers incur if the agricultural productivity of soil has been reduced through erosion, compaction or other degradation processes. These costs are denoted **PC**;
- the **on-site private cost of mitigation and repair measures** to limit the impact of degradation or to prevent further degradation. This includes, for example, the cost of additional fertiliser input to compensate for the impact of erosion, or the cost of measures to restore the physical structure of compacted soils. This category is labelled **MC**;
- the **off-site (social) costs** of soil degradation, which are suffered by other parties. One example is the cost of damages caused by floods and landslides. It also includes the value of foregone ecosystem services, such as biodiversity maintenance or carbon sequestration, which are reduced through soil degradation. These costs are denoted **SC**;
- The **off-site defensive costs** incurred in order to mitigate or limit the off-site impacts of soil degradation. This includes e.g. the cost of soil conservation measures to prevent landslides, or to retain the soil on the site. These costs are abbreviated as **DC**.
- the **non-user costs** that accrue to the individuals that do not use the soil, but are nonetheless distressed by its degradation. This category measures the non-use values attached to soil, e.g. the patrimonial value of preserving soil for future generations. Where such values are affected by soil degradation, the cost are captured as **NC**;

Hence the total cost of soil degradation in the time period t can be expressed as the sum of these five cost components, as expressed in the following formula:

$$C_t = \sum_i \left(PC_{it} + RC_{it} + SC_{it} + DC_{it} + NC_{it} \right)$$

where C represents the total cost. The subscripts (t) and (i) indicate the time period and the type of soil degradation, respectively.

This means that each of the five cost categories has to be calculated and summed for each of the different types of soil degradation. It is important to note that mitigation costs should not be confused with an analysis of possible policy responses: here, mitigation cost are merely used as a proxy, based on the argument that the costs of mitigation is at least as big as the avoided impacts of soil degradation. However, in most cases, mitigation measures will not address soil degradation as such, but rather aim to limit its impacts.

In relation to the theoretical impact categories discussed in section 3.2 and the cost categories explained in 3.3, the five cost components are visualised in Figure 1. As shown in the figure, the private damage costs (PC) and the social damage costs (SC) constitute the *damage costs* of soil degradation. By contrast, the on-site mitigation and repair costs (MC) together with the off-site defensive expenditure (DC) sum up to the *damage avoidance cost*. The non-user costs (NC) can fall into either category.

If added up horizontally, the private on-site costs (PC) and the mitigation and repair costs (MC) give the on-site costs of soil degradation. The sum of off-site, social costs (SC), defensive costs (DC) and non-user costs (NC) yields the off-site costs of soil degradation; in economic terms also referred to as the **external effects**.

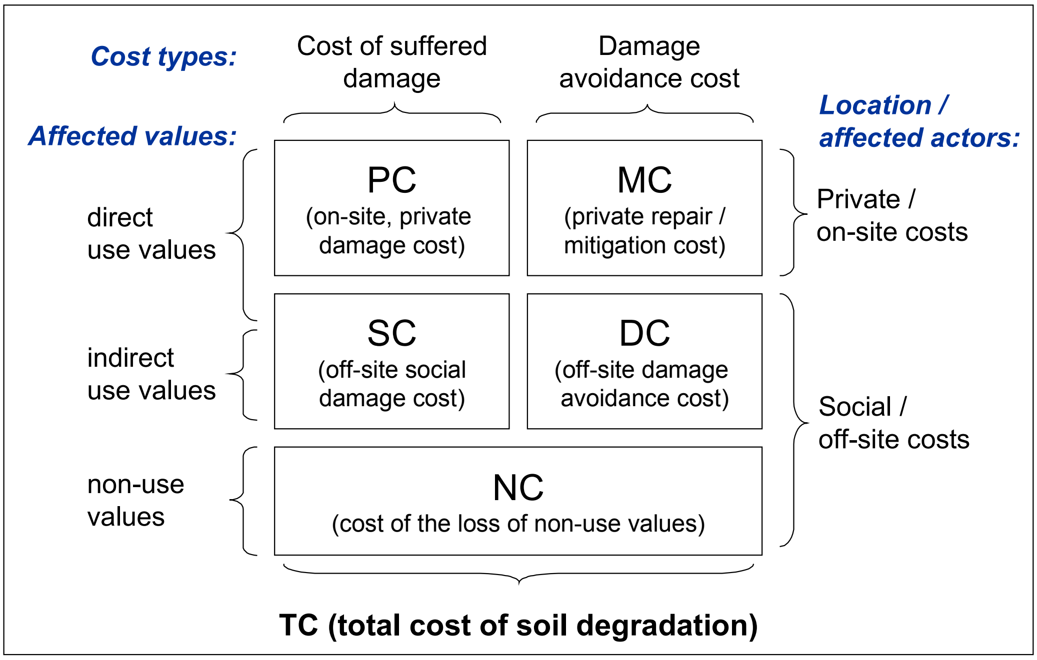

Figure 1: Overview of Different Cost Components

3.5 Quantitative Estimates

The literature review also presents an overview of sixty studies that have quantified the economic impact of soil degradation. Many of these studies are agronomic, focussing on agricultural yield losses associated with soil degradation. In addition, a number of studies have considered the cost of replacing lost nutrients. By contrast, in the case of soil contamination, estimates mainly address the remediation of contaminated land. Thus, the majority of empirical estimates have centred on the impact that soil degradation has on agriculture and forestry, and here concern the direct, on-site effects. The effect of soil degradation on indirect use values and especially on ecosystem services is less researched.

Of the different types of soil degradation identified by the Commission, erosion is covered most extensively in the empirical economic literature. For salinisation and contamination, as well as for floods and landslides, there is some evidence. The economic effects of compaction, biodiversity loss and loss of organic matter are covered only in occasional studies, or are not quantified at all.

In terms of the geographical distribution, the majority of studies comes from those countries where economic valuation has a longer tradition, i.e. Australia and North America. Furthermore, there is some evidence from regions where a substantial part of the economy depends on soil functions. Generally, there is not a large amount of evidence from European countries, with the United Kingdom as a notable exception.

4 Case Studies

In the course of the project, five case studies were discussed in greater detail (see Volume II of this report). These were selected in order to reflect:

- Different types of soil degradation;
- Different Member States;
- Different climatic conditions;
- Different economic uses and affected sectors.

For Erosion, two case studies were selected in order to better cover the diversity of situations in Europe. The first was selected in United Kingdom. This choice was mainly guided by the availability of data at a large scale. The second case study was chosen in France where two small sites, located in very different climatic and soil conditions, have been monitored and studied in detail for several years.

4.1 Erosion, UK

In UK, erosion has been assessed in England and Wales since the early 1980s, through field-based assessment rather than plot experiments, as is usually done for this particular threat. Therefore, this extensive study, involving 17 communities, gives valuable information on the rate, frequency, and extent of the erosion, as well as off-site effects.

4.1.1 Threats encountered in the area

The main origins of erosion are (i) water erosion (80.7%) and (ii) wind erosion (9.1%), and additionally, (iii) upland erosion and (iv) overgrazing. Studies have been conducted at the local level to evaluate the actual risk of erosion (Evans, 1990), covering an overall area of 151,207 km^2 (England and Wales) representing 296 soil associations. The pre-dominant land use is agriculture with a low population density, apart from on the edge of urban areas.

The intensity of impacts have been assessed:

- 38.2% (53,449 km2) of the surveyed land was considered as having a very low risk of erosion (erosion rare or inexistent): 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 km2) 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 km2) 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).

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.

4.1.2 Cost estimation

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.

Table 1: 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
9.99 million €$_{2003}$/yr	625.01 million €$_{2003}$/yr	Not estimated

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

4.1.3 Conclusion

Based on erosion survey data and information relating to costs in several areas, the study estimated the total costs of UK erosion damage taking account of the multifaceted and long-term nature of erosion and its economic impact. The actual erosion risk depends mainly on the present-day land use. Off-site costs are usually broader than on-site costs.

The British situation described in this study is representative of the 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. The links between soil erosion and its impacts (environmental and economic) are immediate. In the context of intensified land use known in Europe, erosion has become more extensive, frequent and severe, and its impacts more widespread and pervasive.

4.2 Erosion, France

Concerning the French case study, two areas were investigated. France presents a wide range of different erosive contexts induced by diversity in soil types, climate, geomorphology, land use and agricultural systems. To account for this variety, two contrasting systems were studied in the pays de Caux and in the Lauragais.

The Lauragais has a hilly topography and is covered by soils rich in clay fraction and with a relatively good structural stability. It is characterised by a temperate oceanic climate with some Mediterranean influence (intense spring storms).

The Pays de Caux is representative of the loess belt of Northern Europe. The topography is relatively smooth and is covered by silt loam soils very sensitive to soil crusting because of low clay content (13–17%) and low organic matter content (1–2%).

4.2.1 Threats encountered in the area

Runoff and soil erosion problems have reached an alarming level both in terms of rate and of geographical extent in this area as catastrophic muddy floods still occur regularly and the pollution of drinking water sources by sediments and agricultural chemicals are recurrent.

Pays de Caux

Soil erosion is not the result of exceptional climatic events in the area, hence it is a recurrent phenomena taking place annually. On the site, 5 ephemeral gullies per year were observed.

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 transported by overland flow (flax). For the public domain (off-site impact), the damages consist of the pollution of the drinking water sources (nitrate, sediment or pesticide) and of sediment deposition on the road. Almost no damages are observed after the conservation measures were installed.

Lauragais

The frequency of storm occurrence is not constant through time. The last three years, up to 2 to 3 intense storms per year have been observed in the vicinity of the field. But if we consider a longer time span (ca. 10 years), only one storm every two years was observed. As an indication, we consider that the return period of a storm on a field is five years.

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 reduction of the soil layer. Soil depth can be relatively low, and an irreversible loss of fertility can occur where the slopes are the steepest. Here also, almost no damages are observed after the conservation measures were installed.

4.2.2 Cost estimation

As for the UK case, soil erosion impacts are divided into on-site and off-site impacts. While on-site impacts are direct effects of losses of soil and affect mainly agricultural production (also designed as on-farm impacts), the physical damages to natural ecosystems and water bodies are off-site impacts. Off site costs are generated by the transport of sediments and deposits in other places (land, roads, rivers, etc.) where they generate a damage cost for third parties (negative externality). The off-site cost of soil erosion depends on the cost of the conservation measures and their effect on the reduction erosion damage. Table 2 below gives a synthesis of the costs estimation at catchment level.

Table 2: Synthesis – Average annual cost of soil erosion for the FR case study

On-site costs (PC & MC)	Off-site costs (SC & DC)	NC
Production losses from eroded agricultural soils Area loss (without government subsidies) Working time loss	Erosion conservation measures (cost of implementing measures and maintenance cost) Remediation / clean up measures (damage of deposits on roads and Cost of restoring property) Government financial subsidies for the reduction of field size	Impact on landscape values and biodiversity etc.
Lauragais: 938 €$_{2003}$/yr	Lauragais: 1582 €$_{2003}$/yr	Not estimated
Pays de Caux: 1295 €$_{2003}$/yr	Pays de Caux: 2786 €$_{2003}$/yr	
Lauragais: 39 €$_{2003}$/ha/yr	Lauragais: 53 €$_{2003}$/ha/yr	
Pays de Caux: 41 €$_{2003}$/ha/yr	Pays de Caux: 35 €$_{2003}$/ha/yr	

These cost figures underestimate the true costs, as they do not take in account the temporal distribution of the costs, and as they do not include estimates for non-use costs. The costs of measures are mainly supported by the owner, in general farmers, at the local level. When necessary at the river level (i.e. implementing an erosion conservation measure upstream), costs are borne by public subsidies.

4.2.3 Conclusion

At the opposite of the UK case, the French case of erosion impacts constitutes a micro case and may not be representative for erosion effects in all France: Firstly, the off-site costs are certainly underestimated. The off-site impacts over the catchments are not considered. Secondly, only agricultural effects are considered and the non-user costs (attached to the decreasing value of soil, for example) are not estimated in this study. Knowing these limits, it is also important to notice that the two French case studies are based on data gathered over several years (to account for the temporal variability of soil erosion processes) and that they are complementary (in terms of soil types, topography and climate) and representative of larger ecolo-physiographic contexts; Northern France being part of the Central and Northern European agricultural zone; Southern France being closer to the Mediterranean.

The conclusion that off-site costs are more important is coherent to what is generally observed in Europe. However, one it should be kept in mind that the ratio on-site / off-site costs are varying in function of the type of soil erosion and of where the vulnerability is.

4.3 Contamination, France, MetalEurop Nord

Soil ***contamination*** from localised sources is often related to industrial plants no longer in operation, past industrial accidents and improper municipal and industrial waste disposal. At industrial plants still in operation, soil contamination is commonly associated with past activities, although current activities can still have significant impacts (EEA-UNEP, 2000). The MetalEurop Nord site is representative of this main category of local point source contamination, and has been classified as a contamination *megasite*.

The MetalEurop Nord site is located in a semi-urban area with low population density, characterised by a dispersed habitat (105 inhabitants per km^2) and significant agricultural activity. In the past, the landscape was highly modified by mining activities (in the coal mining basin), industrial activities (smeltering), but also transport facilities (connection by waterway, road and motorway, railway). The industrial plant is located on chalky permeable ground in its southern part, and on semi-permeable alluvium near the valley of the Courant Brunet.

4.3.1 Threats encountered in the area

This case study deals with local soil contamination, located on the industrial plant (c. 30 ha) and in the surroundings. This industrial activity has had an impact on several environmental compartments, in particular soils on site and in the vicinity, through atmospheric emission (although regulated under the authorisation permit), and water resources (both surface water and groundwater) by fluid discharge. It has also had significant socio-economic impacts:

- Impact on air: important atmospheric emissions from the Pb smelter operating from 1894 until the beginning of 2003. In 2001, the site emitted 18 tons of channelled lead, to which around 10 to 15 tons of diffuse effluent can be added – 0.8 tons of cadmium, 26 tons of zinc and 8,600 tons of sulphur dioxide. Air pollution has, however, decreased significantly over the last 30 years, from 350 tons of lead in the 1970s to around 12 tons in 2003.
- Impact on surface water: the water quality of the Haute-Deule canal (effluent discharge) falls in class 3 (bad quality). The estimated values of contamination of the sediments 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 also significantly reduced with the start-up of a sewage station in 1988 (150 tons of lead discharged in 1988, 4 to 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 limited to the site property boundary by hydraulic trapping. Also, to avoid dispersion of the pollutant plume, 100 m^3/h are pumped from former site wells. The variation in water quality is monitored using a network of 15 piezometers in the chalk aquifer and 4 others in the sandy aquifer in the north of the area. The aquifer remains suited for drinking water abstraction without treatment downstream of the site.
- Impact on soil: heavy metals are mainly confined to the upper soil levels (0 – 40 cm), except for zinc, which migrates deeper. A total of 600 ha of urban soils are heavily contaminated (>250 ppm Pb) and 4,000 ha show a lead concentration >200 ppm.
- Impact on agriculture: about 400 ha of soils used for agricultural production have been heavily contaminated (>250 ppm Pb). As a result, high levels of contaminants are also found in crops and animal products.
- Impact on health: human health has been affected by atmospheric pollution generated by the production units, by the smelter residue deposits (essentially by dust emissions), by the raw materials of the site's soil and by ancient industrial waste dumps. Increased lead concentrations in the blood were reported. Children are particularly affected: in 1995, 14% presented lead levels higher than the standard of 100 micrograms per litre of blood; in 2002, 11% of children aged 2 – 3 years living in the five closest municipalities were still affected. The adult population is equally affected, with 29 people declared inapt for work every year (average 1996-2001). It has to be noted however, that this health problem is

not only due to soil contamination but also to air pollution: assessing the relative responsibility of each contamination channel is almost impossible.

- Socio-economic impact: the decision to withdraw the plant caused unemployment for 830 workers of the company. The company's assets are far from adequate to meet the social liabilities. Also, this social crisis caused economic difficulties, extending to subcontracting firms (3,000 indirect jobs). The associated impacts were not considered in this study.

4.3.2 Cost estimation

Certain damages generated by contamination are due not only to soil contamination, but also to air and water pollution, both having an impact on public health. For this particular threat, it is also difficult to assess costs on a yearly basis as some of the costs are one-off expenditure (e.g. decontamination of soil) and others are recurrent costs that may occur over very long periods of time (more than 50 years). Assessing an average yearly cost requires converting one-off expenditures into a perpetual annuity equivalent. All types of cost, except non-use costs – NC, are identified in this case. As shown above, the costs related to soil contamination are substantial and are not easily bearable for the different actors.

Table 3: Synthesis – Average annual cost of soil erosion for the FR case study

PC	MC	SC	DC	NC
Reclamation of the site within redevelopment project, performed by private investor. Monitoring impact.	Demolition of contaminated buildings Soil decontamination and treatment Acquisition of contaminated land (>250 ppm Pb) and refitting of forests Monitoring impact	Human health impact (costs of disease, those inapt for work, etc.) Agricultural impact (loss of income) Urban impact (decrease in housing prices)	Hydraulic pumping in the aquifer to limit propagation of the pollution plume Survey of groundwater quality Decontamination of school yards	Loss of non-use value for citizens
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 million. The total costs of the off-site measures (SC + DC) outweigh on-site costs (PC + MC) by a factor of 5:1. These figures can be regarded as conservative estimates, as they do not take in account the historical soil contamination damage and the costs of measures realised before the MetalEurop plant was closed.

Due to the particular economic situation of this case study – the company closed down in 2003 due to bankruptcy – three levels of decision-making are involved in the management and funding of the contaminated site: local, regional and national level. The costs for prevention, suffered damages, monitoring and reclamation concerning off-site costs are borne essentially by the public administration (local authorities and ADEME). A private investor will perform the reclamation of the site integrated in the redevelopment project (waste treatment plant), in close relationship with the local partners.

The costs identified above will be financed by the private investor. For on-site soil reclamation within the redevelopment project, public subsidies from the Regional Council, the European Fund for the Redevelopment of Regions (FEDER), and the French Government for reclamation costs in the vicinity of the site (off-site costs) will be paid.

4.3.3 Conclusion

The cost related to soil deterioration due to contamination are significant. This situation is encountered in most megasites leading to new national prevention principles for managing those sites in order to avoid repeating such situations of "orphan sites".

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

The social cost estimation is based on the potential development of human health diseases not yet observed in the population. It should be considered as a maximum estimate for the costs of non-action. The consequences of ongoing actions cannot be assessed at the time.

The spatial distinction between on-site and off-site impacts is of central relevance in the case of local contamination, taking account of the fact that damage occurs both at the polluted site and in spatially remote areas (off-site damage). For soil contamination, off-site costs tend to exceed the on-site costs by far (by a factor 5 in this case).

4.4 Salinisation, Spain, Central Ebro Area

The ***salinisation*** case study is located in Aragón, central Ebro Valley, the most arid inland region of Europe. Spain is the country with the largest irrigated area (3.4 million ha) in Western Europe (FAO 1994). This particular case is related to extensive irrigation, which allows plant growth in otherwise water-deficient conditions. Irrigation is mainly applied in arid and semi-arid regions, and can increase growth and build-up of soil organic matter.

The central Ebro area is an agricultural zone, with a low density of population. It is mainly composed of flat areas, with an average rainfall of 400 to 500 mm/year, and a potential evapotranspiration of 1,300 to 1,400 mm/year. The irrigated land of Aragón has developed over the last 2000 years and comprises 413,100 ha, with an additional 404,600 ha that are likely to be irrigated in the future. Irrigated crops include mainly Alfalfa, winter cereals (barley and wheat), maize, sunflower, deciduous fruit trees, horticultural crops and rice.

4.4.1 Threats encountered in the area

Different events are at the origin of the increased salinisation of soils and groundwater resources, including the intensification of agricultural production, improper irrigation and drainage management, and improper land levelling with soil destruction and burial under geological materials generating salt accumulations underground. Due to the local climatic and soil quality conditions, the central Ebro area very vulnerable to salinisation.

A survey of farmers and local agricultural experts was conducted to establish the relative importance of different land qualities and their impact on the production of different crops. The standard value of relative yield decreases under saline conditions.

Several conservation measures have been undertaken for several years to control salinity in the Aragón area, such as application of low salinity water for soil with good natural or artificial drainage properties; drainage of salts by open ditches and subsurface pipes; a change of crops from corn and sunflower to rice or the use of salt-tolerant crops. Degraded soils were reclaimed through soil amendments (adding calcium ions that displace sodium ions from the soil exchange complex), modification of the irrigation water, breaking up the surface crust, using soil reclaiming plants, and technical specifications in drainage projects.

4.4.2 Cost estimation

The cost estimation focuses on lost crop productivity and reclamation costs, by amendments or modifications of the irrigation system.

Table 4: Gross margin and unit gross magrin loss for different crops production

	Gross margin loss (€$_{2003}$)			**Unit gross margin loss (€$_{2003}$/ha)**		
Crop yield decrease	slight	moderate	severe	slight	moderate	severe
	10%	25%	50%	10%	25%	50%
Wheat	333,409	833,522	1,667,045	74	187	375
Barley	47,662	119,153	238,307	50	127	253
Maize	641,711	1,604,277	3,208,554	173	434	867
Lucerne	497,616	1,244,042	2,488,083	136	341	683
Apple	55,240	138,100	276,200	359	897	1793
Peer	70,431	176,076	352,152	306	766	1531
Peach	115,943	289,858	579,717	366	914	1829
Apricot	23,930	59,822	119,646	239	598	1196
Potato	108,295	270,739	541,477	1245	3111	6224
Total loss	**1,894,236**	**4,735,590**	**9,471,180**	**139**	**348**	**696**

While these are estimates of the on-site costs related to agricultural income, the off-site effects caused by soil salinisation could not be assessed in this case study. This would include damage to the environment and to infrastructure as well as non-user costs (NC). The costs of salinisation are essentially borne by farmers and water users through the impact on crop yields and the modification of irrigation systems, as well as water quality monitoring.

4.4.3 Conclusion

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

- 16% in case of light salinisation (139 €$_{2003}$ per ha),
- 39% in case of moderate salinisation (348 €$_{2003}$ per ha),
- 78% in the case of severe salinisation (696 €$_{2003}$ per ha).

The original values in the case study date back to 1988, these were translated into 2003 Euro values using Spanish harmonised annual average consumer price indices. Data availability did not permit to account for the time distribution of cost or for different soil types and their vulnerability to salinisation. An evaluation of the ecological side effects or long-term revenue losses was not carried out, hence the results should be considered as partial.

4.5 Organic Matter Loss, Sweden

At the European scale, three types of configurations for OM losses issues are encountered: i) peat exploitation in Northern Europe (Scandinavia, Ireland), ii) intensive agriculture and progressive depletion of organic matter content under middle latitude (e.g. France, Netherlands, Germany), iii) historic and intensive OM losses due to climate and desertification in the Southern Europe. The Peat extraction can differ from the two other configurations as it occurs intentionally and is not reversible.

The case studies selected in Sweden are related to peat cutting, thus only addressing a specific facet of the problem of organic matter loss. Although peat soils only cover a minor part of the total global 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 as a hotspot of organic matter loss. The two areas studied hereafter, the Porla and the Västkärr areas, are two adjacent peatlands (10 km apart) in the Southwestern part of Sweden where peat has been harvested almost down to the mineral soil bottom and converted into wetlands.

4.5.1 Threats encountered in the area

Peat cutting is performed from the South of Sweden to almost the far North. Apart from the high mountains in the Northwest, peat-cutting activities are spread over all Sweden. The two peat cutting areas investigated, the ***Porla mire*** and the ***Västkärr site***, are restored as wetlands for 1 to 10 years, and then turned into overgrown mires. The impacts mainly concern biodiversity (changed wetland biodiversity), groundwater quality, and land values.

4.5.2 Cost estimation

Information on costs was received from the peat and energy companies. Due to the specificity of the situation (even Environment Protection authorities do not consider peat mining as soil degradation), there is no cost estimate for prevention or monitoring.

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 the costs of compensatory measures, as the restoration of the organic matter content in the soil is possible at a human time scale. Expenditure of the peat companies to convert the two sites into wetlands was estimated at ca. 25.000 € for Porla and ca. 35.000 € for Västkärr.

4.5.3 Conclusion

This case study should not be considered as soil degradataion as such: peat cutting deliberately uses peat as a source of energy. It is not a loss of organic matter as discussed in the Soil Thematic Strategy. In order to assess the situation more fully, different types of cost would need to be estimates, in particular the total economic value of the bog that is lost as a consequence of peat extraction, restoration costs, benefits of rewetting (e.g. biodiversity), and effects on the property value. This information, however, is not available at present.

5 Empirical Estimation of the Impacts

Based on the review of the literature and the case studies, Volume III of this report assesses the current, annual cost of soil degradation in the European Union. The analysis assessed not only the on-site costs of soil degradation, which have traditionally been the focus of economic and especially agronomic research, but has also considered the off-site costs associated with soil degradation.

5.1 Estimation for Erosion, Contamination and Salinisation

In the current study, three of the eight different soil threats identified by the European Commission were quantified comprehensively: erosion, contamination and salinisation. For the other threats, a qualitative discussion is provided in Volume III of this report, supported by quantified economic evidence where available. For the three threats treated in greater detail, the approach and results are briefly summarised below.

5.1.1 Erosion

In the economic and agronomic literature, there is considerable evidence of the impacts of erosion on agricultural productivity and yields (i.e. the PC category). In recent years, a number of studies have also tried to assess the off-site costs of erosion, in many cases leading to the result that these costs are indeed much higher than the on-site costs. From the identified literature as well as the results of the two case studies, three values were derived for each of the cost categories identified above: a lower-bound and an upper-bound estimate as well as an intermediate mean value. For the category of non-use cost, it was not possible to arrive at an estimate due to a lack of empirical data.

Table 5: Estimates of the Costs of Erosion (€$_{2003}$ / ha*y)

Estimate	PC	MC	SC	DC	NC
Upper-bound estimate	11.06 €	29.24 €	169.09 €	25.87 €	-
Intermediate estimate	7.56 €	2.86 €	85.92 €	25.87 €	-
Lower bound estimate	0.50 €	0 €	21.43 €	0 €	-

These average values were then combined with the BRGM plot database, which assembles real erosion data for 11 land use categories, of which six were excluded (see Cerdan et al. 2003 and Volume II of this report). The database covers the old EU-15 Member States (except for Finland, Ireland, Luxembourg and Sweden) as well as Lithuania and Switzerland.

The remaining five categories cover 98 % of the calculated erosion in Europe. Within these, 70 % of the calculated erosion falls into the category arable land. For this category, the impact of erosion was further differentiated for four levels of intensity: no erosion or light erosion (less than 0.5 tons / ha*yr), moderate erosion (0.5 – 1 tons / ha*yr), severe erosion (1 – 5 tons / ha*yr), and very severe erosion (more than 5 tons / ha*yr).

The following table provides an overview of the estimated total cost of erosion for the thirteen countries covered in the database (equivalent to a surface area of 150.5 million ha). It should be noted, however, that these results were derived by making different assumptions and simplifications in order to overcome data limitations. These necessary simplifications are documented in detail in Volume III of this report.

Table 6: Estimated Total Cost of Soil Erosion (million $€_{2003}$)

	PC	MC	SC	DC	Total Estimate
Lower bound	40	0	680	0	**720**
Intermediate estimate	588	222	6,676	2,010	**9,496**
Upper bound	860	2,272	13,139	2,010	**18,281**
Percentage (intermediate)	6.2%	2.3%	70.3%	21.2%	**100.0%**

Note: the total cost applies to the 13 countries covered in the BRGM plot database and to five land use categories, equal to an area of 150,510,000 ha

5.1.2 Contamination

Contamination is one of the major threats for soils in Europe, which has been assessed at the European level for several years (EEA-UNEP, 2000, EEA, 2002). To adequately assess the economic impact of soil contamination, it would be necessary to reflect the diversity of situations, as the economic impact of soil contamination is highly site specific. Costs depend on the type of contaminant, the spatial extent of the pollution and its intensity, the natural characteristics of the contaminated site and the socio-economic characteristics of the surrounding area. However, while such factors have been addressed in local case studies, the calculation of a Europe-wide figure on contamination is impeded by the fact that much of the data is either unavailable, or not available in a unified format. This includes basic indicators such as the surface area affected or the population exposed to contamination, partly because of differing definitions of tolerable risk levels in the different Member States.

The different cost categories were estimated as follows:

- Private costs (PC) largely consist in environmental impact monitoring costs. An aggregate estimate was calculated based on French figures, assuming that groundwater monitoring is implemented in 0,5 to 1,5% of all industrial sites. This represents a total number between 7,500 and 22,500 sites in Europe, of 1,5 million contaminated sites identified by the EEA. Based on results from the MetalEurop case, with groundwater monitoring costs estimated at € 12,000 per year, the time-adjusted total environmental monitoring cost ranges between **€ 96 and 289 million** per year.
- The total cost of mitigation and clean-up (MC) was assessed using 1999 EEA estimates of public expenditures on remediation of contaminated sites as a percentage of GDP. Reported values range between 0.05‰ (Spain) and 1.5‰ (Netherlands), with 8 countries spending less than 1‰. For those countries without data, annual expenditure was assumed equal to the EU average of 0.59‰ of GDP. The annual cost is computed for each Member State and **the total cost is estimated at € 3,400 million**. However, the annual expenditure of each Member State for remediation is not proportional to the contamination situation, but is rather determined by political considerations. To account for this, the actual annual expenditure for remediation was related to the total estimated cost of removing all contamination. In this way, mitigation costs are calculated as the average annual cost that each Member State would have to bear if the decontamination process was entirely carried out over a fixed period (15, 30 and 50 years). At the European level, the estimated total cost ranges from **€ 2 to 41 billion per year, with an intermediate estimate at € 6.7 billion per year**.

- The social costs (SC) are highly site-specific. In the absence of reliable, comprehensive and uniform data, a pragmatic approach was implemented, based on the results of the MetalEurop case study documented in Volume II of this report. For this case, the off-site costs exceed the on-site costs by a factor of 5. Given that off-site social cost are probably higher in the case of MetalEurop than in other contaminated sites, a factor of 5:1 is taken as an upper bound, and 1:1 as a lower bound. The aggregate off-site social cost of contaminated sites at the European level is thus estimated between **€ 2.3 and 207.6 billion per year, with an intermediate value of € 17 billion per year.**
- For the assessment of defensive costs (DC), it was assumed that only 0,5 to 1.5% of the 1,5 million contaminated sites present a potential threat for groundwater, and that defensive measures have actually been implemented in 20% of these sites where groundwater is contaminated. Based on the cost estimate for the MetalEurop case study (300,000 € per year), the total time adjusted cost on the European level was estimated at **€ 482 to 1,447 million**.

Combining these figures, contamination by industrial and other activities is generating a total cost at the EU level roughly estimated at € 25 billion. Social costs (SC) represent about 69% of this total cost, whereas remediation costs (MC), based on the 'fit-for-use' principle adopted by most European countries, represent another 27%. PC and DC represent approximately 4% of the total cost. However, a large part of the remediation costs is covered by the public budget. From an economic point of view, they can therefore partly be considered as social costs, as they are paid by the taxpayers and not by the polluters. The upper and lower bound values should be used to assess the order of magnitude of the impacts of soil contamination.

Table 7: Cost of Soil Contamination at European level (M€$_{2003}$)

Cost categories	PC	MC	SC	DC	Total
Lower bound estimate	96	2,187	2,283	482	**5,049**
Intermediate	192	6,658	17,126	965	**24,941**
Upper bound estimate	289	41,234	207,615	1,447	**250,585**
Percentage of total cost (1)	0.8%	26.7%	68.7%	3.9%	**100.0%**

(1) Based on the intermediate values

5.1.3 Salinisation

Data presented by the European Environment Agency (EEA 2003) indicates that, in the 25 Member States and the Accession Candidates, salinisation is only problematic in Spain, Hungary and Bulgaria. For European countries other than these, no data is available. Consequently, the extrapolation was limited on the three countries.

In the EU, very little research has looked at the economic impacts of salinisation. Quantified results are few and far between, assessments of off-site effects are virtually non-existent. In the non-European context, research on the economic impacts of salinisation has mainly taken place in Australia.

The extrapolation of the economic impacts of salinisation mainly considers the impacts on agricultural productivity. Based on results of the Spanish salinisation case study, it was assumed that in cases of light salinisation, up to 10% of the output are lost, between 10 and 50% for moderate salinisation, and 50 – 90% in cases of severe salinisation (see Volume II of this report for a detailed description). The impacts of salinisation on agricultural output were then calculated on the basis of the agricultural land area and agricultural gross value added per ha. For this, the EEA data on salinisation in Spain, Hungary and Bulgaria were applied to the total agricultural area of the affected countries.

For the off-site costs (SC & DC), in the absence of European estimates, impacts were estimated based on an Australian study that had assessed the damage to transport infrastructure (roads and bridges) from shallow saline groundwater, damage to water supply infrastructure as well as environmental costs, including impacts on native vegetation, riparian ecosystems and wetlands, as well as knock-on effects on tourism (PMSEIC 1998).

Based on these assumptions, the following costs were estimated:

Table 8: Total Cost of Salinisation for Spain, Hungary and Bulgaria (million €$_{2003}$)

	Spain		**Hungary**		**Bulgaria**	
	LB	UB	LB	UB	LB	UB
Agricultural yield losses	42.71	137.64	70.16	133.91	1.08	5.38
Infrastructure damage	12.08		18.23		1.32	
Environmental damage	4.83		7.29		0.53	
Total	**59.62**	**154.55**	**95.68**	**159.43**	**2.93**	**7.23**

5.2 *Interpretation of the Results*

Given the lack of empirical data that is apparent for many threats, and for many cost categories, the quantitative results presented in this study have to be interpreted with caution. Even for threats like erosion and contamination, which have been researched in greater detail in recent years, tremendous gaps still exist when it comes to placing a monetary value on the observed damage.

Despite these limitations, the current study has provided tentative estimates of the economic impacts of soil degradation in Europe, which may serve to illustrate the dimension of the problem. Table 9 presents the range of estimates calculated for the different cost categories, for three types of soil degradation. Two points should be noted:

- The numbers below should be regarded as **conservative estimates**, as many impacts could not be quantified at all. Hence the values reported as upper bounds in the table below do not provide the upper bound for all impacts of soil degradation, but merely the upper bound *for those aspects of soil degradation that were quantified in monetary terms in this study*. The real costs of degradation, including impacts not quantified here, can be expected to exceed, and in some cases exceed by far, the upper bound figures below. This applies above all to the ecosystem services as part of the social costs (see Box 1), and to the non-use values of soil. The latter were not assessed in this study as they have rarely ever been quantified in economic terms.
- The figures reported above are **annual costs**. In principle, they could be discounted and added up over time. As it is disputed whether discounting can be applied to soil, and at what rate, this was not done. To illustrate the effect of discounting, some calculations for the case of erosion are presented in Volume III of this report, chapter 5.5.

Table 9: Overview of the Total Annual Cost of Soil Degradation (in M€$_{2003}$)

		Erosion			**Contamination**			**Salinisation**	
		LB	**Mean**	**UB**	**LB**	**Mean**	**UB**	**LB**	**UB**
On-site costs	PC	40	588	860	96	192	289	114	277
	MC	0	222	2,272	2,187	6,658	41,234	243*	2,005*
Off-site costs	SC	680	6,676	13,139	2,283	17,126	207,615	43	43
	DC	0	2,010	2,010	482	965	1,447	-	-
Total		**718**	**9,496**	**18,281**	**5,049**	**24,941**	**250,585**	**157**	**320**

LB = lower bound, UB = upper bound (for those impacts that were quantified at all).

* The MC for salinisation are not included in the total, due to their hypothetical nature.

From these calculations, the following conclusions can be drawn:

- On an aggregated level, the **private, on-site costs of soil degradation** (usually suffered by land users) will not be a major cause of concern in many cases. For soil erosion, the upper-bound estimate of the annual private costs does not exceed 0.5 % of the agricultural gross value added in the countries covered. For the case of salinisation, the estimated private costs are only significant in Hungary, where the impacts could lie between 3.3 % and 6.3 % of agricultural gross value added. In Spain, with estimates ranging from 0.2 % to 0.6 % of agricultural gross value added, the estimated private costs are manageable. However, this is also due to the angle of this study, which has focussed only on national or European averages, masking the fact that soil degradation may cause considerable private on-site costs in the affected regions. It should also be borne in mind that the impacts of soil degradation will often be cumulative and, in most instances, irreversible. Hence, while the costs may appear negligible on a year-to-year basis, they can become substantial when added up over a longer time.
- The **social, off-site costs of soil degradation** (covered by society) are far more substantial in most cases. For example, in the case of erosion, cost estimates range from € 1.8 billion to € 14.3 billion p.a., which corresponds to 1.1 % to 8 % of agricultural gross value added for the thirteen countries covered. The off-site costs exceed the on-site costs by a factor of seven (for the upper bound estimate) up to a factor of seventeen (for the lower bound estimate). With regard to contamination, the situation is more complex, as off-site effects are not always present. Consequently, the extrapolation arrives at a situation where off-site-effects may be larger than or equal to on-site effects. For large contaminated sites located in densely populated areas, such as the MetalEurop case documented in Volume II of this report, the off-site costs may well exceed on-site costs by a factor of five or more. The general finding that off-site costs will often surpass on-site costs holds despite the fact that off-site costs are more difficult to delineate and quantify. This difficulty applies to all types of soil degradation, and in particular to subsets like the impact on ecosystem services and on non-use values of soil.

The bulk of the costs of soil degradation will thus not be felt by the people causing it. Instead, the majority of impacts occurs off-site, affecting neighbours, downstream water users, or other ecosystems. Thus, if the focus of the analysis shifts from the individual plot or the farm level to include regional, national or even global off-site effects of soil degradation, the estimated potential impact increases rapidly. At the same time, whereas on-site effects are described fairly well in the literature, off-site effects are subject to more uncertainty. If the relevant off-site impacts, including non-use values and ecosystem services, could be quantified more comprehensively, the imbalance between on-site and off-site impacts would be even more pronounced.

On the whole, the analysis has shown that the inherent complexity of soil functions and their degradation, and the interdependencies between different soil degradation processes are difficult to grasp in an economic valuation study. To adequately account for these factors would require far more data in far greater detail than is currently available, both from the economic and from the soil scientific perspective.

6 Policy Recommendations and Further Research Needs

This study has been the first in Europe to assess the economic dimension of soil degradation in a comprehensive way, across different countries and for different soil threats. The results of the study should not be seen as an exact quantification of all impacts, but rather as a way to assess the dimension of the problem of soil degradation from a different perspective. Still, many impacts need to be explored further before more definite conclusions can be drawn.

To date, it is clear that in many instances, the impacts that were not quantified in this study will exceed those that were quantified. Consequently, the upper bound figures presented here are only the upper limit for the quantifiable impacts, whereas the real impact of soil degradation will be much higher. In line with the precautionary principle, policy recommendations need to reflect not only the quantifiable impacts, but also take into account those impacts that could not be assessed in monetary terms.

6.1 Policy Recommendations

Irrespective of these caveats, this study has demonstrated that the economic impacts of current soil degradation trends in Europe are substantial, and give cause to concern. Even though many impacts cannot be quantified in monetary terms at this stage, the estimated costs presented are substantial, running into the order of several billion Euro per year. In this sense, the added value of the current study has shed some light on the magnitude of the problem, as well as the distribution between on-site and off-site costs.

- The private, on-site costs of soil degradation are significant, but will not be a major concern in the short run. However, on the local scale, impacts will be more substantial for the affected areas. Also, impacts will be felt more strongly over time.
- The off-site costs of soil degradation are substantial. In some cases, they may exceed the on-site costs by a factor 10, despite the fact that a large part of the off-site costs could not be quantified. Off-site costs are generally covered by society: as externalities, they are not reflected in the decision-making framework of soil owners and users.

These discrepancies underline the economic rationale for an ambitious soil protection policy. In the short term, the private, on-site costs are mostly moderate. Even where they are significant, the fact that the soil user is often not the same as the soil owner means that the soil user has no incentive to protect the soil beyond the rental term, leading to unsustainable soil use. The off-site, social costs are substantial, but are covered neither by the polluters nor by insurers, so that there are few incentives for changed behaviour. In line with the polluter-pays-principle, **policy solutions** are therefore necessary to **change these incentives**. By internalising the external costs of soil degradation, off-site impacts can be better integrated into the decision-making and the behaviour of soil users. In principle, this can be done through taxation, through behavioural codes, or through conditionality for subsidy payments.

In practice, however, it may be problematic to relate a specific, localised off-site impact to an individual soil use. For soil contamination, significant time lags may exist between the contamination itself and the detection of off-site impacts. For salinisation or erosion, the relative contribution of individual soil uses to the occurrence of off-site impacts is often difficult to establish. To address this, **more effective and unified soil monitoring** is required. Soil monitoring systems need to be designed in such a way that the link to the assessment of socio-economic impacts is easily made. In particular, soil monitoring can be used to support the use of political instruments aimed at internalising external costs.

To some degree, the internalisation of off-site effects of soil degradation can be achieved through better **integration of soil protection requirements** into other policy areas.

- For soil degradation caused by agricultural soil uses, the most suitable instrument to address off-site effects is through the use of the cross-compliance mechanism established under the Common Agricultural Policy. Here, it is necessary to better integrate off-site effects into the definition, guidance and the practical implementation of "good agricultural and environmental conditions" and "good agricultural practice". Next to the cross-compliance mechanism, voluntary approaches such as cooperative agreements could also be effective solutions.
- Soil protection requirements should also be better integrated into the implementation of the Water Framework Directive. By 2009, the WFD mandates the establishment of programmes of measures, which should achieve the good ecological status for water bodies in the most cost-effective way. Currently, off-site effects of soil degradation are among the main pressures that prevent water bodies from reaching good ecological status, e.g. in the case of erosion-induced water pollution or soil and groundwater contamination. Where impacts on a water body can be related to soil degradation, the most cost-effective way of addressing them could include better soil protection.
- Furthermore, there is a clear link between soil protection and flood risk management. In the developing European approach to flood risk management, flood prevention measures are becoming increasingly relevant to support and complement structural / technical flood protection measures. In order to prevent or limit floods, the capacity of soils to absorb and retain rainwater in upstream areas needs to be enhanced. This can be achieved e.g. through measures that reverse or limit soil compaction and soil sealing. Soil protection and land use policies can thus make a significant contribution to flood risk management. In view of the substantial economic damage caused by flooding events, such measures offer themselves as a relatively inexpensive contribution to flood prevention.
- In the area of climate change, soil protection needs to play a double role: first, maintaining healthy soils and the build-up of organic matter can enhance the role of soil as a sink for atmospheric CO2. By contrast, soil degradation will lead to the release of carbon from soils. Furthermore, soil protection will also be key to adaptation strategies, as the resilience of ecosystems to adapt to the changing climate depends not least on vital and multifunctional soils. The policy objective must therefore be to stabilise and, where possible, increase the level of soil organic matter.
- For the area of land use and spatial planning, the planning of industrial, residential and commercial development needs to take more account of soil properties. In order to minimise the cost of soil degradation, it is not only necessary to protect the most vulnerable soils, but also to identify soils that are more suitable for polluting or degrading activities, and to concentrate such activities on such soils. For the remediation of contaminated land, the objective has to be to minimise new contamination and prevent accidental pollution, to decontaminated existing contaminated sites as far as possible, and to limit the affected area by preventing the spread of mobile pollutants.

Other policy areas where soil protection requirements need to be better integrated are internal market policies, chemicals policies and transport. The issue of demolition waste and construction material is a particular example of this, as it lies at the interface between internal market policies, waste policies and soil protection.

The enhanced integration of soil protection requirements should be supported through the nascent European Thematic Strategy on Soil Protection. For any of the policy areas mentioned above, the integration of soil policy requirements will depend on clear definitions and indicators for soil quality, as well as specified objectives for soil protection. Delivering such definitions, indicators and objectives should therefore be one main focus of the Thematic Strategy.

6.2 Research Needs

The current study should thus be regarded as a first step, which needs to be developed and refined further. In addition to the need for a coherent soil monitoring system identified above, socio-economic **research needs** concern four issues in particular.

- The concept of ecosystem services that captures the interactions between soils and other parts of the ecosphere. Since soil is closely related to the natural processes taking place in the hydrosphere, the atmosphere, the lithosphere and the biosphere. Therefore the degradation of soils will have a direct impact on the functioning of these other compartments; a fact that is of particular relevance in the context of climate change. Through such interactions, soil provides different ecosystem services, not all of which are sufficiently understood. While many ecosystem services could not be assessed economically in the course of this study, there is some evidence that adding ecosystem services into the equation can affect the judgement on the economic viability of different land uses. In particular, the value of lost ecosystem services may far outweigh the short-term benefits of intensive land use, whereas sustainable soil management practices can enhance the ecosystem services provided by soils (see e.g. Balmford et al., 2002).
- A second category that merits closer inspection are the non-use values of soil. Soil as a non-renewable and non-replicable resource has been the fundament of human development since the very beginnings of civilisation, and bears manifold cultural and spiritual connotations. Soil therefore needs to be protected both in its own right, and as an asset for future generations. From an economic perspective, such considerations would form part of the non-use value of soil. However, this non-use value has barely been researched at all, safe for a few Australian estimates.
- In terms of different soil threats, several types of soil degradation could not be assessed comprehensively. This was either due to a lack of economic data, or due to the absence of comprehensive soil data on the European level, or both. For threats such as the loss of soil organic matter, the loss of soil biodiversity, soil sealing and soil compaction, more primary studies are needed in order to assess their economic impacts.
- A fourth research challenge concerns the **intertemporal valuation of soil degradation**. This concerns not only the choice of the appropriate discount rate, but more importantly the questions of how to deal with irreversibility, and how to predict and incorporate the resilience of soils to increasing pressures. To move ahead in this regard, a “baseline scenario” for soil degradation would be necessary in order to assess how pressures on soil are likely to develop over time, how this will affect soil quality and resilience, and what impact this will have on soil users.

To address these questions, research projects and networks would need to be established under future calls of the 6th and in the 7th Framework Programme on Research and Development. These should include both basic research and policy oriented research, with the aim of building up and extending the European knowledge and data base.

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