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RIVM report 481505018

Technical Report on Soil Degradation in Europe: an integrated economic and environmental assessment

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May 2000

This Report has been prepared by RIVM, EFTEC, NTUA and IIASA in association with TME and TNO under contract with the Environment Directorate-General of the European Commission.

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Abstract

The economic assessment of priorities for a European environmental policy plan focuses on twelve identified Prominent European Environmental Problems such as climate change, chemical risks and biodiversity. The study, commissioned by the European Commission (DG Environment) to a European consortium led by RIVM, provides a basis for priority setting for European environmental policy planning in support of the sixth Environmental Action Programme as follow-up of the current fifth Environmental Action Plan called 'Towards Sustainability'. The analysis is based on an examination of the cost of avoided damage, environmental expenditures, risk assessment, public opinion, social incidence and sustainability. The study incorporates information on targets, scenario results, and policy options and measures including their costs and benefits.

Main findings of the study are the following. Current trends show that if all existing policies are fully implemented and enforced, the European Union will be successful in reducing pressures on the environment. However, damage to human health and ecosystems can be substantially reduced with accelerated policies. The implementation costs of these additional policies will not exceed the environmental benefits and the impact on the economy is manageable. This requires future policies to focus on least-cost solutions and follow an integrated approach. Nevertheless, these policies will not be adequate for achieving all policy objectives. Remaining major problems are the excess load of nitrogen in the ecosystem, exceedance of air quality guidelines (especially particulate matter), noise nuisance and biodiversity loss.

This report is one of a series supporting the main report: *European Environmental Priorities: an Integrated Economic and Environmental Assessment*. The areas discussed in the main report are fully documented in the various *Technical reports*. A background report is presented for each environmental issue giving an outline of the problem and its relationship to economic sectors and other issues; the benefits and the cost-benefit analysis; and the policy responses. Additional reports outline the benefits methodology, the EU enlargement issue and the macro-economic consequences of the scenarios.

Technical Report on Soil degradation

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This report is one of a series supporting the main report titled *European Environmental Priorities: an Integrated Economic and Environmental Assessment*
Reports in this series have been subject to limited peer review.

The report consists of three parts:

Section 1:
Environmental assessment
Prepared by G.J. van den Born, B.J. de Haan (RIVM)

Section 2:
Benefit assessment
Prepared by D.W. Pearce, A. Howarth (EFTEC)

Section 3:
Policy assessment
Prepared by D.W. Pearce, A. Howarth (EFTEC)

References
References made in the sections on benefit and policy packages have been brought together in the Technical Report on Benefit Assessment Methodology. The references made in the section on environmental assessment follows at the end of section 1.

Contents

1. Environmental assessment

1.1 Introduction

The issue of soil degradation ranges from erosion and contamination of the topsoil to overabstraction and contamination of ground water. Soil degradation is an issue of growing concern in Europe: 12% of total European land area has been affected by water erosion and a 4% by wind erosion (Dobris [+3]). The loss of fertile soil itself may degrade the productivity of the local agriculture. Also, the eroded soil being deposed downstream/wind may cause considerable damage to water management systems by filling up water storage reservoirs. Flash floods may occur after torrential rains if water-absorbing capacity has been diminished for agri-economic reasons.

According to the Dobris[+3] report about 115 million hectares are suffering from water erosion and 42 million hectares from wind erosion (EEA, 1998). The problem is greatest in the Mediterranean region because of its fragile environmental conditions, but problems exist in most European countries. Soil erosion is intensified by agricultural intensification, but also by land abandonment and forest fires, particularly in marginal areas. Abatement strategies, such as afforestation, for combating accelerated soil erosion are lacking in many areas.

The complexity of soil degradation makes it hard to make a single statement about its underlying causes. Though it is generally accepted that soils should be preserved, landowners may manage their land unrestrictedly. Owners or users of land subject to erosion may have little incentive to control erosion rates if they do not show up clearly in on-site productivity losses. Even if there is an underlying trend to such losses, they are often 'masked' by changes in compensating applications of fertiliser. Where on-site damage is evident and directly traceable to erosion, it will often (but far from always) be profitable to control the erosion by changing management practices, e.g. reduced intensity of crops, better cover from surrounding vegetation, more organic matter in the soil etc.

The justification for policy interventions tends to come in two contexts (a) where off-site costs are significant, since these will tend to be ignored by landowners, and (b) where the effect of soil erosion is not transparent to the owner.

(a) Off-site costs. Because of the difficulties of tracing the 'life cycle' of soil losses, it would seem unlikely that it is possible to develop credible economic instruments that penalise poor soil management behaviour. Any measures would tend to be fairly broad spectrum and hence not related to specific damage incidence. Such broad measures already exist in some countries, e.g. in terms of controls on land drainage, and land use controls. There is, however, a clearer need to adopt economic incentives in some form. Ideally, some tax on erosive technology and on choice of erosive crops (e.g. winter cereals in the UK have led to significant increases in erosion) should be applied. An 'erosion tax' is therefore worthy of further investigation. In the meantime, extension of EU Regulation 2078/92 may be appropriate – see below.

(b) On site costs. Current agri-environmental regulations hold considerable promise as a means of combating soil erosion. Measures include encouragement for organic farming, afforestation, and on-farm crop management changes. Lawrence (1998) cites two case studies from Germany where mulch seeding and catch crops had clearly identifiable impacts on reduced erosion. Lawrence anticipates further improvements under Agenda 2000 because of beef extensification, 'green' rural development measures, more agri-environmental measures and more cross-compliance. It also seems clear that on site losses need far more publicity if land owners are genuinely ignoring significant soil losses because of masking effects.

EU Regulation 2078/92 permits co-financing by the Commission of extensification measures in agriculture such as organic farming, low input technology, and encouragement of pasture. Premia are paid to farmers according to the degree of extensification adopted. It is not clear if these policies have so far been successful, but Frohberg (1995) simulates similar policy measures for Germany and concludes that they could be successful. More effective measures might involve abolishing the standard rates of premia and opting instead for farmers bidding for the payments.
Thus each farmer would ask for a premium of a specified size in return for adopting more extensive methods of agriculture. Similar measures have been used in the USA (Frohberg, 1995).

There is a need to raise awareness in the general public and among policy-makers of the importance of soils and pressures on and risks to soils. In keeping with effectiveness, the subsidiarity principle calls for actions taken at the most decentralised level. Given the close relation between water management and soil management, coherence with the proposed water framework directive will enhance the effectiveness of a strategy to combat soil degradation.

Soil degradation encompasses several issues at various spatial and time scales. Acidification is the change in the chemical composition of the soil, which may trigger the circulation of toxic metals. Eutrophication may degrade the quality of ground water. Groundwater overabstraction may lead to dry soils. Atmospheric deposition of heavy metals and persistent organic pollutants may turn soils less suitable to sustain the original land cover and land use. Some of these problems have been treated in specific annexes. This annex concentrates on the problem of current soil erosion due to lacking soil management. Climate change will probably intensify the problem. To demonstrate this we assessed the threat of future agricultural productivity loss due to climate change. This restriction is made as the issue of increased land degradation is according several sources assumed to be a threat to food production (Scher and Yadav, 1994)

In this reporting on land degradation two main approaches are presented. One approach describing current threat, and another addressing the future threat. The first is discussed by referring to a case study in Spain, where the economic aspects of degradation and degradation conservation have been analysed in details. The second approach addresses the modelling of future water erosion, considering the impact of climate change.

1.2 Method

1.2.1 Current threat of soil erosion

Following the dramatic 1989 events, where flash floods took several lives and caused great damage (more than 7000 persons had to be evacuated in the Malaga province), the Spanish government developed a strategy to control soil erosion (ICONA, 1991). The ICONA report seems to be one of the few consistent cost benefit analyses of soil erosion abatement. It compares two policy alternatives:

1. the <u>minimum</u> costs alternative supposes a basic investment threshold in the order of Pts 400,000 millions [1]
2. the <u>maximum</u> costs alternative implies:
   4.8 million hectares natural vegetation restoration at Pts 165,000 per hectare
   3 million hectares agricultural soil protection at Pts 50,000 per hectare
   8 million cubic meters hydrotechnical work at Pts 18,000 per cubic meter
   add to this augment the sum of the above costs by 10% for auxiliary actions and impact restoration and the alternative would require an investment of Pts 1,200,000 millions

As the minimum plan would require 15 to 20 years and the maximum plan about 40 years of execution, in both cases the annual investment is in the order of Pts 20,000 to Pts 30,000 millions (ICONA, 1991).
<u>Benefits</u> are estimated (Ministerio de Economia, 1987):

[1] Pts 1000 ≈ € 6

limiting the valuation of production losses caused by erosion to 'reduced life time of water reservoirs', 'loss of agricultural soil fertility' and 'direct production losses due to flooding', opportunity costs rise to a minimum of ₧ 40,000 millions per year, with a growing tendency (ICONA, 1991).

In this case study, benefits are a factor of 1.3 to 2 larger than the costs.

In order to estimate the extend of the problem in the EU, we prorated the above cost-benefit analysis to the other Member States. In agricultural policy, special attention is paid to identify so-called 'less favoured areas' (LFA). These are areas where natural conditions handicap farming. Concerning LFAs three types are distinguished:

1. Mountain and hill areas, where altitude and slope reduce the growing season and the scope of mechanisation;
2. Simple LFAs, marked by poor soil and low agricultural income;
3. Specific LFAs, small areas with poor water supplies, periodic flooding, etc.

We selected the indicator 'mountain and hill areas' (CEC-DG06, 1998) as representative for the area vulnerable to water erosion. For Spain this indicator has the value of 7.5 million hectares, which compares well with the 7.8 million hectares mentioned in the ICONA report. However, the result has to be handled with care and should be considered as a first guess. Supplementing data is needed for confirmation.

Results

The European Soils' Charter (1972) addresses soil protection. However, no common policy targets have been proposed. No specific targets for the 'accelerated policies' scenario have been defined. Prorating a case study to the EU15 estimates abatement cost at €10,000 million, while the opportunity costs raise to at least €1,000 million per year. The abatement plan will require an execution of 15 to 20 years.

1.2.2 Climate change induced land degradation

Climate change is likely to affect hydrology and hence land use. Globally, a temperature rise is already discernible and climate model experiments suggest that this trend will continue with increased greenhouse gas concentrations. Many models also suggest an increase in the probability of intense precipitation. In some areas a number of simulations show there is also an increase in the probability of dry days and dry spells (consecutive days without precipitation). Where mean precipitation decreases, the likelihood of drought increases. New model results reinforce the view that variability associated with the enhanced hydrological circle translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places (IPCC, 1996).

Climate change, higher average temperature and changing precipitation patterns, may have three direct impacts on soil conditions. The higher temperatures cause higher decomposition rates of (soil-)organic matter. Soil organic matter is important for ecosystem functioning. It is a source of nutrients, it improves aggregate stability, moisture storage capacity, and microbial activities. Generally, the chemical, physical and biological status of the soil increases with higher organic matter percentages (Sombroek et al., 1993) Especially the decrease in aggregate stability may enhance water erosion.. More floods will cause more water erosion, while more droughts will cause more wind erosion. All changes will require adaptation to the new conditions.

Besides these direct effects, climate change may 1) create a need for more agricultural land to compensate the loss of degraded land, and may 2) lead to higher yields for the major European grain crops due to the CO_2 fertilisation effect. These two indirect effects seem to balance out.

Here, the impact of climate change is calculated using the computer model IMAGE 2, which is a geographically explicit, integrated model developed to simulate the interactions between climate, biosphere and society (Alcamo et al., 1994a; Alcamo et al., 1994b; Alcamo et al., 1998). This section describes the spillover from the issue of greenhouse gas emissions. The emission scenario chosen corresponds with the Kyoto agreement on greenhouse gas emission reduction.

The goal of the assessment is to assess the *qualitative* water erosion risk (e.g. no risk, low, moderate or high) and its impact on crop productivity. Its methodology is based on Batjes (1996) and Hootsmans et al., (1999). The water erosion impact module generates for each grid cell of 0.5^o x 0.5^o a water erosion risk index based on three main parameters: terrain erodibility, rainfall erosivity, and land use pressure. Terrain erodibility is based on soil type (FAO, 1991) and on certain soil characteristics (ISRIC's WISE Database) and on landform, which are regarded as constant parameters. Landform is classified into general types (flat, undulated, mountainous, etc.) by using the difference between minimum and maximum altitudes for each grid cell (FNOC, 1995). The rainfall intensity is derived from monthly precipitation divided by the number of wet days. This is considered to be indicative of rainfall erosion potential. Precipitation is considered a dynamic variable, while the number of wet days is assumed to remain constant. The potential erosion risk is converted to actual erosion risk by land use pressure considerations which are determined by applying the degree of protection afforded by various land covers to land cover maps (Global Ecosystem Database, Kineman 1992). Natural forests give an optimum protection showing 'no risk' and agricultural crops give a much lower protection showing various levels of water erosion risk.

Results

The results for the 15 EU countries is presented here as a combined change in land cover/ land use and in risk level. Four main covers are identified: agriculture, open and closed vegetation and built-up area. Water erosion risk is, under current climate and land cover, high to very high on one third of the European land area. Areas with such high risk are located in South and Central Europe (Figure 1). In the remaining parts of Europe the risk is low to moderate. In Europe water erosions mainly occurs in areas where agriculture is the major land use. Areas covered with natural vegetation, especially with a closed canopy, are not prone to water erosion and therefor not assumed to be subject to water erosion in the model. An exception is the open vegetation types (e.g. shrubs, grassland/steppe), where water erosion is low.

Under the selected IMAGE scenario, the water erosion risk in the agricultural areas of EU15 in 2050 is expected to increase for about 80% of the area. It remains the same in 10% of the agricultural area in Europe and decreases for the remaining 10% (Figure1). The agricultural areas with an increase in erosion risk are mainly located in the west of Central Europe, in the Mediterranean area. Areas with 10% or more decrease in risk can be found in parts of UK and Spain. Outside EU15 these areas are mainly located in the areas south or south-east of the Gulf of Bothnia.

Under the IMAGE scenario, countries where the proportion of high and very high risk erosion risk classes increases include Germany, Italy, Spain, Greece and Ireland. Significant increases in the very high erosion risk classes occur in Spain and Austria. The overall picture shows an halving of the area at moderate risk (to 14% by 2050) and a tripling of the area with high erosion risk (to 23% by 2050).

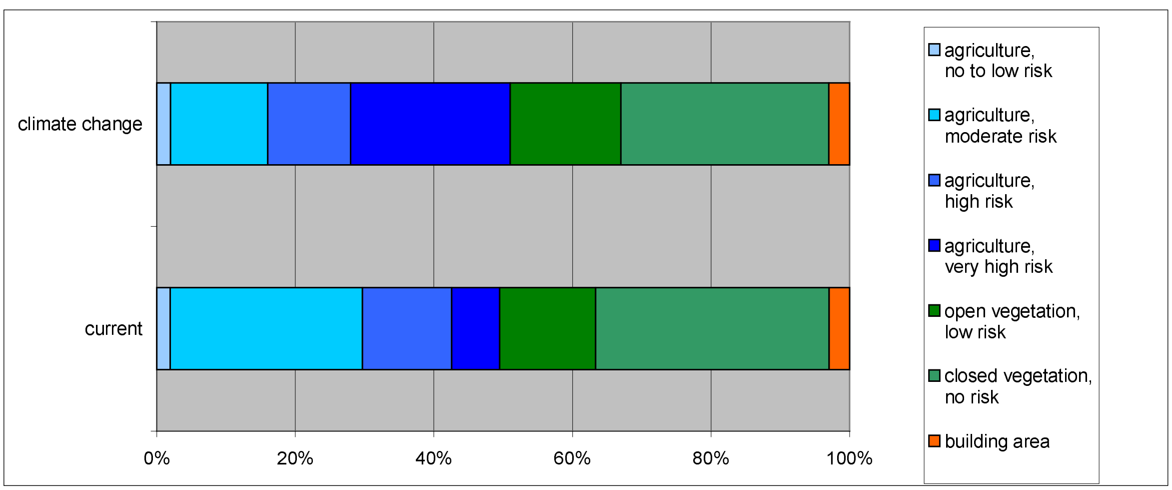

Figure 1 Water erosion vulnerability of soils in the EU-15. Current state (1990) and projection of climate change effects for 2050. Agricultural land becomes more susceptible, there is no impact on the erosion vulnerability of natural vegetation.

Results: impact of degradation on crop productivity:

Overlaying water erosion risk map with potential maize (grains) productivity map learns that water erosion will affect potential productivity in Europe by 2050. To analyse the impact we defined three erosion risk classes and combined these with three yield levels % (Figure 2). In Europe the highest defined yield level does not occur, meaning that there are in total six classes identified. The IMAGE2 results for EU15 show an absolute decrease in the area suitable for maize production and show a tendency towards lower maize yields by 2050 (climate change in Figure 2). Regarding the impact of degradation the results show that the high erosion levels are increasing strongly on the account of the low and moderate erosion risk levels.

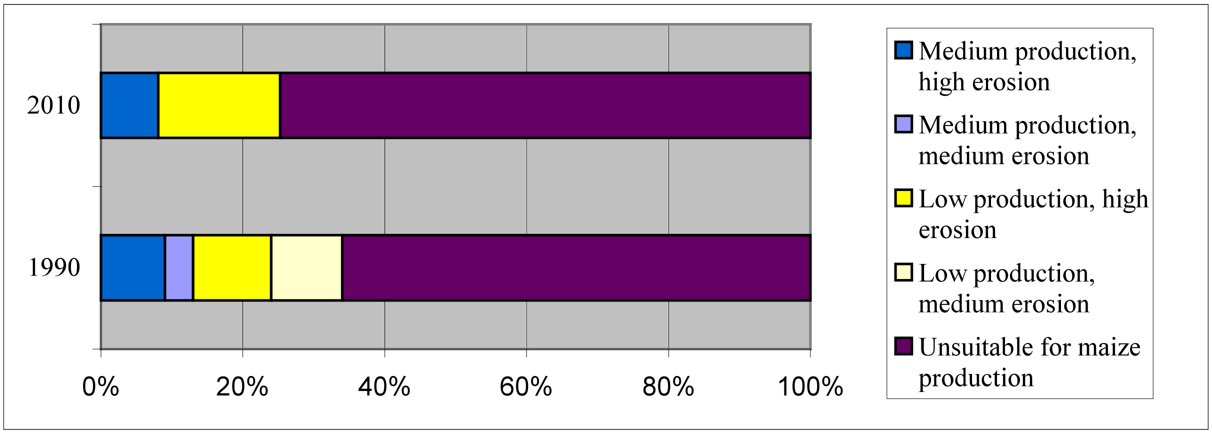

Figure 2: Agricultural area prone to erosion and their potential for maize (grains) production. Current and projected state with regard to climate change.

Identification of major uncertainties.

Although water erosion represents only one factor of soil degradation, it contributes approximately 60% to this issue. Water erosion is a collective name of several types of erosion: surface, gully, rills and tunnel erosion. A general approach, based on universal relationship between precipitation and water erosion, where these individual processes of erosion are not addressed separately does increase the uncertainty, but this is given the data availability and the objective of the analysis an acceptable simplification.

The IMAGE water erosion module has not been extensively used in a policy context, and additional validation is required, for example, for land cover pressure values. The methodology generates erosion risk, rather than actual water erosion. That is, land and resource management is not taken into account and, therefore, the results need to be interpreted with care. The water erosion risk indicator, either as a climate change impact or a soil degradation condition, is not commonly used at national or international levels. The IMAGE model itself is an accepted model and has been subject to various international reviews. The indicator is one of risk, helping policy makers set priorities to avoid high economic costs resulting from damage to the natural capital of Europe's soil.

1.3 Conclusions

Current agri-environmental regulations at both the EU and Member State level hold considerable promise to effectively prevent and mitigate soil erosion. Landowners are encouraged towards more extensive management practices such as organic farming, afforestation, pasture extension, and benign crop production. Nevertheless, there is a need for policy makers and the public to intensify efforts to combat the pressures and risks to the soil resource.

There is a significant association between soil degradation, and water management and climate change. Global warming and higher rainfall will probably intensify degradation; which, without adequate responses, will magnify the problems of water pollution and clogged downstream watercourses, including reservoirs. Such changes could also result in the more intensive use of marginal soils to compensate for the loss of degraded land.

Assessment and Trends

In 1990, high to very high water erosion risk areas occurred over about one third of Europe primarily on the agricultural lands of southern and central regions. Under the continuation of existing policies, water erosion risk is expected to increase over about 80% of agricultural land in the EU by 2050. While the area of high erosion risk will probably triple, the area of moderate risk will probably decrease by half. Countries significantly affected by this overall increase in risk level include Germany, Italy, Spain, Greece, Ireland, and Austria.

Water erosion will probably adversely affect the productivity of maize in Europe by 2050. In the EU, both a decrease in the area suitable for maize production and a tendency towards lower yields are likely to occur.

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Annex Tables providing regional information.

A. Cost benefit analysis of current soil erosion management
In order to estimate the extend of the soil erosion issue in the EU, we prorated a national cost-benefit analysis (ICONA, 1991) to the other Member States. We selected the indicator 'mountain and hill areas' (CEC-DG06, 1998) as representative for the area vulnerable to water erosion. For Spain this indicator has the value of 7.5 million hectares, which compares well with the 7.8 million hectares mentioned in the ICONA report. However, the result has to be handled with care and should be considered as a first guess. Supplementing data is needed for confirmation.
Prorating the ICONA cost benefit analysis for a Spanish erosion abatement plan estimates EU15 cost at €10,000 million, while the opportunity costs raise to at least €1,000 million per year. The abatement plan will require an execution of 15 to 20 years.

Table 1: Prorating a national cost benefit analysis (ICONA, 1991) to all EU15 member states.

	Utilised Agricultural Area 1000 ha	Mountain & hill area 1000 ha	Damage cost M€/year	Policy cost M€/15 years
Austria	3432	2047	76	818
Belgium	1371	0	0	0
Denmark	2727	0	0	0
Finland	2192	1407	53	563
France	30215	5197	194	2078
Germany	17335	336	13	134
Greece	3465	2114	79	845
Ireland	4325	0	0	0
Italy	14685	5218	195	2086
Luxembourg	126	0	0	0
The Netherlands	1969	0	0	0
Portugal	3927	1227	46	491
Spain	30281	7503	280	3000
Sweden	3060	526	20	210
United Kingdom	16149	0	0	0
EU-15	135259	25575	954	10226

B. Water erosion vulnerability
Water erosion vulnerability corresponds with actual erosion risk. The actual risk combines the potential risk, which is based on terrain erodibility and rainfall erosivity, with the actual land use. The four classes of erosion vulnerability cover the whole range from absence of erosion to almost not vulnerable (small) to very vulnerable causing great losses of topsoil causing severe negative impact on productivity of the area.

Table 2: Water erosion vulnerability in percentage of land area.

Classification:

Land use	Erosion risk			
	Small	Moderate	High	Very high
Agriculture	A	B	C	D
Nature	F	E	-	-
Built up area	G	-	-	-

Table 2.a: Water erosion vulnerability 1990

	A	B	C	D	E	F	G
Austria	0%	0%	30%	10%	12%	45%	3%
Belgium	19%	31%	0%	0%	0%	38%	12%
Denmark	10%	45%	0%	0%	30%	10%	5%
Finland	2%	1%	0%	0%	14%	82%	0%
France	0%	50%	8%	3%	9%	28%	2%
Germany	1%	46%	5%	2%	10%	31%	5%
Greece	0%	5%	41%	43%	5%	7%	0%
Ireland	0%	83%	0%	0%	0%	17%	0%
Italy	0%	18%	41%	7%	15%	15%	3%
Luxembourg	0%	100%	0%	0%	0%	0%	0%
The Netherlands	50%	21%	0%	0%	0%	0%	29%
Portugal	0%	0%	15%	30%	43%	12%	0%
Spain	0%	22%	26%	19%	22%	10%	1%
Sweden	1%	5%	0%	0%	10%	83%	0%
UK	5%	67%	1%	0%	16%	2%	10%
EU15	2%	28%	13%	7%	14%	34%	3%

Table 2.b: Water erosion vulnerability outlook for 2050

	A	B	C	D	E	F	G
Austria	5%	0%	0%	40%	5%	48%	3%
Belgium	0%	50%	0%	0%	12%	25%	12%
Denmark	0%	50%	10%	0%	5%	30%	5%
Finland	2%	2%	0%	0%	23%	72%	0%
France	3%	33%	20%	15%	4%	22%	2%
Germany	2%	12%	22%	28%	7%	24%	5%
Greece	0%	2%	0%	86%	7%	2%	2%
Ireland	0%	37%	37%	0%	6%	20%	0%
Italy	1%	1%	10%	63%	11%	11%	3%
Luxembourg	0%	0%	100%	0%	0%	0%	0%
The Netherlands	7%	64%	0%	0%	0%	0%	29%
Portugal	6%	0%	9%	30%	52%	3%	0%
Spain	2%	3%	18%	42%	27%	7%	1%
Sweden	0%	6%	1%	0%	27%	65%	0%
UK	4%	39%	6%	0%	15%	26%	10%
EU15	2%	14%	12%	23%	16%	30%	3%

Remark: in relative small countries the ratio between agriculture, nature and built-up areas may deviate somewhat from statistical information, this is due to gridcell size and selected dominant land use

Table 2.c: Change in water erosion vulnerability for agricultural areas during the outlook period 1990-2050

	A	B	C	D	ratio agriculture / total
Austria	3%	0%	37%	60%	40%
Belgium	6%	12%	31%	50%	50%
Denmark	0%	5%	50%	45%	55%
Finland	0%	3%	0%	97%	3%
France	2%	3%	57%	38%	62%
Germany	2%	2%	50%	46%	54%
Greece	2%	2%	81%	14%	86%
Ireland	8%	3%	72%	17%	83%
Italy	0%	5%	62%	33%	67%
Luxembourg	0%	0%	100%	0%	100%
The Netherlands	0%	7%	64%	29%	71%
Portugal	9%	12%	24%	55%	45%
Spain	10%	8%	48%	34%	66%
Sweden	1%	2%	3%	94%	6%
UK	27%	13%	34%	27%	73%
EU15	5%	5%	40%	51%	49%

Classification: A = decrease in water erosion vulnerability
B = no change in water erosion vulnerability
C = increase in water erosion vulnerability
D = fraction of non agricultural land use

C. Risk erosion to potential maize productivity

To calculate the impact of water erosion on crop production a link has been made with the land degradation module and the crop model of the IMAGE model. The erosion risk to potential maize (grains) productivity is calculated for two potential productivity classes for maize and for three erosion risk classes for 1990 (Table 3a) and 2050 (Table 3b). The differences between 1990 and 2050 are shows in Table 3c. The percentages given correspond with the area of the land that is classificed according to a combination of erosion risk and productivity level.

Table 3 Risk erosion to potential maize (grains) productivity in percentage of land area 1990 and 2050.

Classification:

Agricultural productivity	Erosion risk class		
	high	medium	low
Medium	A	B	C
Low	D	E	F
Non-productive		*G*	

Table 3.a: Risk erosion to potential maize (grains) productivity for base year 1990
(* non productive area)

Year 1990	*A*	*B*	*C*	*D*	*E*	*F*	*G **
Austria	23%	0%	0%	15%	0%	0%	62%
Belgium/Luxembourg	0%	12%	0%	0%	24%	17%	47%
Denmark	0%	19%	0%	0%	24%	0%	57%
Finland	0%	1%	0%	0%	0%	0%	98%
France	7%	12%	0%	12%	10%	0%	60%
Germany	12%	11%	0%	12%	16%	0%	49%
Greece	33%	0%	0%	23%	0%	0%	44%
Ireland	0%	0%	0%	8%	51%	0%	41%
Italy	23%	1%	0%	29%	1%	0%	47%
The Netherlands	0%	0%	0%	0%	36%	21%	43%
Portugal	5%	0%	0%	3%	0%	0%	92%
Spain	16%	1%	0%	22%	1%	0%	60%
Sweden	0%	2%	0%	0%	2%	0%	95%
UK	0%	1%	0%	7%	37%	3%	53%
EU-15	9%	4%	0%	11%	9%	1%	66%

Table 3.b: Risk erosion to potential maize (grains) productivity outlook for 2050

Year 2050	*A*	*B*	*C*	*D*	*E*	*F*	*G **
Austria	23%	0%	0%	15%	0%	0%	62%
Belgium/Luxembourg	0%	0%	0%	12%	0%	0%	88%
Denmark	19%	0%	0%	19%	9%	0%	52%
Finland	0%	2%	0%	0%	0%	0%	97%
France	5%	0%	0%	16%	0%	0%	79%
Germany	25%	0%	0%	25%	1%	0%	49%
Greece	24%	0%	0%	36%	0%	0%	39%
Ireland	0%	0%	0%	0%	0%	0%	100%
Italy	19%	0%	0%	46%	0%	0%	35%
The Netherlands	0%	0%	0%	0%	0%	0%	100%
Portugal	0%	0%	0%	16%	0%	0%	84%
Spain	7%	0%	0%	24%	0%	0%	69%
Sweden	0%	1%	0%	2%	2%	0%	94%
UK	0%	0%	0%	0%	0%	0%	100%
EU-15	8%	0%	0%	17%	0%	0%	74%

Table 3.c Change in risk erosion to potential maize (grains) productivity (1990-2050)

CHANGE 1990-2050	*A*	*B*	*C*	*D*	*E*	*F*	*G*
Austria	equal	-	-	equal	-	-	equal
Belgium/Luxembourg	-	ceased	-	new	ceased	ceased	increase
Denmark	new	ceased	-	new	decrease	-	equal
Finland	-	increase	ceased	-	equal	-	increase
France	decrease	ceased	-	increase	ceased	-	increase
Germany	increase	ceased	-	increase	decrease	-	equal
Greece	decrease	-	-	increase	-	-	decrease
Ireland	-	-	-	ceased	ceased	-	increase
Italy	decrease	ceased	-	increase	ceased	-	decrease
The Netherlands	-	-	-	-	ceased	ceased	increase
Portugal	ceased	-	-	new	-	-	decrease
Spain	decrease	ceased	-	new	ceased	-	increase
Sweden	new	decrease	ceased	new	decrease	-	decrease
UK	-	ceased	-	ceased	ceased	ceased	increase
EU-15	equal	decrease	ceased	increase	decrease	ceased	increase

-	not applicable
equal	less than 10% increase or decrease in area
cease	existing in 1990 and ceased to exist in 2050
new	zero in 1990 and new in 2050
increase	more than 10% increase in area
decrease	more than 10% decrease in area

The results of the analysis of change in risk erosion to potential maize productivity for EU 15 shows a net decrease in areas with medium erosion risk in combination with medium and low yield levels to a combination of high erosion risk with low yield levels over the period 1990 to 2050.

2. Benefit assessment

2.1 Public opinion

Soil degradation is not reported as an environmental problem in any of the public opinion surveys presented in this paper. Soil degradation may not be reported because it is not included within the design of the survey, or it may reflect a general lack of awareness of this issue, or even the fact that this issue is more commonly associated with non-European countries. Thus, omission from public opinion does not imply soil degradation should be given a low priority.

2.2 Expert opinion

GEP et al., (1997) classify 'soil' as a major environmental problem. The category concerns soil degradation due to erosion, salinisation and pollution, but also due to other causes such as intensive exploitation and bad rural management. As it would be expected the score for South Europe is higher (17%) than for North Europe (11%), with a world-wide score of 14%. Interestingly the world-wide ranking is seventh, whilst the European ranking is fifth.

2.3 Benefit estimation

The main problem with estimating the damage effects of soil erosion is that currently we do not have 'overlays' of crop production to match with the areas of erosion. Accordingly, we cannot estimate with precision, the effects of erosion on crop productivity. Instead, an approximate outline approach is presented. Due to the absence of scenarios, only the environmental damage to arable land due to soil erosion in 1990 for EU15, is estimated.

The issue of data compatibility

The area of *wider Europe* affected by *human-induced* land degradation (excluding some soil contaminants) is indicated in Table 2.1, but the areas are not additive as any one area may be affected by more than one 'threat'. The main risk is seen to be from *water erosion*. The RIVM scenarios provide estimates of water erosion risks in terms of the total areas of each EU country under threat.

Table 2.1 Total area affected by land degradation in the wider Europe

Type of degradation	Light	Moderate	Strong/ Extreme	Total	% European land area
Water erosion	21	81	12	115	52
Wind erosion	3	38	1	42	19
Acidification	neg	neg	neg	neg	neg
Pollution	4	14		19	9
Compaction	25	8	1	33	15
Nutrient loss	3	neg	neg	3	1
Salinisation	1	2		4	2
Water-logging	neg	neg		neg	neg

Source: Oldeman *et al.,* (1991)

Table 2.2 selects those areas at 'high' or 'very high' risk in 1990. It suggests that around 1.2 million km^2 of land in EU-15 is at high risk from water erosion. Table 2.2 shows that 'high and very high' water erosion risks are especially important in Southern EU countries Italy, Spain and Greece and France.

There are potential issues of data compatibility here. The UNEP data are for the wider Europe whereas the RIVM data are for EU-15 only. Yet the total area of the wider Europe degraded by water erosion from all classes of risk is some 115 million ha in the UNEP data, or 1.15 million km^2. The RIVM data produce a similar figure but for EU15 only and for high and very high risks only. Since RIVM maps show the high risk areas to be Spain, Greece and much of Eastern Europe, it would appear that either the UNEP estimates seriously understate risk or the RIVM data overstate it. However, the difference may lie in (a) the fact that the UNEP are for human-induced degradation, and (b) the RIVM data are for 'vulnerability' whereas the UNEP data are for actual soil degradation.

Table 2.2 Land area at high and very high risk from water erosion 1990

Country	Area at high/very high risk, km^2	% total land area
Austria	29,350	36%
Belgium/Luxembourg	12,057	36%
Denmark	19,336	53%
Finland	0	0%
France	307,686	58%
Germany	154,155	43%
Greece	89,556	85%
Ireland	29,629	43%
Italy	179,263	66%
The Netherlands	0	0%
Portugal	37,833	43%
Spain	307,794	66%
Sweden	12,821	3%
UK	53,841	25%
EU15	1,233,319	40%

Source: RIVM

Methodology: estimating the damage effects of soil erosion

Table 2.4 shows areas of the EU subject to different classes of water erosion risk by scenario. It will be noted that the *differences* in the areas at risk between the baseline and TD scenario in 2050 are very small, so much so that *for the EU as a whole*, the TD scenario has no significant benefits over and above the baseline scenario. Nor is it the case that there are any significant benefits for the highest risk countries. Based on RIVM data, the percentage of land at high and very high risk is shown in Table 2.3.

Table 2.3 Percentage of land at high and very high risk of erosion

	1990	Baseline	TD
France	58	65	66
Greece	85	88	91
Italy	66	74	71
Spain	66	63	66

Source: RIVM

Table 2.4 Water erosion risks EU-15 by Scenario

	1990	2050 Baseline	2050 TD
no/low risk	44.3% = 1.34 m.km^2	43.5% = 1.32 m.km$_2$	43.4% 1.32 m.km$_2$
Moderate risk	15.1% = 0.45 m.km^2	13.6% = 0.41 m.km^2	14.0% = 0.42 m.km^2
High/v.high risk	40.7% = 1.23 m.km^2	42.9% = 1.30 m.km^2	42.7% = 1.29 m.km^2

Table 2.5 shows the areas of *arable* land in each EU country. In the absence of detailed overlay data to match erosion risks and agricultural output, we assume that the risk factors in Table 2.2 can be applied to the areas of arable land shown in Table 2.5. This gives the areas at risk shown, in italics, in Table 2.5. We have selected only the high / very high risk areas to be conservative.

Table 2.5 Arable land areas in EU-15 countries 1990

Country	Area of arable land km^2	area at high / very high risk from water erosion in 1990, km^2
Austria	14060	5061
Belgium/Luxembourg	7669	2710
Denmark	25608	13572
Finland	25417	0
France	177631	103026
Germany	72805	31306
Greece	23340	19839
Ireland	7748	3332
Italy	90120	59479
The Netherlands	9070	0
Portugal	23500	10105
Spain	143354	94613
Sweden	28450	854
UK	65886	16471
EU15	714658	360368

Source: Eurostat

According to OECD sources (OECD, 1992) crop production (value added) amounted to some € 130 billion. Averaged across total arable area in EU-15 (714,658 km^2) this would be some € 180,000 per km^2 or € 1800 per ha. In the most thorough and detailed investigation into soil erosion losses, Crosson and Stout (1983) estimate that cropland erosion in the USA resulted in the following reductions in 1980 (trend) yield:

corn	-2%
soyabean	-1.5%
wheat	0%

These are lower figures than those widely quoted in 'popular' analyses of soil erosion. Applying a 1% loss to all crops in EU15 - which is a very crude procedure - suggests that erosion-induced losses might have amounted to around € 18 per ha (around € 36 per ha at high or very high risk). Across the whole of the EU this would amount to € 1.3 billion, suggesting that, even though the productivity reduction is very small, it could amount to substantial sums.

However, this figure needs to be modified in respect of:

(a) the fact that it relates to a loss of gross output, rather than combined consumer plus producer surplus losses. Loss of production is not the real cost - we need the change in combined producer and consumer surplus for that. Crosson takes the ratio of net farm income to total output at 0.2, i.e. 'true' damages would be 20% of gross output loss. OECD (1992) suggests a ratio of net income to value added of about 65% for EU countries. Taking the OECD figure gives a net income loss of € 845 million in 1990.

(b) the fact that it relates to all crops, whereas different crops tend to be subject to different rates of erosion. Crosson and Stout (1983) found no effect of erosion on US wheat, but did find effects on soya beans and corn (maize). Arden-Clarke and Evans (1991) suggest that cereals generally are more erosive than root crops. This aspect of the analysis is therefore far from satisfactory. As a working assumption for a minimum estimate, we assume that all cereals are subject to the 1% loss, but that all other crops have a zero loss. OECD (1992) indicates that cereal production alone was valued at € 27.7 billion in 1990. Taking the net income / value added ratio, we have minimum estimates of erosion loss as € 180 million in 1990.

(c) additional costs of treating and farming eroded land. Crosson adds around 40% to the damage costs for this.

(d) off-site costs. Faeth and Westra (1993) suggest that off-site damages are about twice those for on-site productivity losses in the USA. In the absence of any European data we might adopt this.

It is also worth noting that soil is not all 'lost'. Amounts lost in erosion from one area will tend to accrue in other areas and are not lost to production unless accruing in the sea, rivers etc.

Results

Taking all the suggested adjustments we have:

Total arable land output in 1990:			€ 130 billion
	x 0.01 erosion factor:		€ 1.3 billion
Modifications			
a.	*x* 0.65	to obtain *maximum* net income loss	€ 845 million
b.	*x* 27.7/130	to obtain *minimum* loss (cereals only)	€ 180 million
c.	*x* 1.4	to account for extra costs to treat land	€ 252 to 1183 million
d.	+ (2 *x* productivity losses)	for offsite costs	€ 360 to 1690 million
	=	range of on site and offsite costs	€ 612 to 2873 million

Expressed as a percentage of the value added by agriculture in 1990 this range would be 0.5% to 2.2%. We attach more significance to the lower end of the range because of the unlikely assumption of erosion affecting all arable crops equally, the assumption underlying the maximum estimate.

The lower estimate may seem small, but Crosson (1995) comes up with on-site costs of only $100 million pa for the USA, or $300m if the Faeth and Westra offsite costs are added.

3. Policy package

3.1 Key issue

Owners or users of land subject to erosion may have little incentive to control erosion rates if they do not show up clearly in on-site productivity losses[2]. Even if there is an underlying trend to such losses, they are often 'masked' by changes in compensating applications of fertiliser. Where on-site damage is evident and directly traceable to erosion, it will often (but far from always) be profitable to control the erosion by changing management practices, e.g. reduced intensity of crops, better cover from surrounding vegetation, more organic matter in the soil etc. The justification for policy interventions tends to come in two contexts (a) where off-site costs are significant, since these will tend to be ignored by land owners, and (b) where the effect of soil erosion is not transparent to the owner.

(a) off-site costs. Because of the difficulties of tracing the 'life cycle' of soil losses, it would seem unlikely that it is possible to develop credible economic instruments that penalise poor soil management behaviour. Any measures would tend to be fairly broad spectrum and hence not related to specific damage incidence. Such broad measures already exist in some countries, e.g. in terms of controls on land drainage, and land use controls. There is, however, a clearer need to adopt economic incentives in some form. Ideally, some tax on erosive technology and on choice of erosive crops (e.g. winter cereals in the UK have led to significant increases in erosion) should be applied. An 'erosion tax' is therefore worthy of further investigation.. In the meantime, extension of EU Regulation 2078/92 may be appropriate – see below.

(b) on site costs. Current agri-environmental regulations hold considerable promise as a means of combating soil erosion. Measures include encouragement for organic farming, afforestation, and on-farm crop management changes. Lawrence (1998) cites two case studies from Germany where mulch seeding and cash crops had clearly identifiable impacts on reduced erosion. Lawrence anticipates further improvements under Agenda 2000 because of beef extensification, 'green' rural development measures, more agri-environmental measures and more cross-compliance. It also seems clear that on site losses need far more publicity if land owners are genuinely ignoring significant soil losses because of masking effects.

3.2 Recommended policy initiatives

Based on the information presented above, it is our judgement that soil degradation is not a priority environmental issue for the EU15, thus, specific policies targeted at soil degradation may not be necessary.

Even though specific policies may not be necessary, soil degradation could be prevented through the policy initiatives targeted at biodiversity loss, such as: i) agricultural policy reform, ii) the pesticide tax, which reduces the toxicity of pesticide use and iii) the fertiliser tax. Also, the prevention of soil erosion will benefit other environmental issues, such as coastal zones and water quality.

3.3 Policy assessments

Specific policy measures are not given.

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[2] The environmental damage analysis presented in the section on *benefit assessment*, suggests that crop damage due to soil erosion could range from € 252 to 1,183 million in 1990.