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

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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.

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

This report consists of four parts:

Section 1:
Biodiversity assessment
Prepared by B.J.E. ten Brink, A.J.H. van Vliet, C. Heunks, 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
All references made in the sections on benefit and policy assessment have been brought together in the Technical Report on Benefit Assessment Methodology. The references made in the section on environmental assessment follow at the end of section 1.

Contents

1. Biodiversity assessment

1.1 Introduction

Diversity of ecosystems, species, and genes is critical to the functioning of the ecosphere. At present, ecosystems are undergoing unprecedented degradation and loss of species due to the rapid increase in human consumption of natural resources. Biodiversity considerations are beginning to be integrated into sectoral policies. However, negative impacts will probably continue from such factors as agricultural intensification, mono-specific forestry, urban and transport development, climate change, pollution and the introduction of alien species (EEA, 1999).

Various instruments exist to support biodiversity conservation strategies (EEA, 1998). The Convention on Biological Biodiversity, which the CEC has ratified, provides a global framework for countries to prepare biodiversity strategies and action plans. A biodiversity indicator framework has also been proposed to assess whether or not progress is made. This Natural Capital Index (NCI) framework has been applied in this study. Other relevant international conventions include the Bonn Convention (migratory species), the World Heritage Convention (natural heritage), the Bern Convention (wildlife and natural habitats), CITES (trade in endangered species) and the Ramsar Convention (wetlands). In the EU, a Biodiversity Strategy was developed in 1998; the Birds and Habitats Directives support the development of the NATURA 2000 Network of nature conservation sites.

In this study biodiversity change is measured using the -adapted- Natural Capital Index (NCI) framework as developed under the Convention on Biological Diversity. The NCI framework takes into account the remaining ecosystem size (ecosystem quantity) and its quality as two complementary indicators describing natural capital.

This study focuses on the effects of the Baseline and Accelerated Policy scenarios on natural areas. These policy scenarios have been defined in the main report of the study to which this report adds background information. Ecosystem quantity is measured as the percentage natural area of the country's total area of the EU-15 total area. Due to the lack of data, ecosystem quality could not be assessed on state indicators. Instead, pressure indicators have been used as a substitute. It has been assumed that the higher the pressure, the lower the chance on quality. Hence, this study represents a preliminary estimation of the size of effects of various environmental policy scenarios on biodiversity, the relative contributions of single pressures and how they are distributed geographically over Europe.

Loss of biodiversity reduces biological heterogeneity (Pearce and Moran, 1994). It results in the decrease in abundance of many species and the increase in some other species (UNEP, 1997b). This causes concern because biodiversity is the basis of the stability and functioning of natural and agricultural systems which provides a flow of goods or services, now and in the future (Constanza et al., 1997). Experts give biodiversity loss rank seventh as a priority problem, and public opinion ranks it eighth (European Commission, 1995). This ranking remained unchanged since the 1992 survey.

This section provides the current status on Habitats and Birds Directives. Furthermore an exploratory assessment on the future state of Europe's biodiversity is given on bases of two different scenarios: the Baseline scenario and the Accelerate Policy scenario. It consists of four paragraphs:

1.1 Introduction.

1.2 Environmental trends:
- Problem sketch and related economic sectors
- Current status on Habitats and Birds Directives
- Performance of the Baseline and Accelerate Policy scenarios on biodiversity.

1.3 Results
1.4 Conclusions

1.2 Environmental trends

1.2.1 Problem sketch and related economic sectors

Biodiversity loss links to almost all environmental problems such as: i) water and air pollution; ii) climate change; iii) intensive agriculture; iv) forestry; v) fragmentation by infrastructure and urbanisation; vi) exposure to mass tourism; vii) water extraction; viii) over-exploitation and ix) habitat loss. Given the projected growth in economic activity, the rate of loss of biodiversity is far more likely to increase than stabilise (European Community[1]).

Available evidence on several species show a declining trend of diversity within ecosystems, habitats and among species in the EU (EEA, 1996). Data from the EEA and from ECNC (1998) show, for example, that all countries are experiencing declines in many bird species. The major factors underlying those bird specie losses are (a) agricultural intensification, (b) hunting, (c) wetland drainage, (d) recreation and tourism, (e) pesticides, (f) agricultural abandonment and (g) afforestation. As for fish species, pollution, over-fishing and the introduction of non-native species are more important. For amphibians the picture tends to be one of habitat loss. For butterflies the threats are fairly equal across agricultural change, habitat loss (especially woodland), pollution, afforestation, recreation, land drainage, and climatic change. Nevertheless, there is not

1 'Communication of the European Commission to the Council and to the parliament on a European Community Biodiversity Strategy', February 1998. Presented as Background document at the Electronic Conference on Research and Biodiversity (4th May to 14th June 1998).

yet a systematic monitoring system in place, nor a baseline measurement, and therefore it is difficult to quantify the extent of biodiversity loss as a whole.

1.2.2 Current status of Habitats and Birds Directives

Land use planning clearly has a major role to play to maintain and develop conservation areas, connection areas and buffer zones. This concept is already embodied in some national legislation and through Natura 2000 at the EU level. The Habitats Directive creates a network of Special Areas of Conservation; the Birds Directive establishes Special Protection Areas. Both Directives are not yet fully implemented. Figure 1 shows the current designated area. Continuing declines in bird populations indicate failure in the Birds Directive, whilst the full list of sites under Natura 2000, due for finalisation in 1998, has not been established yet. Policy on biodiversity must therefore include renewed efforts to ensure compliance with established biodiversity conservation strategies.

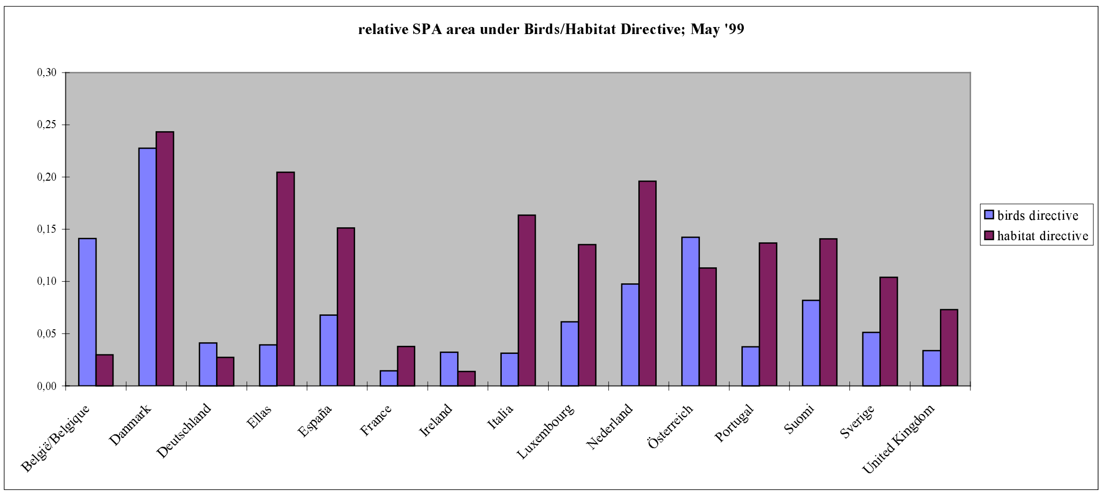


Figure 1: Relative area (designated/total) entered by the Member States for protection under the Birds' respectively Habitat Directive by October 1999 (source: DGXI, 1999: Natura Barometer 9).

1.2.3 Performance of Baseline and Accelerate Policy scenarios

1.2.3.1 Natural Capital Index

To provide an indication on the performance of the Baseline and Accelerate Policy scenarios on biodiversity the so-called Natural Capital Index framework or NCI-framework has been applied. The NCI framework enables to describe the past, current and future state of nature and establish relations to various possible socio-economic developments in an integrated, policy-oriented manner. The NCI concept was previously developed for and applied in UNEP's Global Environment Outlook (RIVM/UNEP, 1997; UNEP, 1997a). The NCI-framework has been further developed under the Convention on Biological Diversity (UNEP, 1997b). The framework was accepted as starting point for

further discussions at the Conference of the Parties in Bratislava, and is still in development.
The NCI framework provides information on the state and changes in biodiversity due to human interventions. It focuses on the changes during industrial times, the period in which loss of biodiversity in natural and agricultural ecosystems was accelerating rapidly (UNEP, 1995).

In general, the process of biodiversity loss results in a decline in the abundance and distribution of many species and the increase in the abundance of a few other species (Figure 2). Species extinction is only the last step of a long process of ecosystem degradation.

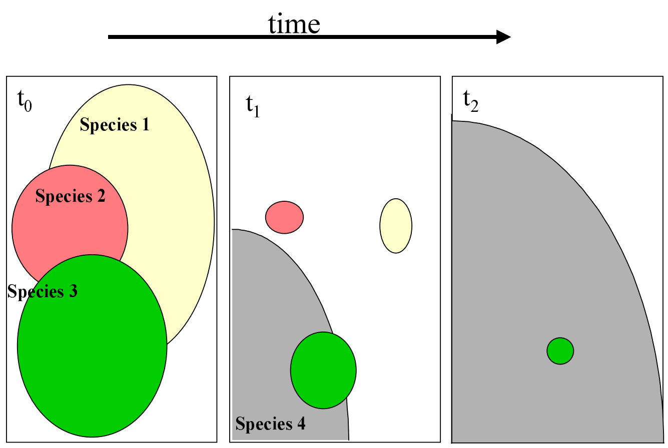


Figure 2: The essence of biodiversity loss is the decrease in abundance of many species and the increase in abundance of some other species. In this illustration the abundance of species 1, 2 and 3 decreases over time while the abundance of a new species (4) rapidly increases.

Note: species abundance (numbers/distribution of one species) is a far more sensitive indicator of biodiversity change than the traditional indicator "species richness" (the number of species). This illustration shows the development of both species richness and species abundance. Initially (t_0), there are three original species. Then (t_1), as a result of environmental pressure, a new species emerge. The species richness increases from 3 to 4, while the abundance of the original species dramatically decreases. Finally (t_2), two species persist, species 4 dominates and species 3 is withering away.

The NCI framework considers biodiversity as a natural resource containing all species with their specific abundance and natural fluctuations. The decrease in abundance of many species on the one hand and the increase in abundance of some other species on the other due to human interference are considered as a depletion of the '*biodiversity resources*', or in other words as the depletion of the '*natural capita*'[2]. Globally, *habitat loss* as a result of converting natural area into agricultural and built-up areas is a major causal factor of this loss of natural capital. The change in abundance of species in the

[2] Not only is the extinction of a species a part of the biodiversity loss but also its decline in abundance. This approach incorporates the spatial aspect of biodiversity which is generally considered very important.

remaining natural areas due to various pressures such as pollution, exploitation and fragmentation is another major factor (*Figure 3*).

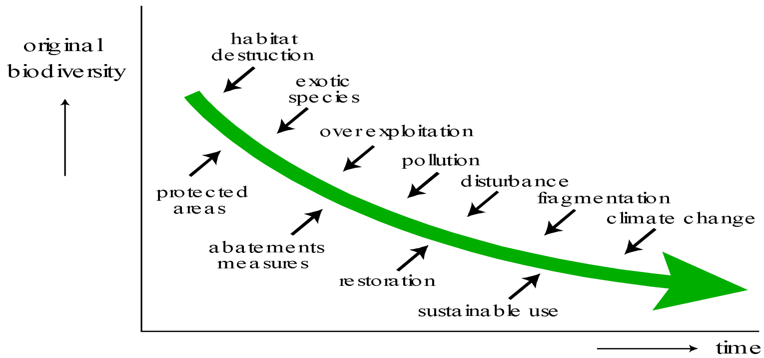


Figure 3: The main causes of biodiversity loss and gains. Habitat loss due to land conversion is the major factor. This affects the ecosystem size or "ecosystem quantity". Other pressures such as over-exploitation and fragmentation change result in loss of quality in the remaining natural areas. This affects the "ecosystem quality". Both the loss of ecosystem quantity and ecosystem quality result in the loss of the biodiversity resource or natural capital.

The loss of biodiversity due both to loss of habitat and to pressures on the remaining habitat are called the loss of *ecosystem quantity* and *ecosystem quality,* respectively. Given these two factors the NCI framework has defined the natural capital as the product of the size of the remaining area (ecosystem quantity) and its quality (Figure 4):

NCI =*ecosystem quantity* × *ecosystem quality.*

Ecosystem quantity is defined as the size of the ecosystem (% area of country or region). Ecosystem quality is defined as the ratio between the current and a baseline state (% of baseline, Figure 5).

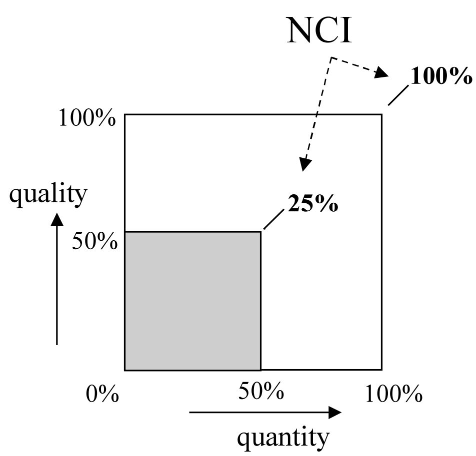


Figure 4: Natural capital is defined as the product of the remaining ecosystem size (quantity) and its quality. For example, if the remaining ecosystem size is 50% and its quality is 50%,

then 25% of the natural capital remains. The NCI can be worked out on any spatial scale and for both natural and man-made ecosystems (UNEP, 1997b).

The Natural Capital Index (NCI) ranges from 0 to 100%. For example, if 50% of a country still consists of natural area and the quality of this area has been decreased to 50%, than the NCI $_{natural\ area}$ is 25% (Figure 4). An NCI $_{natural\ area}$ of 0% means that the entire ecosystem has deteriorated either because there is no natural area left, or because the quality is 0% or both. An NCI $_{natural\ area}$ of 100 % means that the entire country consists of natural area of 100% quality.

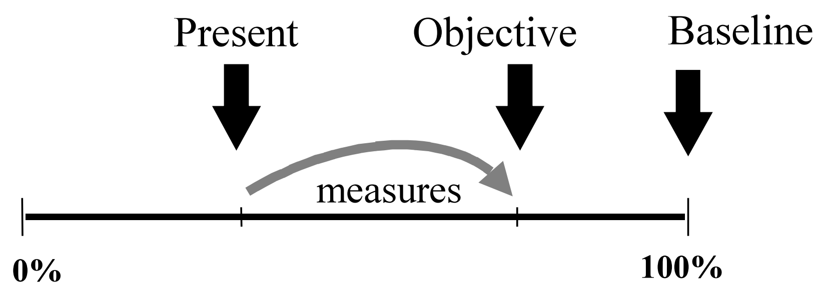


Figure 5: Ecosystem quality is calculated as a percentage of the baseline state.

A baseline is indispensable in assessing ecosystem quality. Information on the presence of "100 white storks" or "40 bird species" does not have any meaning as such without baseline information on what ought to be. Baselines are "starting points" for measuring change from a certain date or state (Figure 5). For instance, a baseline might be "the natural state" or "the year the CBD was ratified (1993)" or viable population levels. Although some indicators are used simply for comparison over time (for example, the Dow Jones Index and the Price Index), biological indicators are far more significant if they are measured against a specific baseline. Under the CBD it has been stated it makes most sense to show the biodiversity change in modern times when human influence was accelerating rapidly. This has been called "a postulated baseline, set in pre-industrial times", further referred to as "natural baseline" or "low-impact baseline". This baseline is a pragmatic point in time and will differ from region to region (UNEP, 1997b. UNEP, 1999).

Man-made and natural areas[3] are assessed differently. Natural areas are compared with a natural baseline state, while man-made areas (mainly agricultural areas) are compared with a pre-industrial agricultural baseline state, which is usually a species-richer state.

[3] Natural or self-regenerating area is defined as: *All not human-dominated land, irrespective of whether it is pristine or degraded, such as: virgin land, nature reserves; all forests except wood plantations with exotic species;* areas *with shifting* cultivation; *all fresh water areas; and extensive grasslands (marginal land used for grazing by nomadic livestock).*
Man-made area is defined as:
All human-dominated, cultivated, land such as: arable land; permanent cropland; wood plantations with exotic species; pasture for permanent livestock; urban areas; *infrastructure; and industrial areas. Most of the man-made area is in fact agricultural land.*

This assessment focuses on natural areas, *not* on man-made areas. It should be stressed that with this approach the quality of an ecosystem is not defined as species richness, making a boreal forest or the Wadden Sea per definition less valuable than a Mediterranean grassland. Ecosystem quality is defined as its integrity, as the extent in which man has affected an ecosystem in modern times. For a more comprehensive description of NCI is referred to the documents of the Convention on Biological Diversity (UNEP, 1997b; UNEP, 1999) and of RIVM (Ten Brink, 2000).

1.2.3.2 The adapted NCI Framework: remaining natural area and Pressure Index

This study only deals with major losses and gains of natural area due to conversion in agricultural area or build up area or vice versa. After all, the main changes in natural area are caused by changes in agricultural area. It does not deal with losses due to road building and other small scaled activities because of the lack of data in the current and future state. Moreover, habitat loss due to local factors is of less importance in this study on environmental priorities for the European Commission.

The extent of land use change is derived from the Baseline Scenario (Hettelingh et al., 1998). Unfortunately, it is not known where exactly conversion of agricultural areas to natural areas and vice versa will take place. Therefore, a Land Use Change Simulator was developed to simulate probable exchanges between three different land use classes: natural area, urban area and agricultural area. Annex 1 provides information on the calculation of the loss and gains of natural areas.

Contrary to ecosystem *quantity* it appears not easy to determine current and future *quality* of Europe's ecosystems. Firstly, no detailed geographic explicit data for Europe is available on the abundance of species in the current and baseline state, for example mammals, birds and plants. Secondly, dose-effect relationships are lacking to calculate the effects of scenarios on these species.

Therefore pressure indicators are applied as substitute for ecosystem quality indicators to explore probable ecosystem effects. Geo-referenced data are available of various relevant pressures and moreover, they are often easy to link with socio-economic scenarios. As in the Global Environment Outlook (UNEP, 1997a) the assumption is made that the lower the pressure, the higher the *chance* on high ecosystem quality and vice versa (Figure 6).

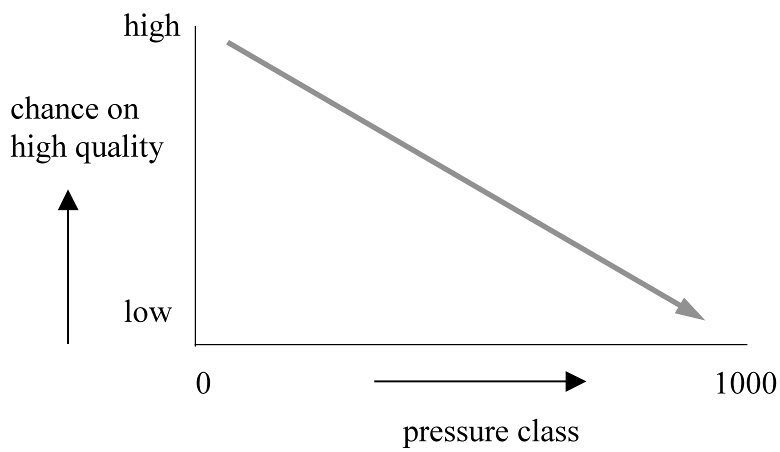


Figure 6: A Pressure Index is used as substitute for ecosystem quality. Assumption: the higher the pressure, the lower the chance on high ecosystem quality.

Seven biological relevant pressures could be elaborated in this study (Table 1): climate change; eutrofication; acidification; ozone concentrations; fragmentation; human population density and consumption/production intensity per km^2. This selection was pragmatically made because: i) they are relevant pressures on ecosystem quality; ii) geographical explicit data are available on these pressures for the year 1990 as well as for the year 2010 under the Baseline[4] and the Accelerate Policy scenarios for entirely Europe; iii) they represent different, additional types of pressures, and iv) literature supplies some knowledge on effect relationships and critical levels.

Climate change, eutrofication, acidification, ozone concentrations, fragmentation have direct effects on ecosystem quality. Human population density has been chosen as a substitute indicator for small-scale habitat destruction and disturbance (Verburg and Veldkamp, 1997). Consumption/production intensity per km2 has been chosen as a substitute indicator for pressures such as extraction of natural resources, contamination from heavy metals and organic pollutants, and physical disturbances. Many important but local pressures such as forestry, extensive grazing, over-exploitation, fire, water use and habitat destruction have not been taken into account *specifically* because data are lacking on both present as future. Moreover, local pressures are less important in respect to this study on environmental priorities for the European Commission.

The effects on nature quality of the above 7 pressures has been preliminarily scaled on a linear scale from pressure class 0 (no pressure) to pressure class 1000 (very high pressure) (Figure 6). Table 1 provides these scaling values. Pressure class 1000 indicates a high chance of extremely poor biodiversity compared with the –yet not impacted-baseline state. Thus when a pressure increases to 1000, the chance of having a high quality ecosystem decreases to zero. As for we are dealing with slow deterioration processes and large ecosystem buffers, it concerns long term pressures and long term

[4] The “baseline scenario” should not be confused with the "postulated baseline" set in pre-industrial times used to assess the quality of ecosystems.

effects[5]. Annex 2 provides background information on the substance and scaling of these pressures.

The next step is to give an indication of the effects from the sum of the 7 pressures. Therefore the pressure classes of each of the seven pressure indicators have been added for each 1 by 1 km grid cell. This results in one sum Pressure Index per grid cell. This sum Pressure Index per grid cell ranges from 0 to 7000. It is assumed that there is a low chance on high ecosystem quality in those natural areas where the sum Pressure Index is larger than 2500. This is an arbitrary level based on the following: a pressure class of 1000 of one single pressure has already severe detrimental effects on ecosystems with a low chance on high biodiversity as stated above. Additional pressures can only make this a little worse. For the purpose of this report it is therefore assumed that a sum Pressure Index affects an ecosystem seriously until a level of 2500. A higher index (between 2500 – 7000) does not make much difference; the system is already highly deteriorated. Consequently, the ecosystem quality in areas with a sum Pressure Index higher than 2500 is assumed to be 0% on the long term after long term pressure. The highest chance on high ecosystem quality is in those natural areas where the sum Pressure Index is 0. Ecosystem quality is then assumed to be 100%.

Table 1: Pressures to biodiversity and scaling values.

Pressures/scaling	**High chance on high ecosystem quality Pressure class = 0**[6]	**Low chance on high ecosystem quality Pressure class = 1000**
1. Rate of climate change	< 0.2°C change in 20 years	> 2.0°C change in 20 years
2. Human population density	< 10 persons/km^2	> 150 persons/km^2
3. Consumption and production (GDP)	US$ 0 per km^2	> US$ 6,000,000 per km^2
4. Isolation/fragmentation	% natural area within 10 km > 64%	% natural area within 10 km < 1%
5. Acidification	Deposition < critical load	Deposition > 5 x critical load
6. Eutrofication	Deposition < critical load	Deposition > 5 x critical load
7. Exposure to high ozone conc.	AOT40 < critical level	AOT40 > 5 x critical level

A Pressure Index can be generated for different spatial scales ranging from grid cell to country or regional scale. In this study, pressure indices are provided at the EU15 region level, at the country level and also for Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, and Switzerland.

1.3 Results

1.3.1 Changes in ecosystem quantity (Area)

Map 1 clearly shows that in 1990 large parts of Europe are man-made areas and that the remaining natural areas are highly fragmented. In EU 15, only about 49 % of the land are

[5] 20-30 year and more.

[6] Within the limitations of this study it was not possible to make the scaling more biotope specific. The scaling is assumed to be valid for all biotopes.

considered to be natural area. This slightly increases to 51% under the Baseline Scenario and Accelerated Policies scenarios in the period 1990 to 2010 (Table 2, Map 2, Map 3). Several countries contain only a relatively small percentage of natural area. In Belgium-Luxembourg, Denmark and the Netherlands less than 25% is natural area of their total area (exclusive marine and coastal waters).

According to the Baseline and Accelerated Policies scenarios (Hettelingh et al., 1998) 127.000 km^2 of the European agricultural area will be taken out of production in the period 1990 - 2010 (excluding former S.U.). Given the Baseline and Accelerated Policies scenario and CORINE data on current land use the proportion of natural area for 1990 and 2010 is calculated per country (Table 2). In most countries, a small increase in natural area can be seen. According to the scenarios, Denmark (+7%) and Greece (+19%) have the largest increase in percentage. Ireland, Italy, Portugal and Spain show a decrease in natural areas.

Table 2: Proportion of natural area in 1990 according to the CORINE land cover database and in 2010 according to the Baseline and Accelerated Policies (AP) scenarios.

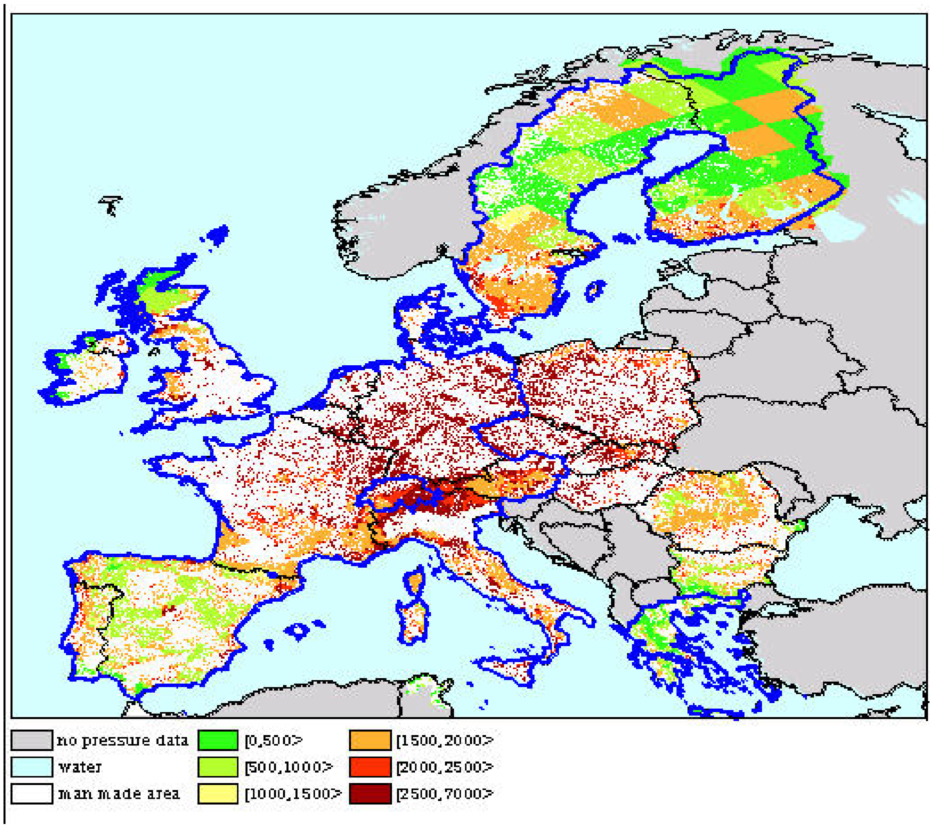
Country	Natural area 1990 (%)	Natural area 2010(%) Baseline and AP
Austria	62	65
Belgium-Luxembourg	22	25
Denmark	14	21
Finland	93	95
France	33	37
Germany	31	34
Greece	60	80
Ireland	29	28
Italy	42	40
Portugal	47	44
Spain	47	45
Sweden	69	72
The Netherlands	19	23
United Kingdom	35	38
EU15	**49**	**51**
Bulgaria	41	44
Czech Republic	44	48
Hungary	21	23
Poland	30	32
Romania	43	47
Slovakia	34	34
Switzerland	70	70
Total	**46**	**48**

1.3.2 Changes in ecosystem quality (Pressure)

Map 1, Map 2 and Map 3 show the sum Pressure Index in Europe's remaining natural areas for respectively 1990, Baseline, and Accelerate Policies scenario. The resolution is 1 by 1 km. The colours range from natural areas with a high chance on high quality (dark green) to natural areas with a low chance on high quality (brown). A blue line surrounds the European Union. The white colour represents man-made areas and the grey colour the no-data areas. Table 3 and Table 4 provide the mean Pressure Index[7] for countries and mean single pressure indices[8] for the EU15 region, respectively.

1990:

Map 1 shows that many of the remaining natural areas are under very high pressure and consequently have a very low chance on high ecosystem quality. In the following countries, the mean Pressure Index for all natural areas is above 2500: Belgium-Luxembourg, Germany, the Netherlands. Threat to biodiversity is also high, as the mean Pressure Index is exceeding the 2000-level, in Austria, Denmark, France, and Italy. Countries with a mean Pressure Index below the 1000-level are Finland, Greece, and Ireland.



Map 1: Pressure index in remaining natural area in 1990.

Map 1 clearly show that the pressures are low mainly in mountainous areas[9] in Ireland (e.g., the Kerry Mountains), Greece (e.g., Pindus mountains), Spain (e.g., Pyrenees,

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[7] The “mean Pressure Index” is the mean of the sum Pressure Index of all natural grid cells per country or for Europe

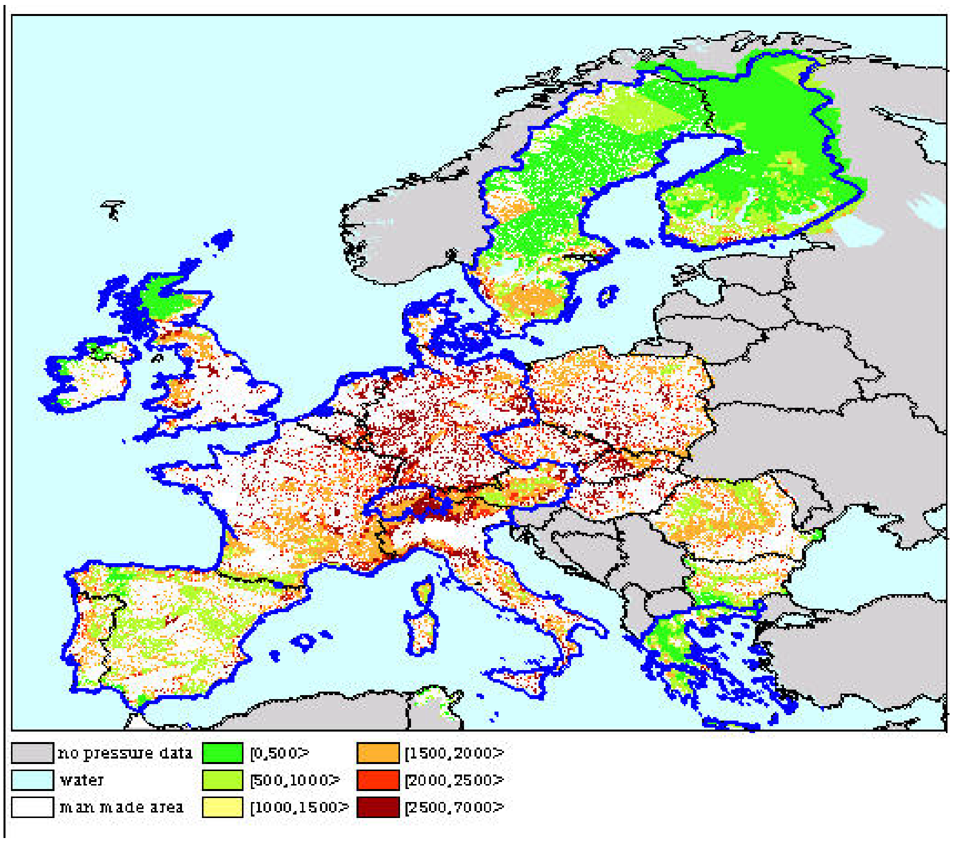
8 The “mean single pressure index” is the mean pressure of one pressure of all natural grid cells per country or for Europe

[9] Important pressures such as forestry, water extraction, fire, and extensive cattle grazing are not included as direct pressures and might change the picture considerably in specific parts.

Cantabric mountains, Serrania de Cuenca and Sierra de Alcaraz) and in the United Kingdom (e.g., Scottish highlands).

It should be stressed that in countries with a mean Pressure Index below 2000 still might have large areas with sum Pressure Indices above the 2500-level (e.g. southern part of the UK). Similarly, although countries may have a high mean Pressure Index, they do have areas with low pressures allowing for high quality ecosystems.

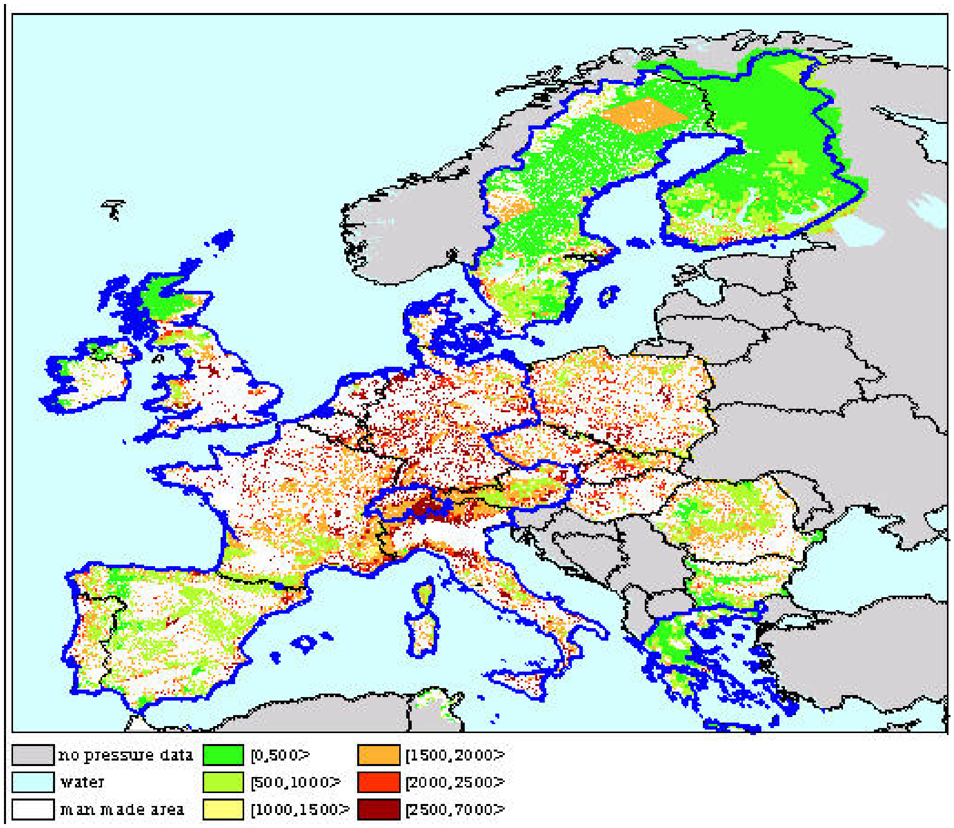
2010 Baseline scenario: The mean Pressure Index decreases in all countries but is still above 2500 in Belgium/Luxembourg, Germany and The Netherlands. Countries with a mean Pressure Index below 1000 are: Finland, Greece, Ireland, and Sweden. No countries have a mean Pressure Index below 500. Although the mean Pressure Index will decrease in all countries under the Baseline scenario (*Map 2*) threat to biodiversity in many natural areas remain still high. Table 4 reveal that the mean Pressure Index of the EU-Region will decrease from 1596 to 1249 (scale: 0-2500). Pressure from ozone, acidification and eutrofication will reduce considerably while pressure from temperature and GDP will increase.



Map 2: Pressure index in remaining natural area in 2010 in Baseline scenario.

2010 Accelerated Policies scenario: The policy measures taken under the Accelerate Policies scenario cause an further reduction in the mean Pressure Index in comparison with the Baseline scenario (Map 3, Table 3). Only Finland, show no improvement compared to the Baseline scenario. Belgium-Luxembourg, Germany, and the Netherlands will still have a mean Pressure Index above 2500. However, these three countries all

show a considerable decrease in the mean Pressure Index. As stated before, although these countries have a high mean Pressure Index, they do have areas with low pressures allowing for high quality ecosystems.
Countries with a mean Pressure Index below 1000 are Finland, Greece, Ireland, Spain, and Sweden[9]. In comparison to the Baseline scenario the mean Pressure Index for the EU15-region decreases further to 1107 (scale: 0-2500).



Map 3: Pressure index in remaining natural areas in 2010 Accelerate Policies scenario.

Table 3: Mean Pressure Index for countries in 1990 and 2010 under Baseline and Accelerate Policies (AP) scenarios

Country	Baseline 1990	Baseline 2010	AP 2010
Austria	2469	1767	1574
Belgium-Lux.	4255	3578	2850
Denmark	2173	1811	1610
Finland	853	523	522
France	2357	1893	1637
Germany	4206	3074	2536
Greece	743	700	644
Ireland	723	673	645
Italy	2439	2142	1973
The Netherlands	4377	3695	2948
Portugal	1293	1262	1134
Spain	1166	1077	959
Sweden	1004	638	591
UK	1442	1197	1015
EU15	**1596**	**1249**	**1107**
Bulgaria	1074	980	795
Hungary	3098	2597	2063
Slovakia	3667	2373	1894
Poland	3055	2059	1730
Romania	1456	1300	983
Switzerland	2716	2587	2363
Czech Rep.	2934	2221	1683

Note: the mean Pressure Index ranges from 0 – 7000; >2500 means low chance on high quality.

Table 4: EU_{15} mean single pressure indices.

Pressure	1990	Baseline 2010	AP 2010
Temperature	161	278	278
Population	225	231	231
Ozone	407	266	191
Eutrofication	216	120	92
GDP	119	156	156
Isolation	111	100	100
Acidification	352	95	53
EU 15 Pressure Index	**1596**	**1249**	**1107**

Note: The mean single pressure index range from 0 – 1000;
The mean Pressure Index ranges from 0 – 7000; >2500 means low chance on high quality

1.3.3 Analysis of the seven pressures

The following sections give an indication of where the considered pressures have the most significant impact. The results are summarised in Table 4. Table 5 (1990), Table 6 (Baseline scenario), and Table 7 (Accelerate Policies scenario) provide detailed figures per pressure, per country and per scenario.

Pressure: High ozone concentration

1990: Tropospheric ozone is relatively the highest pressure in 1990. Highest pressures (>900) to biodiversity are found in Belgium-Luxembourg, France, and Germany. It is also high (500 – 900) in Austria, Italy, the Netherlands, Portugal and Spain. Countries with low ozone pressure (< 100) are: Finland, Ireland, and Sweden.
2010 Baseline scenario: Pressure from ozone reduces considerably in all countries. The highest pressure is found in Belgium-Luxembourg (833). Other countries with a pressure > 500 are France, Germany, Italy, and The Netherlands. For the EU15 region pressure decreases from 407 in 1990 to 266 in 2010.
2010 Accelerated Policies scenario: Pressure reductions are considerable higher in this scenario. Pressures above 500 only occur in Belgium-Luxembourg and Italy. Countries with no or low pressure are Denmark, Finland, Ireland, Sweden and the UK. The mean O_3 pressure in the EU15 region decreases from 407 in 1990 to 191 in 2010.

Pressure: Rate of climate change

1990: Climate change causes a relative low pressure to biodiversity in 1990. The maximum rate of temperature change observed in the period 1970-1990 is 0.6°C in Finland (pressure class = 233). The other countries in Europe were confronted with a climate change, which was less severe.
2010 Baseline and Accelerated Policies scenarios: The pressure from climate changes substantially increased during the period 1990 – 2010 in each country. The EU15 region will be confronted with a mean increase from pressure class 161 in 1990 to 278 in 2010. Almost no differences between Baseline and Accelerated Policies scenario can be observed before 2010. Differences do occur in the period 2010-2050, but are not incorporated in this study because of the large time lag. The highest pressure will be found in Finland where the mean rate of temperature change is 0.9°C in the period 1990 – 2010. In Greece the lowest rate of temperature change (0.4°C) is expected.

Pressure: Human population density

1990: In almost entirely Europe, human population density causes a high pressure to biodiversity. The highest pressure is found in Germany and the Netherlands (615 and 614 respectively, i.e. about 96 persons/km^2) but is also high (>500) in Belgium-Luxembourg and Italy. Very low pressures can be found in Finland and Sweden (population density of 16 and 18 persons/km^2) and to a lesser extent Ireland (population density of 30).
2010 Baseline and Accelerated Policies scenarios: For both scenarios the same changes in population densities are modelled. No large changes in densities are expected. Both increases and decreases take place. The largest increase in pressure from population is

expected in Austria. The pressure from population density in the EU15 region slightly increases from 225 to 231.

Pressure: Consumption and production, GDP

1990: The pressures related to consumption and production are relatively low in Europe except for the Netherlands and Switzerland and to a lesser extent in Germany, Denmark, Italy, and Belgium-Luxembourg.
2010 Baseline and Accelerated Policies scenarios: Like for population density, changes in GDP from 1990 to 2010 are similar for Baseline and Accelerated Policies scenario. GDP increases in all countries. The pressure from consumption and production in the EU-15 region increases from 119 in 1990 to 156 in 2010.

Pressure: Isolation/Fragmentation

1990: Pressure from isolation is highest in Denmark (590). Countries with the lowest isolation/fragmentation of natural areas in Europe are Finland, Sweden, Greece, and Austria.
2010 Baseline scenario: Italy, Portugal, and Spain are the only countries that have a small increase in pressure from isolation. The largest decrease in pressure is found in Belgium-Luxembourg (-57), Denmark (-56), Greece (-41) and the Netherlands (-56) due to conversion of agricultural area into natural area.
2010 Accelerated Policies scenario: The changes in pressure are very similar to the changes as described for the Baseline Scenario. This is because a different distribution of extra natural area hardly affects the mean isolation of natural areas at the country level. However, changes will be more evident when the pressure from isolation is calculated for regional areas or when it is calculated on the bases of connectivity of natural grid cells.

Pressure: Acidification

1990: Acidification is a large pressure in Europe. Countries with the highest pressure from acidification (> 900) are Belgium-Luxembourg (5 x critical load), Germany (4.5 x critical load) and the Netherlands (5 x critical load). Pressure from acidification is also high (> 500) in Austria, Sweden and the UK. Acidification causes no or low pressure to biodiversity in Greece, Ireland, Portugal and Spain.
2010 Baseline scenario: Pressure from acidification decreases substantially under Baseline Scenario in all countries. No countries have a pressure above 900. Pressure still exceeds 500 only in Belgium-Luxembourg and the Netherlands. Acidification causes no or low pressure to biodiversity in Austria, Finland, France, Greece, Ireland, Italy, Portugal and Spain. The pressure from acidification in the EU15 region decreases from 352 in 1990 to 95 in 2010.
2010 Accelerated Policies scenario: All countries show a substantial decrease in pressure from acidification in comparison with 1990. The decrease is in all EU countries larger than under the Baseline Scenario. The EU15 region shows a reduction of 352 in 1990 to 53 in 2010.

Pressure: Eutrofication

1990: Countries with very high pressure from eutrofication (pressure class > 900) are Belgium-Luxembourg (4.6 x critical load) and The Netherlands (4.9 x critical load).

Pressure is also high (pressure class > 500) in Austria and Germany. No or limited pressure from eutrofication can be found in Finland, Greece, Ireland, Portugal, Spain, Sweden and the United Kingdom.
2010 Baseline scenario: Pressure from eutrofication is reduced considerably in entirely Europe but is still high (pressure class > 500) in Belgium-Luxembourg and the Netherlands. In the EU15 region eutrofication reduces from pressure class 216 to 120.
2010 Accelerated Policies scenario: The changes in pressure from eutrofication differ from country to country. Most countries show a clear decrease in pressure in the period 1990 – 2010. Eutrofication in Belgium – Luxembourg and the Netherlands is still above 500. Pressure in the EU15 region decreases from 216 in 1990 to 92 in 2010.

*Table 5: Mean single pressures and mean Pressure Index (Total) in natural areas per country and EU 15 in **1990**.*

Country	*Temperature*	*Ozone*	*Population*	*GDP*	*Isolation*	*Acidification*	*Eutrofication*	*Total*
Austria	135	725	326	151	77	542	512	2469
Belgium-Lux.	201	956	546	274	357	997	923	4255
Denmark	193	432	385	218	590	155	224	2173
Finland	233	0	46	36	3	434	99	853
France	173	947	305	167	223	141	400	2357
Germany	188	900	615	393	328	903	880	4206
Greece	35	375	208	43	64	0	16	743
Ireland	51	85	143	49	236	98	60	723
Italy	101	879	499	271	123	163	402	2439
The Netherlands	204	702	614	477	390	998	982	4377
Portugal	76	548	360	76	160	0	74	1293
Spain	120	555	224	85	122	8	57	1166
Sweden	193	42	57	41	42	554	78	1004
UK	96	105	256	146	128	622	31	1442
EU15	**161**	**407**	**225**	**119**	**111**	**352**	**216**	**1596**
Bulgaria	35	382	299	35	159	0	164	1074
Czech Rep.	110	774	549	109	141	658	594	2934
Hungary	89	830	523	90	415	691	460	3098
Poland	163	552	510	75	341	713	702	3055
Romania	52	441	451	40	160	49	263	1456
Slovakia	153	853	576	154	337	943	650	3667
Switzerland	173	700	415	417	64	618	743	2716

Note: The mean single pressure index range from 0 – 1000;
The mean Pressure Index ranges from 0 – 7000; >2500 means low chance on high quality

Table 6: Mean single pressures and mean Pressure Index(Total) in natural areas per country and EU-15 in 2010 in the ***Baseline Scenario****.*

Country	*Temperature*	*Ozone*	*Population*	*GDP*	*Isolation*	*Acidification*	*Eutrofication*	*Total*
Austria	241	418	397	266	65	60	320	1767
Belgium-Lux.	334	833	544	345	300	512	711	3578
Denmark	323	190	392	299	434	95	90	1811
Finland	379	0	51	52	3	11	27	523
France	297	612	315	218	177	32	241	1893
Germany	316	534	611	428	289	435	461	3074
Greece	105	265	234	64	23	0	8	700
Ireland	121	31	154	115	222	0	32	673
Italy	194	639	484	347	127	56	293	2142
The Netherlands	339	517	663	578	334	545	705	3695
Portugal	163	406	345	121	172	0	56	1262
Spain	226	364	215	119	130	0	30	1077
Sweden	320	10	60	58	34	136	21	638
UK	183	68	267	198	109	324	3	1197
EU15	**278**	**266**	**231**	**156**	**100**	**95**	**120**	**1249**
Bulgaria	101	304	281	44	151	0	99	980
Czech Rep.	203	482	572	142	111	355	356	2221
Hungary	173	527	493	124	374	555	350	2597
Romania	124	316	446	52	142	24	196	1300
Slovakia	264	493	577	209	302	177	352	2373
Switzerland	294	416	449	452	64	307	606	2587
Poland	278	303	517	129	302	76	453	2059

Note: The mean single pressure index range from 0 – 1000;
The mean Pressure Index ranges from 0 – 7000; >2500 means low chance on high quality

Table 7: Mean single pressures and mean Pressure Index (Total) in natural areas per country and EU-15 in 2010 in the ***Accelerated Policies scenario***.

Country	*Temperature*	*Ozone*	*Population*	*GDP*	*Isolation*	*Acidification*	*Eutrofication*	*Total*
Austria	264	337	397	266	66	20	244	1574
Belgium-Lux.	366	621	544	345	318	88	578	2850
Denmark	362	89	392	299	434	33	61	1610
Finland	427	0	51	52	3	11	26	522
France	324	421	315	218	178	5	199	1637
Germany	348	377	611	428	293	185	317	2536
Greece	127	209	234	64	20	0	6	644
Ireland	141	8	154	115	221	0	27	645
Italy	217	504	484	347	129	57	253	1973
The Netherlands	373	378	663	578	319	236	512	2948
Portugal	190	311	345	121	170	0	39	1134
Spain	257	254	215	119	130	0	17	959
Sweden	362	2	60	58	34	104	12	591
UK	209	37	267	198	111	179	1	1015
EU15	**278**	**191**	**231**	**156**	**100**	**53**	**92**	**1107**
Bulgaria	117	120	281	44	150	0	99	795
Czech Rep.	227	21	572	142	111	292	339	1683
Hungary	193	25	493	124	376	529	339	2063
Poland	311	15	517	129	302	44	443	1730
Romania	138	0	446	52	142	22	198	983
Slovakia	292	138	577	209	303	104	296	1894
Switzerland	320	315	449	452	64	287	502	2363

Note: The mean single pressure index range from 0 – 1000;
The mean Pressure Index ranges from 0 – 7000; >2500 means low chance on high quality

1.4 Conclusions

From this study, the following general conclusions can be drawn:

- In the EU, about half of all land cover is still considered to be natural area. This share is not projected to change due to large-scale conversion in agricultural or built area. Neither is re-conversion into nature projected to occur to large extent by 2010.
- From the natural area, only a minor part is protected under the Habitat or Birds Directives, i.e. 10% and 20% respectively.
- The natural area is suffering from acidification, eutrofication, tropospheric ozone, climate change as well as from fragmentation of natural area. In addition, natural areas are effected pressures related to population density and production/consumption. These will contribute towards small-scale habitat destruction, habitat disruption, over-exploitation of natural resources and contamination with heavy metals and organic pollutants.
- An indicator was constructed to quantify some facets of these pressures. The indicator predicts a decrease of these pressures by 22% to 31%, but this probably due to the fact that the air quality related indicators dominate the index.
- Even with the decrease in the indicator the pressure remains high, exceeding several critical loads. Thus, biodiversity loss is expected to continue, though at a slightly lower rate.
- The effect of small-scale conversion[10] has not been studied, but this might well be a serious threat to biodiversity. Biodiversity loss may be accelerated if small-scale habitat loss and fragmentation increase and other major pressures such as forestry, water extraction, fires and extensive cattle grazing, expand in the years to come.
- In sum, evidence exists to demonstrate that biodiversity in the EU has deteriorated and that this negative trend is not likely to reverse. This evidence should be seriously concerned.
- However, at European level, data are not yet sufficiently available to quantitatively assess the status of biodiversity, let alone to make reliable projections. Much data and knowledge already exists, but this is scattered all over Europe. If the data were pooled together, it would be possible to carry out a European-wide quantitative assessment. Such an assessment would pave the way for better understanding of the state of biodiversity in Europe. A general assessment framework, such as the Natural Capital Index framework as developed under the Convention on Biological Diversity, could be applied in such analysis. In the study, systematic monitoring and targeted research into baseline information and pressure-effect relationships would have to be established in order to track changes over time, give significance to data as such, and prioritising abatement measures.

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[10] 'Small-scale conversion' is the term indicating the conversion of an area with small-scales in its landscape like ponds, hedgerows, brooks into a homogeneous area for a more efficient agriculture or transport.

As indicated above, this study has various limitations. Due to lack of coherent information, it disregards some pressures, which are likely of great importance. Furthermore, biodiversity allocated in agricultural areas has not been taken into account. Nevertheless, this study provides an exploration of the relative effect on biodiversity of five abatement measures at the European level. It is based on the present day knowledge and may be of help to further efficient policy making. Limitations and opportunities of the approach are given in Annex 3.

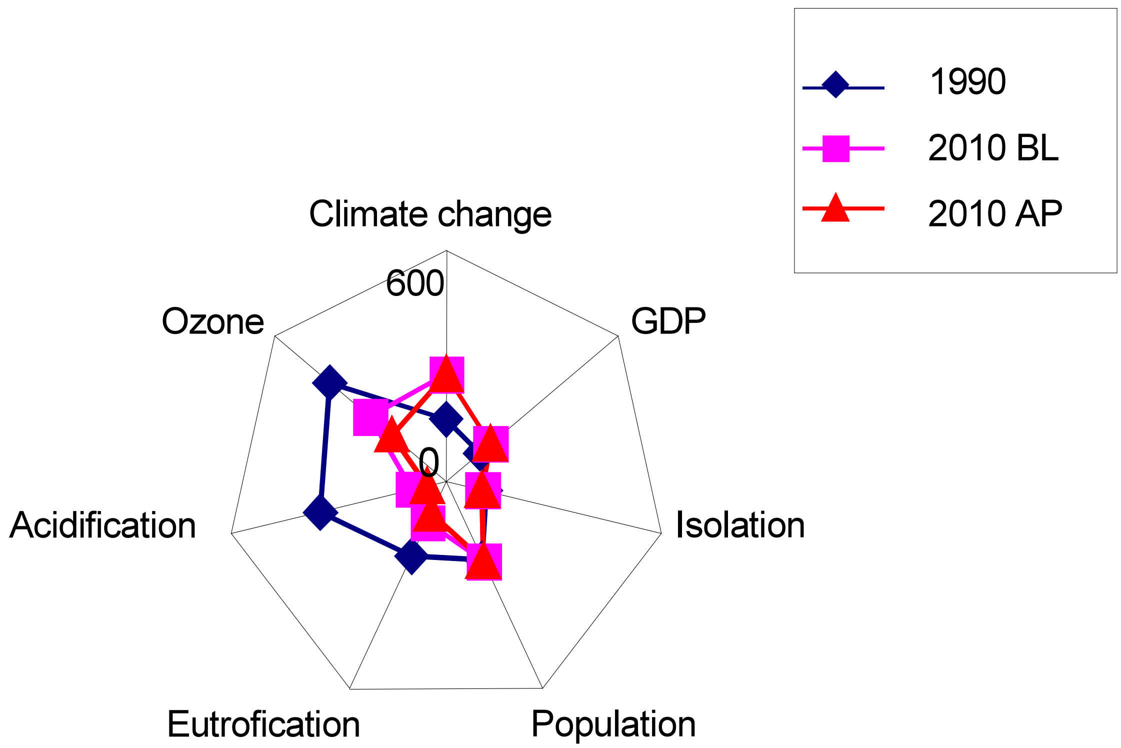

Figure 7: Radar diagram of 7 single pressures in 1990, and the Baseline and Accelerated Policy Scenarios. Eutrophication, tropospheric ozone, and acidification pressures decrease considerably, especially in the Accelerated Policy Scenario, while climate change and GDP related pressures increase. Isolation and pressures related to population density remain more or less stable.

Note: The mean single pressure index range from 0 – 1000, no pressure and very high pressure respectively. The figure showes a range from 0 – 600.

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2. Benefit assessment

2.1 Public opinion

Eurobarometer (1995) cites biodiversity loss as the eighth most important environmental issue. This ranking is unchanged from the 1992 survey.

2.2 Expert opinion

GEP et al. (1997) rank biodiversity loss ninth as a priority issue, with 10.3% of researchers world-wide ranking it as the first or second most important problem. This compares with 11.5% of experts in Europe, again ranking it as ninth most important environmental problem.

2.3 Benefit estimation

Biodiversity loss presents a substantial challenge in terms of measuring its rate of change and measuring its economic value.

First, much of what is measured relates to *biological resources* per se, rather than the *diversity* of those resources. The extent to which an increase in the population of one species is regarded as a substitute for a decline in another species, is unclear. Whole species might disappear, this reducing diversity, but if there is an abundant population of the remaining species, this might be regarded by some as an acceptable situation, and even an improvement. Economic valuation studies have tended to focus on endangered species and habitats at risk of degradation or conversion to some other use and, in general, individuals' willingness to pay to conserves species and habitats appears to be higher the scarcer or more endangered the object of value is. But it remains unclear if economic valuation studies are valuing diversity as such.

Second, indicators of change in biodiversity tend not to ‘match’ the objects of economic value. Thus, valuation studies might estimate the willingness to pay to conserve a given habitat, say a wetland. This suggests that what is required for scenario analysis is an indicator showing how many such wetlands will exist in 2010 compared to 1990. Typically, information is not available in scenario form for such indicators. Hence there is a major problem for both scenario construction - how to estimate changes in biodiversity over time - and for economic valuation, ie how to value those changes.

Suitable indicators needed for the monetary valuation of biodiversity loss would be: (i) change in land area by ecosystem classification (i.e. km^2 of wetland, woodland, agricultural land) and (ii) species change, including change in expected life-time of a species.

Development of the natural capital index

The *Natural Capital Index* (NCI) Framework developed by RIVM for the Convention on Biological Diversity (CBD, 1997; RIVM, 1998) records seven pressure indicators:
rate of climate change, population density by area, GDP by area, Acidification, Eutrophication, exposure to tropospheric ozone concentrations, and ecosystem fragmentation
The aim of these indicators is to capture some of the underlying forces giving rise to biodiversity change. In Europe these come mainly from land use change which both reduces the absolute levels of 'natural areas and also fragments those remaining so that species populations may not achieve minimum viable size. In the longer term, climate change will clearly also be a major influence. Land use change is as much a function of economic and social policy as trends in pollution and economic activity. Thus, the Common Agricultural Policy is known to be a major influence on biodiversity. Hence, reforms in the CAP are likely to be a major factor determining future biodiversity levels. Ideally, this should show up in scenarios in which policy reforms of this kind are explicitly modelled: the Baseline scenario has no policy changes in it.

The RIVM NCI conflates the seven pressures into one, i.e. it assumes that each of the factors measured is of equal importance within the chosen minimum and maximum pressure range. This is unlikely to be the case because pressure-effect relationships are often non-linear, but at this stage it is difficult to see what other procedure can be adopted. The NCI produces Europe-wide maps of areas 'at risk' in 1990 and 2010 for the Baseline scenario. There are seven land cover classifications:

artificial territories
strongly artificial vegetated areas
less artificial vegetated areas
Forests
non-wooded semi natural areas
Wetlands
Water surfaces

Economic analysis of biodiversity loss

Provided the mapped information can be converted back to actual areas, and hence changes in areas for each of these classification, there is some chance that economic valuation can be carried out. The procedure would be as follows:

- Take each land use classification and, as far as possible, match them to habitat types that have been the subject of economic valuation studies. This will give some idea of the economic valuation of each type of land use, allowing for non-market values.
- Take the RIVM risk classification, which consists of a 5 level indicator ranging from 'high chance of high ecosystem quality' down to 'high chance of low ecosystem quality'. What matters is the *change* in land area in any land use classification from one risk category to the next. For damage estimation, the changes that are relevant are those where a given land use *increases its risk* of low quality. For benefit estimation, it is the improvement in risk category that matters provided it is the outcome of a policy

measure. In the Baseline scenario, RIVM estimate that 8 million hectares of land in the wider Europe will convert from agricultural areas to natural areas (RIVM, 1998, p.53).

Problems remain (a) because the classification of land uses will not necessarily correspond to habitat classifications used in economic studies and (b) because we have no obvious way of translating each risk category into economic valuations. On (b), for example, economic studies tend to postulate total loss of habitat or some specified risk, e.g. from pollution. A third problem, (c), is that economic valuations applied to single areas cannot be readily applied to all such areas. This is because the values derived in economic studies are marginal valuations, whereas the scenarios may result in large scale changes[11]. If, however, the changes in land use are marginal relative to the existing scale of that land use then it is probably safe to treat the changes as 'marginal'.

Despite these problems, there is some chance of estimating at least part of the economic value of biodiversity.

One other possibility to be investigated is that change in area of a given land use can be converted to estimates of species loss via biogeographical relationships such as area-species linkages.

Economic values by type of natural capital

The results of an extensive literature review of European studies are given in the next section the outcome is summarised in Table 2.1. With some exceptions, the vast majority of the studies relate to the richer EU countries. Since they are WTP studies, income determines the resulting economic valuation, which means that the results cannot be generalised across the whole of the EU without adjustment. The italicised numbers give the results of adjusting the valuations by the ratio of average EU income per capita to the income levels in the countries where the studies were carried out.

[11] This mistake pervades one global attempt to value ecosystems: see R.Costanza et al., 1997. The value of the world's ecosystem services and natural capital, *Nature*, **387**, May 15. For a critique see D W Pearce, Auditing the earth, *Environment*, **40**, 2, March, 23-28

Table 2.1 WTP for different aspects of biodiversity and different kinds of habitat

Type of natural capital	WTP: € per person per annum		Countries of studies
	Average WTP	WTP adjusted to EU average	
Biodiversity preservation generally	31.1	28.66	UK, Norway, Germany
Wildlife	1.9	1.8	UK, Hungary
Woodlands	20.1	18.8	UK, Netherlands, Sweden, Norway
Wetlands	38	35	UK, Austria, EU
Environmentally sensitive areas	20.6	19	UK, Sweden
Moorland	63	57.8	Scotland
Watercourses	31.2	28.7	UK, Norway
Agricultural landscape	62.5	57.5	Austia, Sweden, Netherlands, UK
Endangered species	128.6	120.9	Sweden, Norway, UK

Literature review of economic studies of biodiversity values in Europe

Biodiversity may be defined in terms of genes, species and ecosystems (Pearce and Moran 1994). Genetic diversity is the sum of genetic information contained in the genes of individuals of plants, animals and micro-organisms. Species are regarded as populations within which gene flow occurs under natural conditions. Here, for valuation purposes, the focus is mainly on ecosystem diversity, which relates to the variety of habitats in the biosphere as well as the diversity within ecosystems.

Benefit analysis of biological diversity in its entirety is impossible given the present level of knowledge. An attempt can be made to estimate the social benefits of preserving certain selected wild and domesticated species of plants and animals, or habitats. Since the RIVM Natural Capital Index operates with land use classifications, the estimates relating to habitat are likely to be the most important.

The total economic value of the benefits of biodiversity, TEV(B) is defined as:

$$TEV(B) = DUV + IUV + OV + NUV$$

Where, DUV is direct use value e.g. for recreational, educational visits, IUV is indirect use value, OV is option value e.g. for future drug discoveries, NUV is non-use value, i.e. willingness to pay for conservation but unrelated to actual or intended use.

Despite the potential biases of the contingent valuation method (CV), it seems that this method is best for assessing WTP to protect and preserve biodiversity, because it spans the total WTP (both the use and the non-use values). Many of the studies reported here use the CV method. Nevertheless, CV estimates for similar goods will differ depending on the technique used to carry out interviews (eg. open-ended questions, dichotomous choice etc), and also over space due to cultural differences, which may exist between sampled populations. Thus, values held in one geographical/cultural region may not be applicable to others (Willis et al., 1996).

Note also that most of the studies relate to the value of biological resources. How far they are capturing diversity is difficult to assess. Those studies looking at the valuation of habitats may well be capturing perceptions of diversity - i.e. valuations may be high simply because the area is known to be rich in diversity (Pearce and Moran 1994).

Here follows a list of European studies that try to value different aspects of biodiversity and different kinds of habitat. The various methods to carry out evaluation are: contingent valuation, contingent ranking, travel cost method and hedonic price methods.
In order to have an idea of the per person per year value for each of the habitats, the WTP figures have been converted to 1997 €, and then only compatible studies (i.e. studies using a similar method of estimation) have been selected. An unweighted average of the WTP values of the selected studies gives the WTP pp/py for the specific habitat/species. The WTP pp/py is then multiplied by 365 millions (total EU-15 population). For the majority of the habitats, the selected studies have used CV methods based on the open-ended format (since values obtained from dichotomous choice are normally higher); moreover, accuracy was taken in choosing studies where the survey sample was randomly selected. In this way, it is theoretically possible to aggregate to obtain the annual total benefit of preservation of habitats/species by multiplying the WTP per household (per person)/per year by the number of households (persons) in EU-15.

Note that the results are only provisional. As can be seen the mean WTPs often diverge highly within the same habitat/species.

Note for the tables: CV = contingent valuation; OE = open ended; PC = payment card; DC = dichotomous choice; TCM = travel cost method; ZTCM = zonal travel cost method; ? = price year unspecified, and assumed to be the year before presentation of the paper.

Biodiversity preservation

Table 2.2 WTP for biodiversity preservation

Study	Country	WTP	Type of Study	Base year
Spash and Hanley, 1995 Biodiversity preservation	UK	Animal rights: £15.07st/£9.08gp biotic rights: £12.17st/£7.54gp ecosystem rights: £19.03/£6.88gp (once-off payment/pp) students £15.42 general public £8.01	CV, OE	1993
Hanley, Spash and Walker, 1995 Biodiversity protection w/ Intl Biodiv.Fund	UK	£46.99 less informed £62.26 more informed (per household/year)	CV, OE	1993
Navrud, 1992 Preserve Biological diversity	Norway	NOK 194 annual per person		1991
Holm-Muller et al., 1991, Preservation of species	Germany	16.1 DM per month		
Macmillan et al., 1995 Biodiv.loss due to acid deposition	UK	OE, £75 per household DC, £308 per household	CV, OE CV, DC	1994

Five values selected. **Average WTP: € 31.1 per person per year.**

Wildlife

Table 2.3 WTP for wildlife preservation

Study	Country	WTP	Type of study	Base year
Willis, Garrod, Benson, Carter et al., 1996 Benefits of wildlife, Pevensey case-study	UK	Conservative truncated mean: Residents: £61.74 Visitors: £ 17.85 Non-visitors: £ 13.83 (per year/p household)	CV, PC	1994
Willis, 1990 Wildlife, 3 sites	UK	£ per year General public: 0.82/0.61/1.29 Visitors:3.12/0.98/2.66 Experts: 4.54/4.28/5.57 Or, £ per ha/yr (cons. surplus per visitor): TCM (users): 23/65/32 CV (users+non-use): 2290/504/440	CV, OE use and non-use values TCM use value (consumer surplus)	1986
Willis and Benson, 1988, Wildlife, Upper Teesdale SSSI	UK	Experts: £25/ha/year/pp Consumer surplus (TCM, £/ha/yr): wildlife visitors 6-34 (range) all recreational use 46-251 (range)	CV(experts only), OE TCM	1985?
Willis and Benson, 1988, Wildlife in 3 nature reserves	UK	£0.6(1.02) to £1.7(2.3) per visit (full travel costs) Per ha: 1) 32, 2) 80, 3) 264	Consumer surplus benefits (TCM) from all visitors (wildlife and recreations)	1986
Hanley, 1989 Value of nature reserves/wildlife 3 sites	UK	£1.18 to £ 2.53 per adult	CV Payment Card	1988
Harley and Hanley, 1989 Value of nature reserves/wildlife 3 sites	UK	£1.99 to £2.60 per capita (or £7.30 to £9.5 depending on functional form and cost components)	ZTCM consumer surplus	1988?
Hanley, 1991 Preservation of flow country, landscape and wildlife assets	UK	£16.8 per capita as once-off payment	CV	

The above studies use very different methods to estimate benefits from wildlife, so that it is very difficult to derive an average WTP. Three values are selected, from the one CV-OE study: **average WTP: € 1.9 per person per year.**

National Parks and Nature Reserves

Table 2.4 WTP for national parks and nature reserves

Study	Country	WTP	Type of study	Base year
Szereny, 1997 preserve Bukk National Park	Hungary	£6 per visitor (use value only)	CV, PC use value	1996
Willis and Garrod, 1991 Preservation, Yorkshire Dales National Park	UK	£24 per household to preserve today's landscape (use value)/pa	CV includes non- use value	1990
Willis, 1990, SSSIs and nature reserves in 1985	UK	£4.54/head (CV)	CV option price including use and non use values	1985
Willis, 1990, SSSIs and nature reserves in 1986	UK	£ 0.82/head (CV)	option price including use and non use values	1986

Three studies selected. **Average WTP: € 9.4 per person per year**.

Woodlands

Table 2.5 WTP for woodlands

Study	Country	**WTP**	Type of study	Base year
Bateman,Diamand, Langford and Jones, 1996 WTP for establishing a Recreational woodland	UK	£9.94per year/household £ 0.82 per visit/household WTA pa by farmers: £250/acre (£617/ha)	CV, OE	1991
Garrod and Willis, 1997 Forest biodiversity, Contingent ranking	UK	Basic standard of biod.cons.: 30.3-33.4 p /yr/pp Desired stand.: 51.7-56.4 p/yr/pp Conversion to native woodland: 18.5-20.7 p /yr/pp	Contingent ranking	1995
Van der Linden et al., 1987	The Netherlands	DFL 22.83 p/ month/phousehold	Prevent deterioration of forests and heath	1987
Kristrom, 1990 Fragile forests	Sweden	95 SEK per year/pp	fragile forests	1991

Johansson and Kristrom, 1988, Preserving virgin forests	Sweden	OE 1014 SEK /household DC 1005-2741 SEK/household (use/non-use value) (once-off payment?)	CV, OE-DC	1988?
Kristrom, 1990, Six areas of forest with recreational value and five virgin forests	Sweden	USD 3-4/pers/yr CV	CV (deduced, probably an underestimate)	1990
Johansson and Zavisic, 1989, Preserve all natural forest/virgin forest in Sweden	Sweden	USD 5-8/per/yr CV	CV	1990
Hoen and Winther, 1991, Coniferous forest areas that resembles virgin forest	Norway	USD 13-18/pers/yr CV or 310 1989 NOK per household per year	CV	1990
Bateman et al.,, 1991, Thetford forest	UK	£1.21 to £7.09, OE CV	CV OE	1991
Hanley, 1991 Heathland conservation in Dorset	UK	£0.74/visit £9.73/year £ 25.57/once off	CV to visitors	1990
Willis and Benson, 1988 Forest recreation	UK	£0.53/head CV (visitors)	CV	1988
Willis et al.,, 1988 Forest recreation	UK	£0.33/head CV (visitors)	CV	1987
Willis and Benson, 1989 Forest recreation	UK	£1.3 to £3.3 per visit	ZTCM	
Hanley, 1989 Forest recreation	UK	£1.25/visit (CV)	CV, Payment Card	1987
Hanley, 1989 Forest recreation	UK	£0.32, £0.56, £ 1.7 and £15.13 depending on functional form	TCM, consumer surplus per capita	
Hanley and Common, 1987 Forest recreation	UK	£ 1.00 per visitor	CV	
Hanley and Common, 1987 Forest recreation	UK	£14.6-£24.5 consumer surplus per visitor pa	TCM	

Garrod and Willis, 1991 Country side characteristics (woodland)	UK	7.1% above sale price	HPM	1990?
Garrod and Willis, 1991 Amenity value of forestry	UK	£43 increase in sale price from a 1% increase in the proportion of broadleaved forested area	HPM	1988
Garrod and Willis, 1991 Empirical estimates of forest amenity value	UK	£0.06-£0.96 per visitor, depending on the site (consumer surplus) £0.43-£0.72 CV	TCM CV	1988
Willis, 1991, Recreational value of Forestry Commission Estate	UK	£ 1.95 per visitor £ 0.53 per visitor (OE CV use value) £0.39 option value	TCM, Average consumer surplus per visitor in 15 sites OE CV(both use and non-use value)	1988
Bateman and Langford, 1995, Woodland walks	UK	£12.55 pa (use)	CV use value	
Bateman, Diamond and Langford, 1995, Provision of forest recreation	UK	£3.51 pa (non-use)	CV non-use value	
Bateman, Brainard and Lovett 1995, Woodland recreation	UK	£1.82 per party visit/£0.60 pp £ 2.78 per party visit/£0.91pp	OE CV, use value OE CV, use + option value (results from 48 CV studies)	1990
Hanley et al., 1991, Heathland reservation	UK	no info: £21.54 p capita info on heath loss: £20.6 Info on species loss: £21.52 Info on both losses: £30.59	CV	
Hanley and Ruffell, 199? Forest characteristics	UK	(visitors) greater tree height diversity:£0.33 pvisit proportion broadleaved trees: £0.49 p visit proportion of water area: £0.69 p visit; average WTP across forests: £0.93 p visit	CV, OE use value	1991

Eleven studies selected. **Average WTP: € 20.1 per person per year.**

Wetlands

Table 2.6 WTP for wetlands

Study	Country	WTP	Type of study	Base year
Gren et al., 1994 Broadland ESA and wetland	UK	£67 per household per year (open ended) £75 iterative bidding	CV, OE CV, IB	1991
Kosz, 1996 Riverside wetlands	Austria	ATS 329.25 per Austrian per year	CV, OE use and non-use value	1993
Brouwer et al., 1997 meta-analysis wetlands	several EU countries	use values 68.1 SDR non-use value 35.5 SDR use and non-use value 63.8 SDR		
Bateman et al., 1995, Norfolk Broads (coastal wetlands)	UK	£ 21.75 pa (non-user)	CV, OE non-use value	1991
Bateman et al., 1995, Norfolk Broads (coastal wetlands)	UK	£76.74, OE £83.67, IB CV/yr/household,1991 prices (use value)	CV OE CV IB use value	1991

Four studies selected. **Average WTP: € 38 per person per year.**

Environmentally Sensitive Areas (ESA)
The following studies provide CVM estimates for ESA in the UK (WTP, £/hsld/yr). All values are for open-ended CVM, unless * (dichotomous choice CVM).

Table 2.7 WTP for Environmentally Sensitive Areas (ESA)

Study	Country	WTP residents	visitors	General public	Base year
Hanley, MacMillan, Wright, Bullock, Simpson, Parsisson, Crabtree, 1997, 2 ESA, Breadalbane	UK	31.43	73.00*	22.02	1995
" Machair	"	13.66	-	13.37	1995
Willis et al., 1993, 2 ESA, South Downs	"	27.52	19.47	1.98	1992
" Somerset	"	17.53	11.84	2.45	1992
Gourlay et al., 1996, 2 ESA. Loch Lomond	"	20.60	1.98 per visit		
" Stewartry	"	13.00	2.53 per visit	-	
Bullock and Kay, 1996, 1 ESA, Southern Uplands	"	-	69.00*	83.00*	1995
Garrod et al., 1995 WTP to maintain ESA scheme	England			36.35	1994

Five studies selected. **Average WTP: € 20.6**

Moorland

Table 2.8 WTP for moorland

Study	Country	WTP	Type of study	Base year
Hanley et al., 1996 Heather moorland in Scotland	UK	Minimum necessary compensation payments to farmers: from £9.10 to £83.60 per ewe removed	ecological-economic model	1994

WTP pp: € 63

Watercourses

Table 2.9 WTP for watercourses

Study	Country	WTP	Type of study	Base year
Hervik et al., 1987, Conservation Plan for watercourses, i.e. protecting surviving virgin rivers from hydro-electric power development	Norway	USD 50-100/pers/yr	CV	1990
Tapsell et al., 1991, River restoration	UK	£0.95 users £0.75 residents value/adult visit/ CV	CV use-value	1991
Willis and Garrod, 1991, Canal and waterways recreation	UK	£0.36/head, CV (visitors)	CV	1989
Coker et al., 1989 Improvement to river corridor, 2 options	UK	Enjoyment per visit: £0.82, £1.03 OE, £13.90, £16.20 year/household (water rates)	CV OE use value	1988
Green et al., 1990 river water quality improvements	UK	£13.59 non-visitors £15.56 visitors year/head	CV, (bidding game) includes non-use values	1987
Green and Tunstall, 1990, river quality improvements	UK	£ 546-562-582 household, lumpsum, OE CV	OE CV, includes non-use values	1987
Green and Tunstall 1991, river quality improvements	UK	£0.51-0.6-0.52 value/adult visit WTP/head/annum: £12.08	CV, bidding game, enjoyment per visit	1987
Garrod and Willis, 1994 Waterside location	UK	3-5% to the property price	Hedonic price model (HPM)	1989?
Willis, et al., 1990 value of canals (Montgomery and Lancaster)	UK	9.2 p-11.2 p per visit consumer surplus	Travel cost method (ITCM)	1988?
Garrod and Willis, 1991 Country side characteristics (river or canal)	UK	4.9% above sale price	HPM	

Willis and Garrod, 1990 Recreation on inland waterways	UK	£3 to £0.51 per visit depending on functional form	ITCM consumer surplus	
Pearson and Bateman, unpub. Cleaning up Rutland waters	UK	£16.74 pa	CV use value	

Five studies selected. **Average WTP € 31.2 per person per year.**

Estimated values for different countries of Danube Floodplains

The values in the table are transfer results from a CV study by Kosz, Brezina and Madreiter, 1992, and are expressed in €/ha/year. The differences in living standards are accounted for by use of PPP index in OECD, 1992.

Table 2.10 Estimated values for different countries of Danube floodplains

Country	Total value (€ million)	Base year	Total value (€ 1997)
Germany	23	1991	26.7
Austria	14	"	16.2
Slovakia	2	"	2.3
Hungary	19	"	22
Croatia	129	"	150
Bulgaria	30	"	34.9
Romania	378	"	439.6
Ukraine	55	"	64

Source: Economic values of Danube Floodplains, Gren et al., 1995

Garrod and Willis, 1994, provide WTP (of members of a trust) for an additional reserve in each habitat type, in the form of an additional membership fee per year to the NW trust in UK:

Table 2.11 WTP for habitat type

Habitats	**Mean WTP**	**SD**	**Base year**
Conifer forest	0.286	1.165	1992
Broadleaved woodland	2.323	4.877	"
Heather moorland	0.673	2.085	"
Peat bog	0.789	2.648	"
Traditional hay meadows	1.441	2.981	"
Marsh and Fen	0.684	1.750	"
Ponds	0.853	2.317	"
Large man-made lakes	0.284	1.2	"
River banks and streams	1.047	2.437	"

Coastal sand dunes and salt marshes	1.662	4.561	"
Total WTP	10.045	16.082	"

Total WTP for the 10 habitats: 15.3 € (1997 prices). **Average WTP: € 1.51**

Preserving the agricultural landscape.

Table 2.12 WTP for preserving agricultural landscape

Study	Country	**WTP**	Type of study	Base year
Pruckner, 1995 Agricultural landscape-cultivating services	Austria	9.20 ATS per person per day, CV	CV, OE, (tourists only) use-value	1991
Drake, 1991 Value of agricultural landscape	Sweden	750 SEK /yr/per person	CV, PC residents	1991
Bullock and Kay, 1997 Policies for the extensified landscapes	UK	£55 p.h./pa, postal subset, £ 49 ph/pa, visitor subset £ 57 and £56 for ramblers and birdwatchers (CV)	CV, DC	1994
Spaninks, 1993, Agricultural wildlife management on Dutch peat meadow land	Neths	55 Dutch guilders, annual WTP/household, CV	CV, PC non-use	1993
Brouwer 1995, Agricultural wildlife management on Dutch peat meadow land	Neths	80 Dutch guilders, annual WTP/household, CV	CV, OE non-use	1994

Again, the above studies are quite different in CV methodology and sampling. Two studies (CV-PC) are selected to obtain an average; note that one of the two values is obtained from a sample of residents only (Drake 1992), and therefore it may not be appropriate to derive an aggregate EU value from it. **Average WTP: € 62.5 per person per year.**

Endangered species

Finally, the WTPs for several different endangered species across Europe are reported in the table below. Particularly in this case, it seems quite hazardous to derive an average WTP and use it to value biodiversity, since, in each study, respondents were asked to value individual, often region-specific, species.

The economic value of endangered species to citizens of the USA has been measured using CV for 18 species. In a meta-analysis, Loomis et al., 1996 show that annual WTP (average of all the studies) range from $6 per household for the striped shiner to $70 per household for the northern spotted owl. Loomis et al., 1996 also show that to date, for even the most expensive endangered species preservation effort, the costs per household fall below the benefits per household.

In Finland, Kuitunen et al., 1994, explore the willingness of students to favour protection of endangered species, and, rather than WTP, provide a ranking. Kuitunen compares it to results in the US (Kellert, 1979). Interestingly, the species preference for conservation of shared common species is almost similar to that perceived by US general public: a seal and an eagle ranked first, and a spider ranked the last.

Table 2.13 WTP for endangered species

Study	Country	WTP	Type of study	Base year
Strand, 1981 All freshwater fish species	Norway	fish: 250-400 UDS 1990/pp/pa or 1700-2750 1991 NOK wtp per person per year	CV,overestimate use and non-use values	1990
Dahle et al., 1987, Brown bear, wolf and wolverine	Norway	USD 15 WTP/pers/yr	CV, Gross WTP. Subtract USD 2 to get net WTP	1990
Johansson, 1987 Forest related animal and plant species	Sweden	USD 7 /pers/yr CV	CV	1990
Johansson 1989 Endangered species	Sweden	85 SEK per year/pp	CV	1991
Garrod and Willis, 1994 Conservation of red squirrel in Kielder Forest	UK	£ 2.94 pa (additional payment on top of existing membership to a Trust)		
Fredman, 1994 White-backed woodpecker	Sweden	406 SEK pp	CV, DC	1993

Navrud, 1992	Norway	domesticated forest: 3.3 billion NOK saltwater fish: 2.5 billion NOK domesticated plants and animal: 9 billion NOK	direct use values, derived from the net product in the gross accounts for each sector	1991

Five studies selected. **Average WTP: € 128.6 per person per year.**

3. Policy package

3.1 Key issues[12]

One of the dominant and immediate causes of biodiversity loss is the conversion of 'natural' land to other land uses, i.e. conversion of open landscape to housing, roads etc. Ten Brink et al., (Chapter 1 of this report) suggest that the total area of 'natural' land in the EU will actually increase by 2010 due to the conversion of agricultural land to other uses including conservation. However, this pattern of change varies between countries and Italy, Spain, Portugal and Ireland are anticipated to experience decreases in natural areas. Moreover, coastline areas are poorly represented in the Ten Brink analysis due to data difficulties. EEA (1999) acknowledges the data difficulties but reports serious threats to many of the EU Member State coastlines: e.g. tourism, urbanisation, transport and shipping in the Mediterranean, Baltic and North Sea coasts. Recommended policy options for coastal zones are given in Technical report on policy responses.

Targeting land use change

Table 3.1 presents some illustrative statistics on land use change in major EU countries.

Table 3.1 Land use change between 1970 - 1995 for 6 EU countries

Country	1970-1994 change in Total ag land km^2 and as % of original ag land area	1970-1994 conversion of meadow and pasture km^2 and as % original M/P area	1970-1995 increase in built up land km^2	1970-1994 change in arable land km^2
UK	-29,860 -16%	-17,770 -15%	na	-12,090
France	-26,670 -8%	-27,820 -21%	+ 4179 (1980-1995)	+ 1,150
Netherlands	- 2,490 -11%	-3,140 -24%	+ 2394	+ 650
Germany	-17,370 -9%	-13,610 -21%	+ 6411	- 3,760
Italy To 1990 only	-33,300 -16%	-3,720 -7%	Na	- 3,720
Spain	-25,610 -8%	-2790* -2%*	+ 524	-22,820

* possibly suspect figure

[12] See also coastal zone management.

For any one country we have the identity:

$$L = AG + WOOD + OL$$

Where L is total land area (net of rivers etc), AG = agricultural land, WOOD = wooded area, OL = built up land and 'other land'. Since L is a fixed quantity, we have

$$-\rho AG = +\rho WOOD + \rho OL$$

This shows that any reduction in agricultural land must result in either an increase in wooded area and / or built up land and "other land".

Similarly, any reduction in agricultural land is shown by changes in arable or pasture land

$$\rho AG = \rho ARABLE + \rho PASTURE$$

Table 3.2 applies the above identities to determine the change in agricultural land for five European countries.

Table 3.2 Change in agricultural, woodland and built up land between 1960 - 1990

	France 1960-1990 km^2	UK 1960-1990 km^2	Germany 1960-1990 km^2	Neths 1960-1990 km^2	Spain 1960-1990 km^2
-ρAG =	- 39,580	- 19,630	- 13,430	- 3,080	- 27,580
+ρWOOD	+31,970	+ 6,750	+ 1,830	+ 310	+29,070
+ρOL	+ 7,610	+12,720	+10,550	+3,050	- 1,830
+error	(0)	(160)	(1050)	(280)	(340)
-ρAG =	-39,580	-19,630	-13,430	-3,080	- 27,580
-ρARABLE	-22,040	- 6,380	- 3,100	-1,170	- 5,580
-ρPASTUR	-17,540	-13,250	-10,330	-1,910	- 22,000
+error	(0)	(0)	(0)	(0)	(0)

The results in Table 3.2 begin to offer some insights. First we see that there has been a systematic loss of agricultural land in all countries. Other things being equal, this will contribute to reductions in biodiversity, depending on what the land is converted to.

Second, conversion of agricultural land to woodland should, again in principle, assist biodiversity, depending on the type of woodland produced. Thus, of France's 40,000 sq.kms of converted agricultural land, some 80% goes to woodland and only 20% to built up areas and other uses. Spain actually develops woodland to more than offset agricultural losses. Germany, however, offsets only about 13% of its converted agricultural land by developing woodlands, and the Netherlands only 10%.

Third, the nature of the agricultural land 'lost' is important. Of major significance is that, with the exception of France, where arable land accounts for 55% of losses, the dominant losses are in meadow and pasture which is particularly important for biodiversity. But even arable land lost has effects on biodiversity, especially birds.

Overall changes in land use are therefore probably of some significance in biodiversity loss but a great deal else must be happening as well. Change in farming practices are clearly also very relevant.

Targeting farming practice
First, we have the homogenisation of agricultural practice: the decline of the 'mixed' farm and the rise of more uniform farms, specialising in particular crops. Homogenisation is the enemy of diversity. Many bird species dependent on mixed farming have declined.

Second, crop growing seasons have changed, away from spring sown crops to autumn sown cereals. This has reduced habitats for ground nesting birds and some mammals such as hares.

Third, there has been a substitution of crops: oilseed and sugar beet are planted at the cost of oats and fodder crops**.**

Fourth, while agrochemical development was taking place before the CAP, CAP greatly encouraged more use of pesticides and fertilisers. The 1992 MacSharry reforms sought to substitute area payments to compensate for yield reductions as support prices were lowered for some crops, and set-aside was introduced as a qualifier for area payments. Agrochemical use has eliminated or endangered quite a few plant species and are widely thought to be implicated in loss of bird populations. Fertiliser use has contributed to surface water pollution (as well as groundwater which has some effect on biodiversity through outflow).

Fifth, pre-CAP history also matters since the switch from pasture to arable was taking place long before the CAP. Again, pasture losses are very important for biodiversity loss since grassland plant species disappear and with them the biodiversity further along the foodchain.

Sixth, CAP has encouraged hedgerow removal, with direct consequences for biodiversity.

3.2 Recommended policy initiatives

The EC Biodiversity Strategy sets out the EU's commitment under Article 6 of the Convention on Biological Diversity. Across Europe, the Pan-European Biological and Landscape Diversity Strategy seeks common objectives and a consistent approach in national plans. Within the EU, there are the Habitats Directive and Birds Directive. The former creates a network of Special Areas of Conservation, the latter establishes Special Protection Areas. Continuing declines in bird population indicate failure in the Birds

Directive. Thus, policy on biodiversity must therefore include renewed efforts to ensure compliance with established biodiversity conservation strategies.

Land use planning (LUP) would appear to be a candidate for managing land better, i.e. through the creation of ecological networks (core areas of conservation, corridors, buffer zones and habitat restoration), and through the prevention of insensitive development, especially in mountain areas and coastal zones. This concept is already embodied in some national legislation and through Natura 2000 at the EU level. However, it is difficult to see how it would prevent the overall loss of agricultural land in the face of population and cultural changes (e.g. smaller families) . Nor can LUP specify which crops are grown once land is classified as agricultural.

This suggests that price incentives have to be the major force driving beneficial change. The McSharry reforms had this aim in mind, but it is unclear if the switch to area (as opposed to output-based) payments and the set-aside provisions have worked. Even if they work, it seems clear we cannot return to the ‘old days’: farming technology has changed, rural areas are facing many other changes, and there is almost certainly a need to manage land for biodiversity rather than simply hoping that removal of disincentives to conservation will work.

As an example, consider dairy farming. The MacSharry reforms have had little impact on dairy farming. Milk quotas exist in an effort to contain production and they are tradable in some countries. CAP has encouraged intensive livestock so that dairy farm slurry and waste has dominated farm-related water pollution incidents, which in turn, are associated with biodiversity loss. Concentration of units in a given area means investment in waste storage and the spreading of waste on limited land areas, contributing to chronic as opposed to acute pollution.

The experience in biodiversity incentives is, in general, too recent to be able to draw clear conclusions on the effectiveness of available instruments. However, it is clear that a large number of variables - related to each country's regulatory and institutional structure, geographic location, specific biodiversity problem and uncertainty - need to be considered when selecting the appropriate incentive. Moreover, the best policy measures seem to be those that combine economic incentives with regulations (OECD, 1996). For the majority of the instruments reviewed, an appropriate legal structure to enforce restrictions and monitoring capacity are essential requirement for their implementation.

Policy has to be ‘decomposed’ to target specific issues. Suitable policies would include:

Agri- environmental schemes

Agri-environmental schemes are the most effective policies. Many schemes are already in place in many European countries. Thus effort should focus on the widespread use of such policies.

Agri-environmental schemes are designed especially to encourage environmentally-friendly farming and public enjoyment of the countryside. The schemes are voluntary and offer payments to farmers who agree to manage their land for the positive benefit of biodiversity, landscape amenity, natural resource protection, historical / cultural heritage or public access. The payments are based on the agricultural income which farmers forego by participating in the schemes and are partly funded by the European Union.

These voluntary agreements involve a legally binding contract for a set period of time under which the landowner agrees to undertake, or refrain from, certain activities in return for reimbursement for the cost of the service provided to society, rather than as a compensation to lost value. Ideally, the schemes should be set for a very long period of time, otherwise many biodiversity benefits will be lost. Some of the advantages of the agreements are the fact that they are easily targeted, flexible, and help to clarify property rights.

In the UK, ten agri-environmental schemes have been introduced in order to implement the Environmentally Sensitive Farming Regulation 2078/92. Each policy targets a specific agri-environmental issue, they include:

Environmentally Sensitive Areas (ESA) scheme.
These areas are all of high landscape value containing important wildlife and/or historical assets. They are also areas that are under threat of change from intensive farming practices. Incentives are offered to farmers to adopt agricultural practices, which will safeguard and enhance the rural environment and improve public access for the countryside. In the UK, Environmentally Sensitive Areas (ESA) scheme is just one of many types of management agreements, which aim to maintain the value of existing vegetation on arable land. ESAs success is shown by their growing use both within the UK, and the rest of the EU. The rates of payment are attractive to farmers because they have a low risk compared to switching to high intensity farming. Nevertheless, the success of ESA has been undermined by other government policies (e.g. CAP subsidies and government grants for drainage) that act as a disincentive to more sustainable farming. Effectiveness is also undermined by lack of co-ordination at the local level. The main criticism, though, is that ESA schemes prevent farmers from damaging the environment further, but they are not as good at encouraging environmental improvements.

The countryside access scheme
These offer farmers additional payments on top of the set-aside payments (see below) for providing new opportunities for public access to suitable farmland for walking and other forms of quiet recreation. The scheme is intended to provide for permissive access and is not meant to create new permanent rights of way. Only particularly suitable areas of the countryside are targeted i.e. providing access to landscape vantage points or offers networked links to other existing access ways. Any land entered into this scheme has to be also put into guaranteed set-aside. Farmers must therefore manage this land in accordance with set-aside rules and, in addition, observe a range of other accessibility conditions. The annual supplementary payments are based on 10m wide access strips along field margins and/or on whole or part fields. Payments per annum are € 130ha for access strips and € 65 ha for whole or part fields (Nix, 1999).

The Countryside Stewardship Scheme

This is developed as the central incentive scheme for the achievement of the wider countryside conservation objectives. It operates outside of ESAs, and seeks to protect, enhance, restore and re-create targeted landscapes, their wildlife habitats and historical features; as well as improving public accessibility to the rural environment.

3.2.1 The Arable Stewardship Scheme

This is a smaller scheme being run as part of the Countryside Stewardship programme. This sub-scheme seeks to address the problem of negative environmental externalities triggered by intensive arable farming methods and regions. Ultimately the scheme is intended to boost efforts to recreate and enhance wildlife habitats in arable dominated areas of the countryside. It is a pilot scheme offering payments to farmers in arable dominated areas if they 'adapt' their farming methods to reduce the externalities generated. Limiting herbicide use in cereal or linseed crops, followed by over-wintered set-aside stubbles could, for example, attract a payment of € 80 ha (in addition to set-aside payments). The creation of conservation headlands in arable fields would be financed by a payment of € 30 ha, while the creation of 'beetle banks' at a rate of 15 per 100 metres attracts a payment of € 1080 ha. Capital grants are also available for hedge restoration, tree planting and ditch restoration.

3.2.2 The Farm Woodland Premium Scheme and Woodland Grant Scheme

These provide grants to farmers towards the cost of establishing new woodlands. In the UK, payment is 70% after planting and 30% in year five, with the provision that acceptable maintenance standards must also be met for ten years after planting. Payments are also available for restocking woods and for planting short rotation coppice. The Farm Woodland Scheme gives compensation to farmers who establish woodland on previously worked agricultural land. Farm woodland planted under these schemes on arable land meeting the eligibility requirements for arable area payments count towards a farmer's set-aside obligations. Thus, farmers who receive the woodland grants then lose the set-aside payments. The exception is short-rotation coppice planted on set-aside land, which is not eligible for entry into the Farm Woodland Premium Scheme and will receive set-aside payments.

3.2.3 The Habitat Scheme

Introduced in 1994, it is designed to encourage farmers to take land out of production for up to 20 years to create important wildlife habitats. The scheme is targeted on land coming out of the former voluntary Five-Year Set-Aside Scheme, which is suitable for conversion to salt marsh and land alongside watercourses and lakes in selected areas. The annual payments are intended to reflect the cost of entering land into the scheme. For example, for land currently in grass, € 760 ha (€ 640 ha for land counted as set aside) is available for creation of inter-tidal habitat, and € 700 ha (€ 585 for set aside land) for the establishment of water fringing habitat devoid of all agricultural production.

3.2.4 The Moorland Scheme

Introduced in 1995 is meant to encourage the conservation and enhancement of heather and other shrubby moorland vegetation in those parts of Less Favoured Areas which are not part of the ESA. Sheep farmers who adopt a more extensive system of production will receive an annual payment for each ewe eligible for Hill Livestock Compensatory Allowances by which their flock is reduced. Applicants must enter at least 20 ha of moorland containing at least 25% heather and the flock must be reduced by at least 10 animals. Compensation is at the rate of € 45 per ewe removed.

The Organic Farming Scheme

Introduced in 1999, is available to farmers who wish to convert to organic production in accordance with the rules of the UK Register of Organic Food Standards (UKROFS). The scheme will be part funded by the European Community. It replaces an existing Organic Aid Scheme under which there was an additional payment of € 45/ha/annum on the first 5 ha for five years. This will be replaced by lump sums per organic unit of € 430 in the first year, € 290 in the second year and € 150 in the third year. These payments recognise additional costs arising from, for example, training and organic certification. The new payment rates over five years range from € 70 ha to € 650 ha depending on the type of land being converted.

Management agreements

Management agreements for sites of special scientific interest (SSSI) and other designated sites involve different instruments that offer compensation to farmers/landowners for losses incurred as a result of environmental conservation. Two of the most commonly used instruments are SSSI agreements and ESAs (see earlier section). These two arrangements differ in their impact on the property rights of owners and in the method of determining compensation. Compensation for proprietors in all SSSI is individually negotiated on each farm, while in ESAs it is predetermined at flat rates for each area. Some SSSI agreements have resulted in more compensation than the ESA rate, others have been settled for less. Whitby and Saunders (1996) found that on a financial cost per hectare "protected" basis, SSSI agreements are a more cost effective measure. The different assignment of property rights embodied in the two measures result in different opportunity costs and levels of transactions costs as well as different equilibrium prices and delivery of the conservation public good.

Nitrate Sensitive Areas (NSAs)

These are selected areas covering groundwater sources used to supply drinking water. In 1990 ten pilot NSAs were set up in England to reduce nitrate levels in water supplies to below the EC-permitted levels of 50 mg/litre. A further 22 areas were established in 1994, adding another 35,000 ha to the 10,500 ha of the pilot areas. Under the scheme, farmers who change their practices to reduce nitrate leaching receive payments of between € 90 and € 900 ha. Entry into the scheme is voluntary and agreements last for 5 years. Options available are conversion of arable land to extensive grassland, conversion of intensive to extensive grassland and restricted nitrogen applications to arable land.

Payments to set-aside

Set-aside schemes are already an integral part of the CAP. Set-asides are voluntary agricultural land retirement schemes. The scheme provides payments to farmers who remove environmentally sensitive land from production for a few years. To achieve biodiversity goals at least cost, they need to be targeted at land, which is of most value from a biodiversity perspective, and of long enough duration to ensure that the benefits of conserving biodiversity are fully realised.

Set-aside schemes are rarely of long enough duration to ensure that the benefits of conserving biodiversity are fully realised. The current schemes have nevertheless already produced tangible benefits for individual species, e.g. the corn-bunting in the UK.

Other policies that can target habitat and ecosystem function preservation are:

Mitigation banking (land banking) for the achievement of biodiversity conservation

Mitigation banking (MB) offers potential for conserving threatened areas, and especially wetland areas. MB is essentially an offset procedure such that conversion of a natural area to some developmental use has to be compensated for, in advance of conversion, by the creation of a 'like' area. The new area thus 'offsets' the converted area, resulting in, as far as possible, a 'no net loss' situation. By varying the requirements for the 'exchange rate', it is also possible to expand the area under conservation, e.g. by requiring that compensation take place on a basis of, say, 2 km^2 per km^2 lost.

Compensating offsets are part of the US policy on wetlands conservation under the Clean Water Act of 1972. Some reduction in wetland loss has resulted but there are concerns that (a) the resulting 'new' wetlands are of low quality; (b) that compliance is low, and (c) that the offset projects often fail. Particular concerns relate to the lack of understanding of complex systems such that recreation of 'similar' ecosystems is very difficult (Crooks and Ledoux, 1999). Mitigation banking seeks to overcome the problems by ensuring that the offset area is created in advance of the loss of the developed area, so as to monitor the degree of similarity, and that offsets should, as far as possible, be in similar or the same ecoregions. Mitigation banks consist of a 'bank' of land areas suitable for conversion to natural areas. They may be owned by corporations anticipating that their corporate plans will displace habitat in the future, or they may be owned independently (entrepreneurial banks), such that 'credits' can be purchased by developers. Credits reflect the quality of the wetland so that higher quality wetlands need to be compensated for by high credit value new wetlands. Assuming some unit of value is established, say money willingness to pay, then a bank of land worth $100 per ha could be drawn down by 10 ha to replace a developmentally converted wetland worth $1000. If the converted wetland is worth $10,000, then 100 ha would be needed to compensate for its loss. The US system does not use willingness to pay but values 'emerge' from negotiation and some formal analysis of preferences for particular wetland features (King

and Wainger, 1999). Federal regulations require that some unit suitable for computing 'exchange rates' be developed. The various arguments for and against mitigation banking are rehearsed in Crooks and Ledoux (1999).
The issue is whether mitigation banking could be used for wetlands (and other ecosystems) in the EU. The Habitats Directive can be interpreted as having a no-net-loss policy for the Natura 2000 sites, i.e. sites listed as Special Protection Areas (SPAs) under the Birds Directive, and Special Areas of Conservation (SACs) under the Habitats Directive. Articles 6(3) and 6(4) explicitly require that compensatory measures are undertaken where conversion is unavoidable. In principle, therefore, MB could be used to implement the Directives and to extend the area under conservation.

The results of the speculative cost benefit analysis suggest (see below) that a mitigation banking policy that prevented all of the conversion of agricultural land to built up uses could result in benefits of € 15-30,000 per hectare. Costs are unknown. James and Green (1998) report typical EU budgets for protected areas as high as, € 30,000 per km^2 in the Netherlands or € 300 per ha. Mitigation would, of course, involve potentially major capital works compared to protection expenditures, but it seems unlikely that they would exceed the magnitudes for benefits.

Tax allowances on reforesting, soil and water conservation
They allow taxpayers to write off or deduct, in the form of business expense, reforestation, soil and water expenses in the year in which they take place. It is also possible to focus tax reduction or exemption on land which is biologically diverse and where the owner undertakes conservation measures. The value of the reduction is repaid if land use subsequently changes.

Outright land purchase
Land purchase for conservation purposes generally takes place through grants or environmental funds, established by non-profit organisations to acquire environmentally sensitive areas. Land purchase allows to regulate subsequent use and land can also be re-sold with a covenant agreement attached. Acquisition is usually voluntary, alternatively land may be compulsory acquired by the government.

Cost-effectiveness of outright purchase versus perpetuous payments in management agreements has been demonstrated (see Colman 1989). Furthermore, experience in Australia has shown that the leverage of government funds applied to such activities can be quite high: Henry and Olson, (1992), calculate that for every dollar (0.85 $€_{1997}$) of grants to voluntary conservation organisations, the organisations generated \$3.22 (2.75 $€_{1997}$) to the conservation effort in Australia.

Land restoration with Performance Bonds
Performance bonds provide a profit-related incentive to comply with a standard. Resource users are required to post a bond with the regulating authority to cover costs of use of biological resources. The bond is refundable if the users demonstrate that their environmental damages are lower than the estimates laid out in the bond and than the ecological thresholds. Since they incorporate the costs of exceeding thresholds, bonds are

used to control activities that threaten to reduce biodiversity below a minimum standard. Bonds could also be required to cover habitat mitigation banking plans: if the habitat meets the performance goal, the bond is returned.
There are no reports on PBs effectiveness. However, performance bonds seem to provide incentives to improve data on the environmental costs of economic activity, and also to develop and adopt new cost-effective technologies.

Fines for damage to natural assets
Fines for damages to nature may cover all types of activities, from road construction to mining and housing. Compensation may be made in the form of land or actual payments. Charges can be made proportional to the environmental downgrading of a site. Application of fines obviously requires some monetary assessment of damages caused.

3.2.5 Multiple benefits

Agriculture policy reform will also benefit other environmental issues, such as: water quality, chemical risks, soil degradation and coastal zones. Whilst policies targeted at other environmental issues will also benefit biodiversity, these would include the initiatives recommended for:

i) coastal zones protection,
ii) water availability, i.e. the correct pricing of water, at long run marginal cost ensures that the cause of excess demand is addressed. This policy can be used to target current farming practice, for example, if irrigation water is priced in this manner, we doubt if some of the agricultural activity in water scarce areas would have an economic justification;
iii) water quality; i.e. the fertiliser tax with payments to switch crops, again this policy targets current farming practice and could be used to encourage more organic farming;
iv) chemical risk, i.e. the pesticides tax levied on toxicity.

3.2.6 B/C ratios for recommended policy initiatives

Mitigation banking system: a speculative exercise
Assessing the costs and benefits of a mitigation banking system is complex. A comprehensive survey of willingness to pay for natural capital was undertaken in the previous section. WTP for habitat conservation tended to cluster round value of € 20-60 per person per annum, but sums are not additive across the different kinds of habitat and the similarity of the results suggests that some embedding is present in the WTP numbers. Nor is it possible to express WTP values per hectare since in many cases the area was not stated in the original study. Nor is there any particular reason to suppose that WTP will vary linearly with area. The following is therefore a speculative exercise. Taking a conservative estimate of €s 20 per person per annum would give an annual WTP of € 4.5 billion for 150 million households multiplied by 1.5 adults per household. If those expressing WTP were aware of the rates of land conversion from natural to ‘developed’ sites, then the € 4.5 billion could be thought of as an aggregate valuation for the marginal change in land use per annum. Taking the figures for land use change 1960-1990 as

recorded in the various EEA (1999) Dobris statistical technical background reportes, Table 3.3 gives us:

Table 3.3 Conversion of agricultural land to other uses

Country	Overall loss of agricultural land, p.a. 1960-1990, km^2 converted to woodland and other uses	Conversion to 'other land' (built areas), p.a. 1960-1990, km^2
France	1319	254
UK	654	424
Germany	448	352
Netherlands	103	102
Spain	919	- 61

The relevant column is the last one, i.e. the conversion of agricultural land to other uses. The final column assumes that agricultural land converted to woodland is 'biodiversity neutral', i.e. there is no net gain or loss in biodiversity. In practice, gains in biodiversity might be expected for some conversions to woodland, but since much of the conversion of agricultural land is from pasture to woodland, the net effect on biodiversity is unlikely to be significant.

One possibility, then, is to argue that the 20 €s pp. pa is a valuation of the losses of agricultural land to other uses shown in the last column above. This would give the following results, see Table 3.4.

Table 3.4. Valuation of the losses of agricultural land to other uses

Country	Conversion to 'other land' (built areas), p.a. 1960-1990, km^2	WTP at 20 €s p.p.p.a x adult population, and implied value E per hectare
France	254	687 m.E => 27,000
UK	424	646 m.E => 15,200
Germany	352	1118 m.E => 31,760
Netherlands	102	192 m.E =>18800
Spain	- 61	n.a

Possibly, then, a mitigation banking policy that prevented all of the conversion of agricultural land to built up uses, could result in benefits of € 15-30,000 per hectare. Costs of mitigation are not known. James and Green (1998) report typical EU budgets for protected areas as high as € 30,000 per km^2 in the Netherlands or € 300 per ha. Mitigation would, of course, involve potentially major capital works compared to protection expenditures, but it seems unlikely that they would exceed the magnitudes for benefits.

3.3 Policy assessment

Agricultural policy reform, through the re-direction of subsidies in the form of price support mechanisms to agri-environmental schemes such as:

i) Management agreements for environmentally sensitive areas (ESA),
ii) Habitat scheme,
iii) Moorland scheme,
iv) Countryside Stewardship scheme,
v) Countryside Access scheme,
vi) Arable Stewardship Scheme,
vii) Farm Woodland Premium scheme and Woodland Grant scheme,
viii) Organic Farming scheme,
ix) Nitrate sensitive areas,

Mitigation banking offers the potential for conserving threatened areas, and especially wetland areas.

3.3.1 Causal criterion

Table 3.5 presents the driving forces behind the problem of biodiversity loss, the underlying causes are also identified.

Table 3.5 Driving forces and underlying causes of biodiversity loss

	Driving force	Underlying cause		
		MF	IntF	ImpF
D1	Recreation (hunting, fishing and collecting)			
D2	Transport growth			
D3	Intensification of agricultural production and introduction of high yielding varieties, mono-cultures and Genetically Modified Organisms		X	
D4	Over exploitation of natural resources (over harvesting, over grazing, over fishing, property rights failure)	X	X	
D5	Afforestation for energy forestry and planting of fuel crops		X	
D6	Introduction of non-indigenous species		X	X
D7	Missing market in conservation value	X		

X = main underlying cause, MF = market failure, IntF = intervention failure, ImpF = implementation failure. Note that for driving forces D1 and D2 the main causes are growth in real income and population growth.

The proposed policies address land use and / or farming practice, thus the main causes of biodiversity loss are addressed. The suggested agri-environmental schemes are targeted at specific environmental issues. Mitigation banking is recommended because it has the potential to conserve threatened areas.

3.3.2 Efficiency criterion

Agricultural policy reform

It is generally recognised that subsidy reform involving a switch from price support mechanisms to direct payments has the potential to be both economically and environmentally beneficial. Direct payments can achieve the same distributional goals for farmers, while reducing the regressive impact on households and encouraging a more efficient allocation of resources. If properly targeted, they can reduce the negative and increase the positive environmental externalities of agriculture.

A recent paper (MAFF, 1999) explores the overall economic impact of Agenda 2000[13] for EU15. Overall, the consumer benefits of reform exceed the combined losses to taxpayers and producers by a significant margin. MAFF (1999) forecasts of the benefits and costs of Agenda 2000 commodity reforms, in 2008 compared with a continuation of current policy show the following:

- benefits to consumers from lower agricultural support prices of around € 10 billion across the EU15;
- increased taxpayer costs, resulting from higher direct payments, of some € 2.5 billion; whilst,
- losses to the agricultural producers are estimated to be some € 1.8 billion, reflecting the net effect of lower support prices and higher direct payments.

In the long term, the economic benefits from reform are expected to be significantly greater for two reasons: i) in the absence of reform, taxpayers expenditure on the disposal of surpluses would probably have continued to grow and ii) because re-structuring, in response to the reforms will reduce producers' losses and improve the competitiveness of European agriculture, MAFF (1999).

Importantly, the report concludes, that despite reduced support to producers, there are good grounds for believing that large parts of EU agriculture will be able to sustain competitiveness at much reduced levels of support over and beyond the Agenda 2000 reforms. This is because the reduction in support coupled with the unwinding of production controls can be expected to prompt changes, which enhance agriculture’s viability, in particular:

- world market prices for several commodities would be expected to increase as a result of lower European production;

[13] In the mid 1990s, it was clear that the Union faced the prospect of a return to substantial surpluses despite the MacSharry reforms in 1992. The Union needed to prepare further progressive reductiosn in support and prtedtion in a successor WTO agreement and for the enlargement of the European Union to central and Eastern Europe. These circumstances lead to the Commissions Agenda 2000 proposals in March 1998. The final Agenda 2000 package was agreed in March 1999. The main features are: i) reduced price support to cereals, ii) reduced price support to beef, iii) reduced price support for butter and skimmed milk powder and iv) measures to more closely integrate rural development policy into the CAP, as well as a new element of national discretion in the operation of parts of the CAP, i.e. increase direct payments to farmers through agri-environmental schemes.

- at the same time, reduced demand for inputs will in some cases be expected to lower their prices;
- the productivity of agriculture would be expected to increase due to restructuring.

Mitigation banking
The results of the speculative cost benefit analysis (see Section 3.1) suggest that a mitigation banking policy that prevented the conversion of all agricultural land[14] to built up uses, could result in benefits of € 15-30,000 per hectare. Costs are not known, but, James and Green (1998) report typical EU budgets for protected areas as high as, € 30,000 per km^2, € 300 per hectare, in the Netherlands. Mitigation would, of course, involve potentially major capital works compared to protection expenditures, but it seems unlikely that they would exceed the magnitudes for benefits.

Public opinion
Although public opinion regarding the issue biodiversity preservation is not known with certainty, the European population may be in favour of measures that ensure greater integration between agricultural and environmental demands.

3.3.3 Administrative complexity

Agricultural policy reform: The problems of making inroads into the substantial subsidies in the CAP are well known. Subsidies effectively create ‘rents’, which are then captured by the beneficiaries. They then have strong incentives to maintain the system, making it very difficult to reduce subsidies on any significant scale. Most subsidy reforms have come about through very radical action on the part of governments or through wholesale changes in political systems (e.g. subsidies in the economies in transition have been reduced markedly since the fall of communism). Analysis of subsidy reform elsewhere suggests that very careful redesign of incentives is required. Gradual reform may not be possible if it enables those who benefit from the rents to intensify their lobbying activity, as may have been the case with the broadening of farmers concerns with a wider ‘countryside’ concern (Pearce, 1999). This perhaps suggests that the best chances lie with the retention of subsidies and their redirection towards the suggested environmental payments.

Redirecting subsidies towards environmental payments is very simple in administrative terms.

Mitigation banking: The Habitats and Birds Directives can be interpreted as having a no-net-loss policy for the Natura 2000 sites, i.e. sites listed as Special Protection Areas (SPAs) under the Birds Directive, and Special Areas of Conservation (SACs) under the Habitats Directive. Articles 6(3) and 6(4) explicitly require that compensatory measures are undertaken where conversion is unavoidable. In principle, therefore, MB could be used to implement the Directives and to extend the area under conservation.

[14] For France, Germany, UK, Spain and the Netherlands.

Based on the US experience, mitigation banking is administratively feasible and relevant institutions are already in place. Opening a mitigation bank in the US, involves a regulatory process that includes review by several federal agencies. The US Army Corps of Engineers is the lead agency working with other state agencies. They all contribute to the Mitigation Banking Review Team (MBRT), which determines whether the project is to take place and then, if granted, the MBRT oversees the progress of the proposed site. The MBRT is expected to consider a wide range of issues, these include; i) design of proposed habitats / ecosystems, ii) the impact the projects will have on existing habitats / ecosystems on the site, iii) wildlife uses, iv) site evolution (i.e. to plant the site or rely on existing seed banks), v) administrative issues such as how the credits are used, vi) who will manage the site in the long term and vii) contingency funds to address any potential maintenance concerns in the future.

3.3.4 Equity criterion

Agricultural policy reform: Current policies of price support have regressive impacts for households, which may be substantial: it has been estimated that the CAP has increased food prices for the average household by as much as € 15 per week. Furthermore, the inefficiency of current arrangements is significant: for example, while UK producers receive just under € 8.5 billion in support, total UK transfers under the CAP amount to approximately € 16 billion. The discrepancy is accounted for by taxpayer expenditure on storing surplus produce, as well as UK support to producers in other EU Member States. Re-directing subsidies towards agri-environmental schemes can achieve the same distributional goals for farmers, while reducing the regressive impact on households, through the overall reduction in subsidies paid out, i.e. reduced expenditures on the disposal of surpluses.

MAFF (1999) suggests that many rural areas, in the UK, have been able to adapt to the long term relative decline in agriculture. Over the last 20-30 years, most rural areas have seen a sustained growth in population and employment has also increased more rapidly than in other areas. These trends result from improvements in transport and communications, the growth in leisure activities and the shifting balance of economic activity between services and different types of manufacturing activities. However, not all rural areas, particularly the more remote and less leisure focused have shared in this growth.

Mitigation banking: If MB is implemented correctly there will be a redistribution of like-for-like environmental benefits. Without detailed information on site specific population it is not possible to determine who will benefit from such a policy.

It is probable that the higher costs to land developers will be passed on to consumers through higher prices of the relevant end product. It is not possible to determine if such a policy is regressive or progressive at this stage.

3.3.5 Jurisdictional criterion

The issue of biodiversity loss is a transboundary issue, i.e. migratory species, ‘joined-up’ habitat, as well as a national issue. Whilst non-use values are regional and maybe even global. The recommended policies mainly involve a redirection of subsidies from price support to direct payments for environmental services, centralisation of policy reform is therefore recommended.

Macroeconomic effects

Details given in *Technical Report on Socio-Economic Trends, Macro-Economic Impacts and Cost Interface* .

Annex 1 Calculation of the remaining natural area Quantity)

Different socio-economic scenarios will have different effects on both the total area of natural areas and the location of these areas, leading to different ecosystem quantity (total area) and quality, as a result of isolation patterns. Therefore, changes in land use in the period 1990 - 2010, caused by socio-economic changes, have to be dealt with. Information on the amount and location of natural areas in 1990 is based on the CORINE database (CEC, 1993) (250 x 250 m resampled for this study to 1 by 1 km). This database consists of 7 different land use classes: 1) Artificial territories; 2) Strongly artificial vegetated areas; 3) Less artificial vegetated areas; 4) Forests; 5) Non-wooded semi-natural areas; 6) Wetlands; and 7) Water surfaces. Classes 1, 2 and 3 are considered to be man-made areas, the others as natural areas. The change in amount of natural area is mainly based on changes in agricultural area and build up area.

Changes in agricultural area are based on information from the Baseline Scenario and are similar to the changes in Accelerate Policies scenario (Hettelingh et al., 1998). Unfortunately, it is not known where exactly conversion of agricultural areas in natural areas will take place or vice versa. Therefore, a Land Use Change Simulator was developed to simulate possible changes. The modeling is based on clear assumptions that determine the allocation of three different land use classes: natural area, urban area and agricultural area. Reallocation of the current pattern of land use is conducted by a stepwise procedure, realized by multiple ArcInfo AML’s. As changes in the amount of agricultural area from 1990 to 2010 were only available at the country level, modeling of land use change took place on the country level. A first reallocation step concerns the process of urbanization. On an arbitrary basis it was decided to reserve 20% of the total amount of agricultural land-taken-out-of-production for urbanization within each country. It is assumed that only arable land adjacent to current urban centers can be urbanized. A randomized chance is used to select those grid cells adjacent to urban centers that will actually get urbanized.

To be able to influence the allocation process, two re-allocation scenarios are developed which determine whether re-allocation takes into account attractivity from the agricultural and/ or nature conservation perspective. Factors such as: soil quality, distance to urban areas, pressures on ecosystem and connectivity of natural areas are the variable factors in these re-allocation scenarios. From an agricultural point of view, the attractivity is first supposed to be determined by the soil capacity. The soil reduction capacity is used as an appropriate determinant. Additionally the distance to urban centers is taken into account. The smaller the distance to urban areas, the higher is the attractivity for agricultural activities. From a nature conservation point of view the total pressure (i.e., quality as discussed in previous sections) to biodiversity first determines the attractivity: the lower the pressure, the higher the attractivity. Further, the connectivity between current natural land is taken into account. The higher the connectivity, the higher is the attractivity for nature conservation. Finally, the distance to urban areas is a determinant for nature conservation as well. The larger the distance to urban areas, the higher is the attractivity for nature conservation.

Reallocation for the Baseline Scenario is mainly determined by agricultural attractivity (e.g., taking areas out of production with low soil quality). Reallocation for the Accelerate Policies scenario is mainly determined by nature conservation attractivity (e.g. by taking out of production those areas that reduce isolation of natural areas). After re-allocation of land the total amount of natural areas is calculated and the pressure from isolation for each grid cell.

Annex 2 Explanation of the pressure factors used

Below, an explanation is given of the seven pressure factors taken into account in the pressure index.

1. Rate of climate change

It is expected that climate change can have serious impact on biodiversity (Watson et al., 1996; Markham et al., 1993; Abrahamson, 1989; Pearman, 1988; McNeely et al., 1990; Dawson, 1992). Changes in physiology, competition, phenology, abundance and distribution of species are expected to occur at a much higher speed than most species can deal with. Therefore, not so much the absolute temperatures as well as the rate of climate change is selected as pressure variable. The pressure is rated on a scale ranging from a change of mean annual temperature of < 0.2°C per 20 years (minimum pressure class = 0) to a mean annual change of 2°C in 20 years (maximum pressure class = 1000) based on calculations of the IMAGE model (Alcamo et al., 1996). For 1990, the rate of temperature change between 1970 and 1990 is used and for 2010 the rate of temperature change between 1990 and 2010 is used.

The minimum pressure class is a 'threshold of rate of change at which ecosystems might be able to adapt effectively to climate change (Jäger, 1987; 1990). This is based on the still rudimentary understanding of the vulnerability of ecosystems to pre-industrial temperature changes. The maximum pressure class is set at ten times this threshold: 2.0°C in two decades. This increase has been suggested as the “absolute limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly”(Jäger, 1990).

2. Human population density

Many studies have indicated that human population density can function as an indicator of habitat destruction and thus as an indicator for threat to biodiversity. According to Groot and Kamminga (1995) population density is one of the typical examples that can be used to describe the process of deforestation. Lanly (1982) also concluded in this study that population growth was the cause of deforestation globally. According to a study of Verburg and Veldkamp (1997), the area devoted to residential and industrial sites is obviously correlated to the population density. “Population size and rates of growth are key elements in environmental change. At any level of development, increased populations increase energy use, resource consumption and environmental stress.” (United Nations Population Fund, Population Issues Briefing Kit, 1993).

The pressure of human population density is rated on a scale ranging from 10 to 150 persons per square kilometer in and near natural areas (if population density < 10, pressure class = 0; if population density >150, pressure class = 1000). The maximum pressure classes for population density are derived from Bryant (1995), Hannah et al.

(1994), Harrison (1992) and Terborch (1989). Data on population density is obtained from Eurostat/RIVM and the UN-Medium scenario.

3. Gross Domestic Product (GDP)

GDP is used as an approximation of the production and consumption rate and the related land use of, and pressures on, natural area by factors such as extraction of natural resources, contamination and physical disturbances. The maximum GDP per square kilometer is similar to values found in highly populated and highly industrialized areas such as the lower trajectory of the river Rhine. Consumption and production rate is characterized by GDP on a scale from US$ 0 (pressure class =0) to US$ 6,000,000 (pressure class = 1000) per square kilometer per year (RIVM/UNEP, 1997). It is the product of the number of inhabitants and the average GDP per person.

4. Isolation/fragmentation

Isolation reduces the rate of exchange of individuals between sub-populations which affects the genetic variability of species. Furthermore, with decreasing size of the natural areas relatively more of the area will be influenced by edge effects (ACT, 1997; EWGRB, 1997). This may lead to an increasing predation pressure from invading predators and human interventions such as exploitation, pollution and disturbance. Fragmented areas, with consequently smaller populations, are also more susceptible to natural random and extreme events (such as fluctuations in weather, sex ratio, genetic sampling at reproduction), that influence the variance in population growth rate and the chance on extinction (EWGRB, 1997). Isolation can, furthermore, result in changes in types and qualities of food resources, alteration to microclimate (temperature, moisture), changes in availability of cover types and changes in species associations (which can affect rates of competition, predation and parasitism).

Based on CORINE data, the percentage of natural area is calculated within a radius of 10 km around each grid cell of natural area. This percentage is scaled. The minimum pressure class is assigned per grid cell when the percentage natural area within a radius of 10 km is >64%. This is an area larger than 20,000 ha. Under this conditions enough natural area is present to guarantee sustainable populations of most mammal and bird species (Kalkhoven et al., 1995). If the percentage nature within a radius of 10 km is less than 1% it is assumed that the natural area is highly isolated, therefore, maximum pressure class 1000 is assigned for that grid cell. This is an area smaller than 310 ha. (Kalkhoven et al., 1995).

The projections on fragmentation have been made by using a Land Use Change Simulator given the agricultural policies in the Baseline scenario.

5. Acidification

Acidification due to deposition of SO_2, NH_3, and NO_x causes leaching of metal cations and other plant nutrients from the soil into the (ground) water. This leaching results in limited plant nutrients (nitrogen, phosphorus, potassium, magnesium etc.) and a decrease in biomass production. In many cases, a plant's ability to absorb these nutrients depends on the level of acidification in the soil. Furthermore, acid rain kills mycorrhiza and

portions of the detritus food chain. Vegetation exposed to acid rain will therefore absorb less of essential nutrients. The result is poorer quality of a plant's proteins, stunted growth and exposure to diseases. As green plants are the foundation of the food chain, a reduction in plant production will have consequences higher up in the food chain. Animals and human beings may experience less valuable nutrition.
The leaching of metal ions has lead in extreme circumstances to damages of forests, lakes, watercourses, and fish. Sources for drink water may become poisoned by high concentrations of copper, lead, and aluminium. Aluminium causes the most severe problems to e.g. the water in southern Norway.
Death of fish, caused by leaching of metal ions, is the best known effect of acidification. There are two reasons for the death of fish. When the acidification reaches a certain level, the fry die. Species of fish have specific tolerance levels to acidic water. The presence of aluminium in the water is common cause of fish death. Aluminium is toxic to fish, because it prevents a fish from absorbing salts and destroys the gills (Bjørke and Parmann, 1997).

A common method to give an indication of threat to ecosystem caused by acidification is the use of critical loads. A critical load of an ecosystem is essentially a 'no-effect' level for a pollutant, that is, the level of a substance (acid deposition, as an example) which does not cause long-term damage to an ecosystem (Grennfelt and Thörnelöf, 1992). Areas, which have a limited natural capacity to absorb or neutralize acid rain, have a low critical load. Ecosystems that are more able to buffer acidity (through e.g., different soil chemistry, biological tolerances, or other factors), have a correspondingly higher critical load[15]. Therefore, the critical level for each grid cell depends on the ecosystems present. When the sulfur and nitrogen deposition are below the 5th percentile of their maximum critical loads no threat to biodiversity is assumed (pressure value = 0). If the sulfur or nitrogen deposition is higher than five times the 5th percentile of the maximum critical loads , threat to biodiversity is assumed to be at its maximum level (pressure class = 1000). Moreover, by this pressure class the critical load is exceeded more than one time in the greater part of the natural area, so fairly the entire area will be at risk at the long time. In this study, the acidification pressure of each grid cell is determined by the highest exceedence: sulfur or nitrogen.
Acidification loads in the so-called gravely affected Black Triangle-area in Central Europe are between 5 to 10 times the 5th percentile of the maximum critical loads of sulfur or nitrogen. The critical levels as well as the modeled exceedences of these critical loads for the N and S deposition are obtained from the Co-ordination Center for Effects (CCE) (Posch et al., 1997).

6. Eutrofication

One of the major threats to the structure and the functioning of natural and semi-natural ecosystems, and thus to the natural variety of plant and animal species, is the increase in air-borne nitrogen pollution (NH_3 and NO_x) in the past decades (Bobbink et al., 1996). The impacts of increased nitrogen deposition upon biological systems are diverse, but the most important effects are:

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[15] http://www.iiasa.ac.at/Research/TAP/rains_asia/docs/critload.html

- Accumulation of nitrogen compounds, resulting in changes of (competitive) relationships between species;
- Increased susceptibility to secondary stress and disturbance factors such as pathogens, frost and drought damage;
- Soil-mediated effects of acidification;
- Direct toxicity of nitrogen gases and aerosols to individual species

The different ecological effects of nitrogen deposition can lead, alone or in combination, to severe changes in species composition and, finally, to losses of diversity. The severity of the effects depends on the amount and duration of the inputs and on the abiotic conditions in the ecosystem (e.g., buffer capacity, soil nutrient status, and soil factors which influence the nitrification potential and nitrogen immobilization rate (Bobbink et al., 1998).

Similar to acidification, ecosystem specific critical loads for excess nitrogen deposition are known. The critical loads have been set on the basis of observed and published changes in the structure or function of ecosystems using experimental (field) data, field observations and/or dynamic ecosystem models (Bobbink et al., 1992; Bobbink and Roelofs, 1995). When the deposition of NH_3 and NOx is below the critical level no threat to biodiversity is assumed (pressure class = 0). If the deposition of NH_3 and NOx is higher than five times the critical level, threat to biodiversity is assumed to be at its maximum level (pressure class = 1000). However, in some biotopes large changes in species composition might already occur at two to three times the critical load (e.g., Bobbink et al., (in press), Heij and Schneider (1995)). The critical levels as well as the modeled exceedences of these critical loads are obtained from the Co-ordination Center for Effects (CCE) (Posch et al., 1997).

7. Exposure to high ozone concentrations

High ozone concentrations have adverse effects on plant and animal species and human health and it can also affect materials such as paint and plastic. Ozone affects leaves from the inside (stomata) which will negatively affect the water balance in plants. It affects cell membranes with leakage and death of the cells as a result. It will also cause oxidative stress within plant cells, which disrupts many physiological processes. The plant can defend itself by forming substances that can function as antioxidants (mainly vitamin C for protection of outside of cells and vitamin E for within cell membranes). The plant will try to repair its cells. This is energy consuming and results in limited plant growth and production. Furthermore, when a plant is stressed by ozone it will increase the production of Ethane (plant hormone) which has large physiological consequences. Crops will ripen or die too early and leaves will fall too early. Besides its effects on plants ozone will also affect humans and thus probably also mammal species. High ozone concentrations can cause premature aging of the lungs, lung tissue damage, eye, nose and throat irritation, and thus causing breathing difficulties, coughs and headaches (California Air Resources Board Status Report, 1994; Stanners and Bourdeau, 1994)

Based on the scientific work on critical levels carried out under the UN/ECE Convention on Long-range Transboundary Air Pollution Working Group on Effects (UNECE, 1997, 1996), a number of guideline values are recommended by WHO (1997). The

Accumulated exposure Over a Threshold (AOT) is used as indicator for effects of ozone. The cumulative exposure index using a threshold of 40 ppb (AOT40) has been accepted as the best available exposure index for damage to crops and natural vegetation (Kärenlampi and Skarby, 1996, UBA, 1996) using hourly concentrations during daylight hours over a three-month period (growing season). The critical level for agricultural crops and natural vegetation (excluding forests) (relating to a five percent crop loss) has been set at an AOT40 of three ppm.hours. It has been shown elsewhere that for the currently prevailing European ozone regime the critical level for crops and natural vegetation is stricter than the critical level for forest trees.
In this threat assessment it is assumed that the pressure class for ozone is 0 when the AOT40 is below the critical level for crops and vegetation. Determining the maximum level is difficult, as scientific information on this issue is very scarce. Based on expert judgements, which suggest that there is a very marginal difference between toxic and non-toxic ozone levels in the atmosphere we assume that threat to biodiversity is at its maximum when the critical level is exceeded 5 times (pressure class = 1000).

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Annex 3 Limitations and opportunities of the Pressure Index

Limitations of the Pressure Index

To make it possible to use the Pressure Index properly it should be clearly emphasized and realized that there are limitations to the method presented here. They are: 1) The availability of geographical explicit data; 2) The uncertainty of the modeling / projections for the future; 3) The number of pressures included; 4) Linear grading; 5) The threshold 2500; 6) Use of the Land Use Change Simulator; 7) The local situation; 8) The Management aspect. Below, these limitations are shortly explained.

Availability of detailed geographical explicit data

Availability of detailed geographically explicit data remains a problem. For example, data on GDP was only available for most eastern European countries on a country scale level. Data on acidification as also eutrofication were at the time of computing only available at a scale of 150 by 150 kilometers (EMEP grid). This course resolution causes the appearance of the EMEP-grid cell borders in Sweden. Data on land cover was lacking for countries like Norway and former Yugoslavia. For most countries 40 land cover categories were used for the classification. However, because several countries had land cover data available with only 7 categories, these 7 categories were used to determine the location of man-made and natural areas as also for the calculation of isolation.
Another data limitation was caused by the data set on climate change. Coastlines are difficult to include exactly as the data are only available on a relatively course scale (50-by 50 kilometers) that caused that some coastal areas were considered to be water (as these models consider a grid cell to be water with a certain percentage of water in it). Consequently, no data on e.g. temperature is available for those areas. Therefore, many coasts do not have complete data coverage on all pressures and are considered as no data areas.
Another problem with the data sets is that they do not all use the same geographical coverage/projections (e.g. location of coasts) and spatial detail. Therefore, some manipulations have to be made to match all the data sets.

Uncertainty of modeling / projections for the future

Modeling of all these pressures to get information on the future situation is based on assumptions, trends and simplifications. Therefore, it should be taken into account that there are large uncertainties which are of course difficult to quantify. The results should not be considered as the absolute truth but merely as possible scenarios for the future based on the best available data, models, and knowledge.

The number of pressures used to calculate the Pressure Index only seven pressures are used. In reality, important biodiversity threatening factors like fire, water use, water availability, forestry, extensive grazing, management, hunting, tourism and fragmentation by roads should also be taken into account to give a more complete overview.

Linear grading
To determine the pressure class between the maximum and minimum threat level linear grading has been applied. This is, of course, an assumption as ecosystems, or at least parts of it, will respond in complex non-linear ways. Many interactions exist between biotic and abiotic components of ecosystems and –given the current state of knowledge- only some can be included in modeling exercises as these on the European scale.

The threshold 2500
Low ecosystem quality is assumed when the Pressure Index is higher than 2500. This value is arbitrarily chosen. However, this choice can be justified. When the Pressure Index is 2500 or more it is very likely that there are at least two or three pressures with a high pressure class meaning for every pressure a high chance on a very low ecosystem quality. When these high pressures are combined it is assumed that there will be an extremely low change on high quality caused by synergistic effects. However, this assumption needs further underpinning.

Land Use Change Simulator
The general concept of weighted attractivities in the land use change simulator appeared to be appropriate for simulating different allocation scenarios. Its framework is transparent and flexible for implementation of new parameters of interest. However, the different scenarios have no significant effect on the indices. Therefore, the method appears to be not sufficiently sensitive and should be adapted.

Local situation
The current and future state of the biodiversity is related to the history of the specific site. Environmental or socio-economic damages (like e.g., pollution, restoration on agricultural land, or clear cutting) will reduce the chance on high ecosystem quality in that area. This European study is, as may be clear, not able to include these effects in the Pressure Index. It should be stressed that biodiversity studies on a local scale are much more accurate, but are not realistic on a European scale.

Management aspect
An important aspect in determining the actual threat to biodiversity is management of the area. Management practices can increase or decrease the quality of the ecosystems. Sustainable ecosystem management or ecosystem restoration will positively affect biodiversity while overgrazing negatively affect biodiversity.

All these limitations should be taken into account with the interpretation of the results. The results give a rough picture of the order of magnitude and distribution of some relevant pressures and their changes in different policy scenarios. In the future many of these limitations should/can be reduced by improving the data sets, modeling techniques, adding more pressures and increasing knowledge of how the pressures interact/affect biodiversity in different ecosystems. However, at the end, it is better to use state indicators in stead of pressure indicators. In addition, the quality should also be determined for agricultural areas.

Opportunities of the Pressure Index

Even with all the limitations mentioned above, the method described here is still valuable. The following characteristics contribute to its value: 1) Effect of different socio-economic scenario's (policies) on biodiversity can be assessed; 2) Several pressures to biodiversity are included in one approach; 3) One method for the whole of Europe; 3) Many different spatial and temporal scales; 4) Use of the best available databases; 5) Both qualitative as quantitative information used; 6) Plans for (European) ecological networks can be made.

Effect of different socio-economic scenario's (policies) on biodiversity can be assessed
To be able to assess how the pressures and thus the chance on ecosystem quality will change, several models are developed. With these models different socio-economic scenarios with their own assumptions on e.g. economic development and population growth will be calculated resulting in potential changes in pressures.

Several pressures to biodiversity are included in one approach
Until now, science tends to give a fragmented overview of the pressures to biodiversity. In many cases only one or two pressures at the same time are considered and thereby excluding the potential synergistic effects. In this study, as many pressures as possible were scaled, added and visualized at a specific location in Europe. A start has been made to compare the effect of different pressures and to make cost-benefit analyses of various policy scenarios on several measures.

One method for the whole of Europe
In Europe, many different ecosystems can be found and each type will have its own abiotic and biotic characteristics. This makes it difficult to compare the different regions concerning biodiversity and decline of biodiversity. In this study however, one method was applied for the whole of Europe, which makes it possible to roughly identify the most and least threatened areas in Europe in a mutually comparable way.

Many different spatial and temporal scales
It is possible to calculate the mean Pressure Index and a pressure-based NCI for any defined region (climatic, geographical, or biological). With regards to biological meaning of the results, stratification towards physical/ecological regions is possible next to political stratification on EU-country level.

Use of the best available databases
For this study the best available databases were used on the topics involved. In the future remote sensing based information on the state and change in natural and man-made area is most promising.

Both qualitative as quantitative information used
Biodiversity is threatened by changes in quality of the ecosystems but also by changes in the available natural area. Therefore, to give an overview of threats to biodiversity, it is

strongly recommended to take into account both aspects. This study enables to visualize changes in quality and quantity of ecosystems separately or together at each required spatial scale.

Plans for (European) ecological networks can be made
Based on ecosystem quality and quantity information on a geographical explicit way can support the development of plans for the establishment of a European ecological network.