REFLECTING ENVIRONMENTAL LAND USE NEEDS INTO EU POLICY: PRESERVING AND ENHANCING THE ENVIRONMENTAL BENEFITS OF "LAND SERVICES": SOIL SEALING, BIODIVERSITY CORRIDORS, INTENSIFICATION / MARGINALISATION OF LAND USE AND PERMANENT GRASSLAND

Reference: ENV.B.1/ETU/2008/0030

FINAL REPORT

31st January 2010

Institute for European Environmental Policy

15 Queen Anne's Gate
London, SWIH 9BU
United Kingdom

Quai au Foin, 55
1000 Brussels
Belgium

In cooperation with:

Alterra (Netherlands)

Alterra
Wageningen University and Research;
Droevendaalse steeg 3, 6708 PB
Wageningen, The Netherlands

REPORT AUTHORS AND CONTRIBUTORS

Recommended citation:

IEEP and Alterra (2010). *Reflecting environmental land use needs into EU policy: preserving and enhancing the environmental benefits of "land services": soil sealing, biodiversity corridors, intensification / marginalisation of land use and permanent grassland.* Final report to the European Commission, DG Environment on Contract ENV.B.1/ETU/2008/0030. Institute for European Environmental Policy / Alterra Wageningen UR.

Project contact person:

Dr Graham Tucker
Head of Biodiversity Programme
Institute for European Environmental Policy
15 Queen Anne's Gate
London
SW1H 9BU
United Kingdom

E-mail: gtucker@ieep.eu

Overall project management and coordination:

Graham Tucker (IEEP) and Leon Braat (Alterra)

Chapter authorship:

Chapter 1: Graham Tucker[1] and Leon Braat[2]
Chapter 2: Graham Tucker, Andrew McConville[1] and Clunie Keenleyside[1]
Chapter 3: Marta Pérez-Soba[2], Gerard Hazeu[2], Peter Verburg[2], Michiel van Eupen[2], Matthijs Danes[2] and Laure Roupioz[2]
Chapter 4: Simone Verzandvoort[2], Nanny Heidema[2], Jan Peter Lesschen[2], and Catherine Bowyer[1]
Chapter 5: Rob Bugter[2], Michiel van Eupen, Irene Bouwman[2] and Arjan Griffioen[2]
Chapter 6: Andrew McConville, Graham Tucker and Marianne Kettunen[1]
Chapter 7: Clunie Keenleyside and Graham Tucker
Chapter 8: Leon Braat and Graham Tucker
Chapter 9: Leon Braat and Graham Tucker
Chapter 10: Graham Tucker, David Baldock[1], Catherine Bowyer, Kaley Hart[1], Clunie Keenleyside and Andrew McConville

[1] Institute for European Environmental Policy

[2] Alterra Wageningen UR

ACKNOWLEDGEMENTS

This study was funded by the European Commission. We thank the European Commission Desk Officer, Eva Viestova and Commission staff including Vivianne Andre, Anna Barnett, Jacques Delsalle, Marco Fritz, Ariane Labat, Rene L'Her, Claudia Olazabal, Inge van-Oost, Caroline Raes, Patrick Salez, Martin Scheele, Thomas Strassburger and Karin Zaunberger for their helpful advice and guidance.

We are especially grateful to Joop van Bodegraven, Alun Evans, Petri Heinnonen, Els Martens, Pranas Mierauskas, Peter Roth, Kalev Sepp and Reinhard Schmidt-Moser who provided presentations at the study's workshop on biodiversity corridors and questionnaire responses on the biodiversity corridor initiative case studies. Rozália Érdine provided the information on the Hungarian case study and Mischa Indeherberg provided additional information on the Flanders case study. Kerstin Sundseth and Lawrence Jones-Walters provided presentations at the workshop on other studies related to biodiversity corridors. We also thank the other participants of the workshop, who contributed to useful discussions on the presentations: Anna Barnett, Boris Barov, Andreas Baumueller, Rob Bugter, Erik Gerritsen, Paul Grigoriev, Pieter de Pous, Ana Suarez, Theo van der Sluis, Aleksandra Sylwester, Eva Viestova, Adriane Viviane and Chris Walzer.

Source data for the indicator for water retention, SWSC_eff, were kindly provided by Brian Irvine from the University of Leeds, UK, on behalf of the PESERA consortium.

We also thank many colleagues at IEEP for assistance during the project, and in particular Martin Farmer for assistance at the start of the project, Sonja Gantioler for initial research on the ecological network case studies, Katherine McCoy for editorial assistance, and Andrew Farmer and Tamsin Cooper for advice on policy recommendations..

REFLECTING ENVIRONMENTAL LAND USE NEEDS INTO EU POLICY: PRESERVING AND ENHANCING THE ENVIRONMENTAL BENEFITS OF "LAND SERVICES": SOIL SEALING, BIODIVERSITY CORRIDORS, INTENSIFICATION / MARGINALISATION OF LAND USE AND PERMANENT GRASSLAND

Reference: ENV.B.1/ETU/2008/0030

FINAL REPORT

CONTENTS

LIST OF ACRONYMS

BAP	Biodiversity Action Plan
C	Carbon
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CLC	CORINE Land Cover
CLUE	Conversion of Land Use Change and its Effects [model]
CORINE	CO-oRdination of INformation on the Environment
DG	Directorate General
EAFRD	European Agricultural Fund for Rural Development
ECA	European Court of Auditors
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EPA	Environmental Priority Area
EU	European Union
EU-12	Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom
EU-25	EU-27 other than Romania and Bulgaria
EU-27	All 27 Member States of the European Union
FSS	Farm Structure Survey
GTAP	Global Trade Analysis Project
GAEC	Good Agricultural and Environmental Condition
GDP	Gross Domestic Product
GDR	German Democratic Republic
GHG	Greenhouse Gas(es)
GIS	Geographical Information System
HISLU	Historical Land Cover [dataset]
HNV	High Nature Value
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution and Prevention Control [Directive]
IRENA	Indicator Reporting on the Integration of Environmental concerns into Agriculture
JRC	Joint Research Centre
LCF	Land Cover Flow
LEAC	Land and Ecosystem Accounts
LEAF	Linking Environment and Food
LFA	Less Favoured Area
MSA	Mean Species Abundance
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
PEEN	Pan-European Ecological Network
PESERA	Pan-European Soil Erosion Risk Assessment
PLCM	Pan-European Land Cover database
RDP	Rural Development Plan
SAC	Special Area of Conservation
SAPS	Single Area Payment Scheme
SCaMP	Sustainable Catchment Management Programme
SDS	Sustainable Development Strategy
SEA	Strategic Environmental Assessment
SFP	Single Farm Payment
SPA	Special Protected Area

SPS	Single Payment Scheme
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SRES	Special Report on Emission Scenarios (IPCC, 2000)
SWSC_eff	Effective Soil Water Storage Capacity
STS	Sustainable Development Strategy
TEEB	The Economics of Ecosystems and Biodiversity
UAA	Unitised Agricultural Area

EXECUTIVE SUMMARY

Background and objectives of the study

There is increasing global awareness, through studies such as the *Millennium Ecosystem Assessment* and the initiative on *The Economics of Ecosystems and Biodiversity* (MA, 2005; TEEB, 2008, 2009), of the important benefits that ecosystem services provide to humankind. This has also been recognised in Europe, where there is a growing political ambition to maintain and where necessary restore or enhance ecosystem services. This ambition is reflected in the EU biodiversity strategy (COM (2006) 216) and is reinforced in the proposals for a new EU post-2010 biodiversity target, which explicitly refer to ecosystem services as well as biodiversity (COM (2010) 4 final[1]).

This study was commissioned by the European Commission to contribute to the delivery of four key ecosystem services, namely the provision of food, water (in terms of quality and quality), soil carbon (in particular soil organic matter) and biodiversity[2]. These are hereafter referred to as the land services. Its overall purpose was to develop an approach at the EU level for the protection of these land services, against the background of changing land use and climate change. In particular, it aimed to establish recent trends and likely future changes in land use in the EU up to 2030, and how these may impact on the land services through the following four key pressures:

- **Soil sealing** (i.e. making the upper layer of the soil impermeable through the use of asphalt, concrete or similar materials that prevent or severely restrict the exchange of water and gases between the soil and the atmosphere).
- **Habitat fragmentation,** including the loss of biodiversity corridors (i.e. land areas and associated habitats that functionally connect patches of suitable habitat for plants and animals).
- **Land intensification and marginalisation** (i.e. intensification being an increase in agricultural inputs for the purpose of increasing productivity; marginalisation being defined in this study as the reverse of intensification, which leads to extensification and in some cases agricultural abandonment[3]).
- **The loss of permanent grassland,** which often results from land intensification in the sense of arable conversion or reseeding of permanent grassland or abandonment of agriculture (with permanent grassland being defined in this study as all farmland under grass or herbaceous forage that has not been in an arable rotation for 5 years or more[4]).

---

1 http://ec.europa.eu/environment/nature/biodiversity/policy/pdf/communication_2010_0004.pdf

2 In itself biodiversity is not a service, but underpins supporting, regulatory, provisioning and cultural services. However, it was treated as a service in this study.

3 Strictly speaking marginalisation is a process driven by a combination of social, economic, political and environmental factors, by which the management of certain areas of farmland cease to be viable under existing land use and socio-economic structures. This can in fact lead to intensification or extensification and abandonment.

4 In accordance with the definition of 'permanent pasture' in EU Regulation 793/2009 on direct CAP support for farmers. But permanent grassland can in fact be defined in many ways, with ecological definitions typically referring to much older grasslands.

The final objective of the project was to draw together assessments of likely land use changes and resulting pressures in Europe in the coming years to provide an integrated evaluation of potential impacts on the four land services. This has led to a set of recommendations (that take into account existing legislation and other policy instruments) that provide an outline blueprint of how land services might best be protected from the potential future threats identified in this study.

The following sections summarise this study's results relating to:
- observed and projected land use changes in the EU;
- the implications of these projected changes in terms of soil sealing and its impacts on land services, and habitat fragmentation and its impacts on biodiversity;
- assessments of the effectiveness of biodiversity corridor initiatives that aim to mitigate the impacts of fragmentation;
- assessments of policy instruments that may reduce the impacts of intensification/ marginalisation (including the loss of permanent grassland) on land services, and overall likely impacts of intensification/ marginalisation on land services; and
- key recommendations for maintaining and restoring land services.

Analysis of land cover trends and projections of land use for the next 25 years
The first stage of this study is an analysis of land cover trends in the EU (using HISLU60 and Pan-European Land Cover Mosaic datasets) over two time periods: 1960-1990 and 1990-2000. This revealed that there were dramatic overall changes in land cover in the EU-27 between 1960 and 1990, which led in particular to substantial losses of grassland (from 19% to 7% cover) and increases in forest cover (from 25% to 33% cover), and a smaller but significant increase in arable land (from 38% to 40% cover). Forest expansion was associated with significant losses of grasslands in many parts of Europe, including central Europe, parts of France, the UK and Portugal, and northern Spain.

Over the following 10 years, the rates of change in land cover declined considerably such that there were only relatively small declines in arable land and grassland, and virtually no change in other land cover types other than urban areas. It is difficult to quantify pre-1990 urban land cover accurately but the available data suggest that there was considerable urban growth from 1960 to 1990, which continued after 1990 but at a slower rate. Loss of agricultural land to urban development has been most prevalent in north-western Europe but it has only affected a small proportion of land.

Superimposed on the broad changes in land cover were changes in agricultural land use in terms of intensification and abandonment. These changes are more difficult to measure and map, and therefore past trends in these processes are uncertain. However, available information suggests that over the last few decades abandonment has been relatively widespread in areas with extensive production and small farms, especially in mountainous regions and/or on poor soils. Abandonment seems to have been most common in the Alps, Pyrenees, Portugal, central Spain, Sardinia, the former GDR, the Baltic States and parts of eastern Europe. Abandonment also occurred sporadically and at various times in parts of north-west Europe including Ireland, Denmark and the Netherlands, but was very often localised and relatively small-scale.

Intensification indicators suggest that over the 1990-2000 period, the main areas of intensification were in Ireland, Spain and parts of North Western Europe, and during the later part of the decade in the former GDR, Hungary, and the Baltic States (following earlier extensification and widespread abandonment of agriculture).

Looking to the future, as a result of expected trends in land use drivers (see below) and policy responses, it is likely that there will be major changes in Europe over the coming few decades, particularly in the spatial patterns of agricultural land use and intensity of agricultural practices. This study therefore sought to identify potential land uses changes up to 2030 in the EU-27 through spatially-specific land use modelling (using a chain consisting of GTAP, IMAGE and CLUE models). The main external driving factors specified as input to the models were demographic changes, overall economic development (GDP), technological change and policy measures. These factors were set according to the chosen reference scenario of "B1 global cooperation" based on the IPCC Special Report on Emission Scenarios (IPCC, 2000)[5]. It is therefore important to note that the projections from this study are not predictions of what is likely, but what may happen according to one set of plausible assumptions.

According to the modelled projections of land use change the main areas of future intensification in the EU up to 2030 are expected to occur in the EU-12 Member States, especially the Baltic States, because there is considerable scope for further investment, restructuring and technological improvements in the agriculture sector in the region. There are large areas of High Nature Value[6] (HNV) farmland in these countries, but it appears likely that these will be more at risk of abandonment than intensification (although this is a possibility following restructuring of farm holdings).

Losses of permanent grassland as a result of both intensification and abandonment are projected to be widespread across the EU, with particularly large declines predicted in Portugal, Greece, Spain and Estonia.

It was not considered appropriate to quantify abandonment given the high levels of uncertainty in assumptions and the degree to which land owner decisions will actually be directly linked to economic drivers. Nevertheless, from an inspection of the maps of projected land use change, under the B1 scenario, it is obvious that abandonment will be widespread, particularly in Spain and Portugal, parts of Finland and Sweden, highland areas of France, Italy, central Europe, Romania, Bulgaria and the UK, and parts of Greece. This is consistent with previous studies, which indicated that the regions most susceptible to marginalisation are those where extensive farming and small-scale farming is predominant. It is also of concern that HNV farmland areas (which are important for biodiversity) will be particularly affected by land abandonment, according to the detailed analysis carried out in this study. The incremental projected land use changes indicate that by 2030, 9.0% of non-irrigated arable land within HNV areas may become (semi-) natural vegetation and 10.9% may turn into recently abandoned arable land. The projected abandonment trend for HNV pasture is even

[5] The B1 scenario has been further developed for Europe by Westhoek *et al* (2006) and combines a global orientation with a preference for social, environmental and broadly defined economic goals (i.e. more than simple profit). Governments are considered to be actively regulating and ambitiously pursuing goals related to, for example, equity, environmental sustainability and biodiversity.

[6] HNV farmland includes arable farmland, grazing land and permanent crops that support important biodiversity, typically because of their low intensity, presence of semi-natural vegetation and habitat diversity; they are often an integral part of extensive livestock farming systems.

greater, with 20.4% developing into recently abandoned pasture, and 7.7% developing further into semi- natural vegetation[7]. Of existing semi-natural vegetation, 17.3% is projected to develop into forest.

Soil sealing: trends, projections, policy instruments and likely impacts on land services
Soil sealing was observed to result in a loss of suitable land for arable cropping and permanent grassland amounting to 1% of the land area per annum in EU countries in the period from 1990 to 2000. Similar overall losses from soil sealing are projected for 2000-2030 under the B1 reference scenario. The largest projected impacts on the loss of land capable of food production are likely to occur in the Netherlands (3.0% loss of arable crop area and 3.2% loss of permanent grassland) and in the UK (1.5% losses of both arable land and permanent grassland). This is a result of the relatively high projected growth rate of built-up areas, and the high percentage of land suitable for food production in the areas likely to be converted. Although the projected loss of land suitable for agriculture is relatively small compared to the total stock of agricultural land in the EU27, the loss may nevertheless be significant in terms of net primary productivity.

Averaged over the EU, the effective soil water storage capacity decreased as a result of soil sealing by 0.5% in the period 1990-2000, and is projected to decrease by a further 0.8% between 2000 and 2030.

The projections suggest that the impacts of soil sealing on biodiversity will be generally relatively small, due to the low biodiversity value of areas that are most typically affected by soil sealing.

Due to the high variability of soil organic carbon in urban areas and lack of sufficient studies it is difficult to make generalizations on the likely impacts of soil sealing on carbon stocks. However, it is estimated that soil sealing in the period 1990-2000 resulted in a loss of 4.6 Mton C in 23 EU countries, which is equivalent to an annual emission of 1.7 Mton CO_2. The highest losses occurred in northwest Europe (i.e. the Netherlands and Germany). For the period 2000-2030 soil organic carbon losses due to soil sealing are projected to decline substantially to an annual emission equivalent of 0.7 Mton CO_2.

Analysis of the effects of projections of land use change on habitat fragmentation and its subsequent impact on the provision of land services
The implications of this study's projections of land use change up to 2030 on habitat fragmentation were examined in the context of proposals for biodiversity corridors, using the spatial connectivity model LARCH. On the basis of maps of projected changes in land cover and of expected road networks and traffic densities, functional habitat networks were identified for generic species groups ('ecoprofiles') for forest habitats, wetland habitats and semi-natural habitats (other than wetlands and forests). However, the absence of high resolution and detailed spatial data on the distribution of detailed habitat types hampered the quantification of projected European scale habitat fragmentation impacts.

Nevertheless, despite the data limitations, it is clear that the combined effects of the projected land use changes and increases in road traffic densities will most probably have large negative impacts on the connectivity / corridor functions of important natural habitats in large parts of

[7] The model is based on CORINE categories and therefore some HNV pastures are included in the projections for pasture and others for semi-natural habitats.

the EU, especially in areas with mixed landscapes, unless mitigated or compensated for through additional connectivity conservation actions. The countries where the impacts of fragmentation are likely to be greatest on species that depend on forest habitats are Latvia, Lithuania, Poland, the Czech Republic and Slovakia. Fragmentation of non-wetland semi-natural habitats is likely to be greatest in southern Europe (except Italy). Due to data constraints fragmentation impacts on species of wetland habitats could not be reliably assessed.

A visual analysis was carried out of the congruence between areas that are important for connecting existing functional habitat networks (as revealed by the LARCH model maps) and maps of national and regional plans for ecological networks. This suggested that there was mostly a broad match between plans and the important connectivity zones as indicated by the LARCH model. However, the plans and available habitat maps are too general to assess the potential adequacy of the proposed ecological networks. Moreover, it is difficult to assess the actual contribution that the proposed ecological networks can be expected to make to maintaining and restoring functional connectivity, because (as discussed below) few ecological network initiatives have been adequately implemented to date. Nevertheless it is clear that current connectivity conservation measures in most EU Member States are insufficient to overcome existing and expected fragmentation impacts. Further action is also undoubtedly required to reduce the underlying drivers of fragmentation, in particular the growth of transport infrastructure and other causes of habitat losses in the wider environment.

The effects of policy instruments and ecological network initiatives on habitat fragmentation

The maintenance and restoration of biodiversity corridors, usually as part of an ecological network, has been long proposed as an approach to tackling fragmentation. But despite the development of numerous proposals for ecological networks, few appear to have been adequately implemented and there is little evidence that the corridor components of these networks have provided significant biodiversity conservation benefits. This study therefore examined the following nine ecological network case studies (through a questionnaire survey and workshop with practitioners): Cheshire (UK), the Czech Republic, Estonia, Schleswig-Holstein (Germany), Flanders (Belgium), Finland, the Netherlands, and Lithuania. These were selected because they are established initiatives that reflect a range of approaches and degrees of successful implementation. The aim was to assess their achievements and identify factors that helped or hindered them.

The review highlighted the importance of developing and agreeing clear biodiversity and broader objectives for biodiversity corridors and ecological networks. To achieve ecological goals, it is vital that each corridor is designed with the needs of a particular species or sets of species in mind, and is based on principles of sound scientific evidence. The design should also be very clear about why connectivity is necessary (e.g. for facilitating migration or linking small isolated populations), and focus on addressing these needs. It should also be remembered that ecological corridors are but one approach to tackling fragmentation. For example, there is good evidence that fragmentation impacts can often be reliably addressed by firstly protecting, increasing and enhancing important core areas of habitat.

The case studies also revealed that most effort has often been put into the design of the proposed networks rather than their implementation, with the result that they exist more on paper than in practice. This is mainly because most network proponents have limited powers and/or capacity to protect, manage and restore habitats. In many cases network maps have been incorporated into spatial plans, and where biodiversity benefits have occurred these have mostly been through the legal protection of existing habitats in core areas and biodiversity corridors. Legal protection of the network components is therefore very important, and should include measures ranging from strict legal protection for the most important habitats and features to indicative planning guidance maps for corridors of lesser or substitutable importance. However, in practice effective protection rarely extends beyond existing protected areas. The implementation of ecological networks, and especially the maintenance and restoration of corridor components, is therefore highly dependent on the support of landowners and available funding, but this is often hampered by inadequate or ill-timed consultation with stakeholders.

A related problem is that some network initiatives are focussed on relatively narrow ecological objectives, and therefore lack wide support from the public and other stakeholders. Network proponents should therefore look for opportunities to create local partnerships at an early stage, to identify and work towards mutually beneficial goals and multi-functional uses of areas where these are compatible with biodiversity conservation objectives (for example recreation or water protection). Achievable aims and a clear vision should then be agreed, to guide the design of the network and to help communicate the network's potential benefits.

Network proponents also need to consider the technical capacity and resources required to implement plans on the ground (such as land purchase or agreements with land owners to restore and manage habitats). Securing adequate funding and targeting it at the most cost-effective actions in core areas and biodiversity corridors is therefore of prime importance.

This study also found that there is very little monitoring and evaluation of the practical implementation of ecological network actions and their actual ecological outcomes (e.g. in terms of benefits to populations of particular species). This is considered to be a significant weakness, because monitoring and evaluating the implementation of both policy interventions and ecological impacts facilitates adaptive management and provides an evidence-base to support further actions and network proposals.

Drivers and policies that influence intensification, marginalisation and the loss of permanent grassland

An examination of the drivers of agricultural change and policy interventions that potentially affect the delivery of the land services was carried out to establish whether there is a need to review EU policy design and implementation. This highlighted that European farmers are increasingly exposed to a range of influences including a rising global demand for agricultural products and bioenergy, technological changes, trade liberalisation and climate change. These influences are linked to significant recent reforms of the CAP, likely to be continued in 2013. At the moment there is period of consolidation and adjustment, as farmers adapt to the introduction of decoupled Pillar 1 payments (i.e. no longer linked to production) and Member States address the 'new challenges' that were agreed in the CAP health check of 2008.

Existing trends of specialisation and the exploitation of economies of scale are expected to continue, as production moves towards the most competitive (and climatically favourable) parts of Europe, with intensification likely in parts of the EU-12. Arable production is expected to increase, but profitability of the beef, dairy, sheep and goat sectors will probably decline, with the result that production becomes concentrated in fewer, larger units on fertile land, while the numbers of grazing livestock decline elsewhere. There will be some partial or complete abandonment of marginal grassland (although as described above, the extent of this is uncertain). On these assumptions, and given the large number of older farmers who will retire over the next decade or so, many HNV grazing systems will not survive, and those that do will probably require significant long-term public funding.

It is clear that the CAP framework already has a number of policy instruments that could be used to alleviate the negative impacts of intensification and marginalisation (and associated losses of permanent grassland), in particular, GAEC[8] cross-compliance requirements for receipt of payments, and agri-environment schemes and other Pillar 2 environmental measures. Requirements under the Water Framework Directive may also lead to new actions that will help to address the impacts of intensification. However, although the cross-compliance requirements on conversion of permanent grassland should limit total losses at the Member State level nationally, they offer no specific protection for habitats of high biodiversity importance (including old semi-natural grasslands). Furthermore, the leverage exerted by cross-compliance requirements could gradually weaken in the EU-15 Member States as assuming that Pillar 1 payment rates per hectare decline after 2013. Another challenge will be the rising cost of Pillar 2 environmental support, as a result of the relative profitability of arable and intensive dairy farms and the marginalisation of small, low-intensity livestock and permanent cropping farms. Without significant changes in budget allocations this could reduce the scope, coverage and effectiveness of agri-environment schemes.

Assessment of impacts of intensification / marginalisation and loss of permanent grassland on land services

It is evident from this study that the impacts of land use drivers and policies is very context-dependent, therefore leading to intensification in one place and to structural or land use change in another, or to loss of grassland on some farms but improved biodiversity management elsewhere. These variations make it difficult to draw EU wide conclusions on impacts of the drivers on land services, which has implications for both the design and implementation of policies. Furthermore, there are few EU datasets that are sufficiently consistent and complete to enable quantitative assessments of impacts on land services. In particular it is not possible to quantify overall impacts on food production, as expected increases from intensification in some parts of the EU may be offset to some extent by the expected decline in total agricultural area. There may also be some negative impacts on food production as a result of climate change and ongoing soil degradation and erosion (which may be exacerbated by climate change). Nevertheless, there is little indication that there will be potentially significant declines in overall production that could contribute to food shortages or food security issues in the EU.

There is, however, good evidence that the projected intensification of conventional agricultural systems will contribute to further losses of soil carbon, and reductions in soil water retention and water quality. This may be mitigated to some extent by improved farming practices and technology, and extensification and abandonment of farming in some areas, especially where these coincide with erosion prone soils. It is not possible to quantify these changes or establish the net impact resulting from intensification in some areas and marginalisation in others.

---

8 Good Agricultural and Environmental Condition, as defined by Member States within the framework in Annex III of Regulation 73/2009

There is also little doubt that this study's projected levels of intensification/marginalisation and associated losses of permanent grassland would have significantly detrimental impacts on biodiversity. These impacts are likely to be most significant in central and eastern Europe, because agricultural production in these areas is most likely to be intensified or abandoned, and these areas hold a high proportion of remaining HNV habitats and associated species of conservation importance in the EU. In some situations abandonment could provide some biodiversity benefits, particularly if combined with strategic and proactive habitats restoration measures, but overall, abandonment is expected to be an ongoing significant threat to biodiversity in the EU.

Assessment of overall impacts of pressures on land services

The final analytical component of the study attempted to provide an overall assessment of the combined impacts of each of the considered pressures on the four land services. Due to substantial data gaps and difficulties with matching datasets it was not possible to provide a quantitative assessment of combined impacts. However, semi-quantitative judgements on overall impacts were made by drawing on and assimilating all the results of this study.

It was not possible to assess and quantify in a meaningful way the likely overall net change in food production in the EU as a result of the projected changes in agricultural intensification and land use (let alone the impacts of climate change and other indirect influences on food production). Nevertheless, there is no clear evidence that the EU will face a risk of undersupply of food. There may be some concern in this respect over the projected large-scale abandonment of agricultural land, but this will mainly affect extensive grazing systems and therefore meat and diary production losses will be relatively low. Indeed, the market economics that drive marginalisation suggests that production losses from these systems will be compensated by intensification elsewhere in the EU and/or displacement of production outside the EU where this is more cost-effective.

It is evident that the four land-use related pressures considered in this study will continue to have significant impacts on biodiversity in the EU. In particular, many of the most valuable remaining areas of semi-natural habitat are likely to be threatened by agricultural intensification or abandonment. Such impacts will be especially severe in parts of eastern Europe where intensification will probably predominate in areas that are favourable for agriculture, whilst abandonment will be commonplace in the extensive areas of HNV farmland within the region. Abandonment will also be a significant threat to HNV farmland habitats in southern and south-eastern Europe. Furthermore, these pressures will also interact with each other. Fragmentation resulting from urbanisation and infrastructure developments (which also causes soil sealing) will exacerbate expected losses and fragmentation of patches of semi-natural habitat as a result of intensification and abandonment. The withdrawal of extensive grazing as a result of abandonment is a particular concern, because of the potential loss of valuable semi-natural grasslands to self-regenerating scrub and forest. Although it is expected that some new semi-natural habitats will develop (such as woodland), without strategic placement and proactive restoration management, most will be of low biodiversity value, at least for many decades. All of the pressures on biodiversity will be further exacerbated by climate change, which will make habitats and species more susceptible to the impacts of habitat loss, degradation and fragmentation.

In conclusion, there is little doubt that terrestrial biodiversity will continue to decline in the EU as a result of these pressures, and therefore any potential post-2010 target of halting biodiversity loss, or even reducing the rate of loss, will be very difficult to achieve without further urgent, widespread and more effective actions that effectively address the key pressures on biodiversity.

There is a body of existing evidence to indicate that soil sealing and agricultural intensification (including the conversion of permanent pasture to more intensive temporary grasslands) will have significantly detrimental impacts on water quality and (to a lesser extent) water retention and soil carbon levels. Fragmentation may also have small detrimental impacts on these services (e.g. by reducing interception of nutrient-rich runoff and spray drift). In contrast, environmentally sensitive farming practices, extensification and abandonment can reverse these impacts. Indeed, there is considerable scope for increasing the provision of clean water and carbon storage and sequestration through better strategic planning of land uses and improvements in land use practices. Moreover, such actions could provide multiple "wins" including contributing to carbon emission reduction targets, water resource provision and biodiversity conservation. And with the expected impacts of climate change, such actions will be increasingly important contributions to climate change adaptation.

Policy analysis and recommendations for measures to maintain and enhance land services

A number of policy recommendations are made that aim primarily to avoid further losses of the services provided by biodiversity, water and soil carbon, and secondly, to restore and enhance these services where feasible; whilst avoiding significant impacts on net food production capacity in the EU. They also aim to avoid the development of conflicting policy measures, and instead identify measures that have multiple and potentially synergistic benefits.

One of the main conclusions that can be drawn from this study is that the concept of "land services" (like "ecosystem services", of which it could be considered a component) is helpful in challenging compartmental modes of thinking. It draws attention to the importance of different forms of land management and the links between them and has value as an analytical tool. However, in operational policy terms the various elements inside the circle described by land services are rather disparate and straddle different policy fields. Therefore there seems to be limited scope for general policy responses. Instead it seems more appropriate to enhance awareness of the different dimensions of the challenge and direct action to a series of relatively specific and not necessarily related policy domains. Consequently, the development of a dedicated policy instrument for ecosystem services, such as a framework directive, does not seem appropriate.

Furthermore, it is evident that a relatively strong and comprehensive framework of environmental legislation and other instruments exist that can help to maintain and restore the provision of the land services. Consequently, most recommendations focus on improving the implementation of existing instruments. A few more ambitious policy proposals are made that relate to, for example, coordinated implementation of instruments to provide ecosystem services at a landscape or catchment scale, the strategic planning of land use and the allocation of budgets. These suggestions are made because their potential benefits for land services are considerable. But it is recognised that some are longer-term measures, requiring considerably more analysis to develop practical and politically feasible proposals, followed by full impact assessments.

Adequate funding is of critical importance to the effectiveness of many policy instruments and therefore some key broad recommendations relate to the EU budget. In particular it is recommended that:

- The Commission should review opportunities to improve the effectiveness and integration of the different elements of the EU budget that could be used to encourage and support the provision of land services where these services are not likely to be provided by the market.
- Sufficient budgetary resources should be secured for the CAP to deliver revised CAP priorities for the provision of environmental services (see below), allocated between Member States/ regions according to robust criteria appropriate to the CAP objectives.
- Consideration should be given to the establishment of a new EU biodiversity fund to address issues outside the scope of the CAP and CFP which are likely to be the principal source of EU funding for biodiversity beyond 2013.

Many of the sectoral policy recommendations relate to the CAP, as this is the main EU policy and funding instrument influencing land management practices in all Member States and hence the provision of the land services. A recent report for DG Agriculture noted that there is considerable unmet demand for environmental public goods that could be provided by agriculture and could be met by use of policies within the CAP policy framework. Some of the key CAP related actions considered necessary at EU and Member State level to maintain and restore the land services are:

- Refocus the CAP beyond 2013 to include a core objective of delivering ecosystem services on farmland that the market does not provide and ensure sufficient budgetary resources are secured to provide these services at the necessary levels.
- While cross-compliance remains a component of the CAP, keep farm-level requirements updated with relevant new EU environmental legislation (especially on soils), provide further guidance for Member States on GAEC implementation, and investigate the potential consequences and effects of "Environmental Priority Areas" as a cross-compliance requirement.
- Member States should provide better protection for species-rich permanent grassland from intensification or conversion to other uses (including use for biofuel production).
- Give higher priority to providing integrated packages of measures from both CAP Pillars to support HNV farming systems that are delivering land services, and provide guidance on this for Member States.
- Use CAP measures on a much larger scale to help intensive farming systems provide a basic level of land services and incentivise further provision.
- Improve geographical targeting of policy measures; encourage landscape scale delivery; intensify advisory and information services and tailor them to different farming systems and land services.
- Develop, adapt and implement common monitoring and evaluation programmes, and invest in data, to provide an evidence base for future policies on land services.

Of particular importance is the need to strengthen and better implement many existing biodiversity policy measures. Although biodiversity underpins the provision of ecosystem services this has not been sufficiently recognised to date, as a result many biodiversity conservation measures have been weakly, slowly or incompletely implemented. As a result, in part, the EU will fail to meet its 2010 target of halting the loss of biodiversity. It is therefore recommended that:

- The Commission should develop and agree with the Member States a strong and binding post-2010 target for halting and reversing biodiversity loss and related ecosystem services. But most importantly, whatever target is adopted, it will be necessary for all Member States and EU institutions to fully engage with and adhere to it to achieve the agreed objectives for biodiversity and associated ecosystem services.
- Greater encouragement should be given to the implementation of the EU Biodiversity Action Plan, through cross-sectoral actions by EU institutions and Member States.
- Member States should increase their efforts to establish management plans and measures for Natura 2000 sites (and other areas of high biodiversity importance) and to integrate these with the provision of other ecosystem services where there are mutual benefits. In particular, opportunities to facilitate ecosystem-based adaptation to climate change should be identified and acted on. This would help to justify increased targeting of Natura sites and biodiversity under existing funding instruments, in particular agri-environment schemes.
- The Commission should further encourage Member States to implement Article 10 of the Habitats Directive (and similar measures arriving from the provisions of the Birds Directive), through the establishment of national frameworks for assessing functional connectivity needs, and planning, integrating and implementing necessary actions.
- An explicit target of no-net biodiversity loss from projects and programmes should be included in a revised EU BAP, for individual projects and programmes. This could be underpinned by the establishment of a habitat banking policy framework that supports and regulates a habitat banking market involving developers who would purchase credits that would then be used by landowners or land managers to enhance or create land areas for biodiversity and ecosystem service gains.

Other key recommendations relate to a variety of sectoral actions and policies, including soil policy, the Water Framework Directive, environmental impact assessments and planning. With regard to these, some of the key actions put forward in the light of the challenges considered in the report are:

- Finalise a Soil Framework Directive that provides a mandate for action to address soils of concern but also protects valuable soil functions giving adequate weight to issues such as carbon sequestration, waste management and delivery of food/maintenance through agriculture.
- Review the Soil Thematic Strategy to examine successes since 2004/2005, taking account of the shifting policy priorities including more effectively covering the protection of soil functions in the light of issues arising in relation to agriculture, climate change and water resources.
- Ensure that during the implementation of the Water Framework Directive, river basin management plans thoroughly consider impacts on water availability (quantity) as well as quality and contribute to biodiversity and flood defence objectives.
- Provide policy guidance that encourages Member States to ensure that relevant biodiversity objectives are considered alongside Water Framework Directive and Flood Directive objectives in river basin management plans and flood risk management plans.
- Ensure the appropriate implementation of the Strategic Environmental Assessment and Environmental Impact Assessment Directives to improve their use as tools to assess the environmental impacts of plans, programmes and projects and help determine the most environmentally friendly approach to support spatial planning.

Finally, a potentially very beneficial cross-sectoral action would be to encourage and assist Member States to develop holistic visions of land use and policy instruments that support the strategic provision of land service requirements. Such strategic visions may then be combined with indicative strategic land use planning to encourage and support the optimal use of the land by spatially targeting the use of public funds (or other incentives) to deliver the most desired land services.

Looking ahead, it is worth considering whether land use and land services should figure more strongly in strategic thinking on the environment in the EU. For example, if there is a Seventh Environmental Action Programme this is a theme that could be explored more fully, in the same way that soil policy was given some prominence for the first time in the Sixth Environmental Action Programme.

1 INTRODUCTION

Graham Tucker (IEEP) and Leon Braat (Alterra)

1.1 THE STUDY'S OBJECTIVES AND TASKS AS DESCRIBED IN THE SPECIFICATION

According to the Commission's technical specification "*The purpose of the study is to develop an approach related to the protection of land notably for food production, biodiversity, water retention and quality and soil organic matter, hereafter 'land services', against the background of changing land use and climate change.*

The areas of particular interest as the study is concerned relate to the following land uses, processes and features: soil sealing, land intensification and marginalisation, permanent grassland and biodiversity corridors. Each of these land uses has particular relevance to the provision of land services and developments in them will greatly influence the delivery of these services over the coming 25 years.

Soil sealing can be described as the impermeabilisation of the upper layer of the soil through the use of asphalt, concrete or similar materials that prevent or severely restrict the exchange of water and gases between the soil and the atmosphere, thus affecting the delivery of land services.

Intensification of agricultural land use generally implies an increase of livestock production and/or more concentrated arable production at a sufficiently large regional scale. The vocation of intensive food production impedes the delivery of the other land services. Marginalisation, sometimes leading to land abandonment, implies the reverse with regard to food production, but in many instances does not lead to a higher delivery of the other services, and indeed can result in their loss, for example where biodiversity is dependent on traditional extensive farming systems.

Permanent grassland covers a large part of the EU and notably natural and semi-natural permanent pastures play a significant role in the delivery of land services notably with respect to biodiversity, water retention and quality and soil organic matter.

Biodiversity corridors are land areas and features that allow plants and animals to travel from one patch of suitable habitat to another. A corridor provides shelter, food and protection from predators by providing or imitating the structure and diversity of native habitats. Populations that would otherwise be isolated can utilise corridors to migrate between patches with relative ease and safety".

The technical specification also provides the following description of the study's tasks.

"The contractor is required to describe trends in changing land use and in likely climate change effects on land use for the next 25 years. This first part of the study (Task 1) should account for approximately 25% of the workload of the study.

Against the background of task one, the contractor is then required to describe in detail the role of the four phenomena described above, namely soil sealing, biodiversity corridors, land intensification and marginalisation and permanent grassland, and their implications on land services. This second part (Tasks 2-5) should account for 50% of the study.

Drawing together conclusions from the first and second parts of the study, the contractor, taking into account the existing legislative backdrop of EU policy, in particular in the environment and agriculture fields, is required (Task 6) to draw up a detailed outline blueprint of how land services might best be protected, to face the challenges and threats posed in the first part of the study. Moreover, the contractor shall include suggestions on how to better use existing policy instruments or point out in detail any modifications needed to achieve an adequate protection of land services crucial for sustainable development across Europe in a context of a changing climate. This third part (Task 6) should account for approximately 25% of the value of the study."

A summary of the background to the study and the causes of concern over the provision of these land services is provided below.

1.2 WHAT ARE LAND SERVICES?

Land services can be considered to be a sub-set of ecosystem services, which have been described as flows of goods and services from ecosystems to human systems as functions of nature (Braat, 1979; de Groot, 1992). More recently they formed a key focus of the *Millennium Ecosystem Assessment* (MEA) (Millennium Ecosystem Assessment, 2005), in which they are defined as follows:

> *"Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits".*

The MEA also produced a framework for classifying the main types of ecosystem services and illustrating their contributions to human well being (see Figure 1.1). This classification of services, into four broad categories of supporting (e.g. soil formation), provisioning (e.g. food), regulation (e.g. water retention and purification) and cultural services (e.g. recreational benefits from open countryside), has been successful in demonstrating the importance of ecosystems as constituents and determinants of human well being.

Amongst the many services that different land uses provide, the four land services that this study will focus on are briefly described below. The impacts of pressures on them are then outlined in Section 1.3.

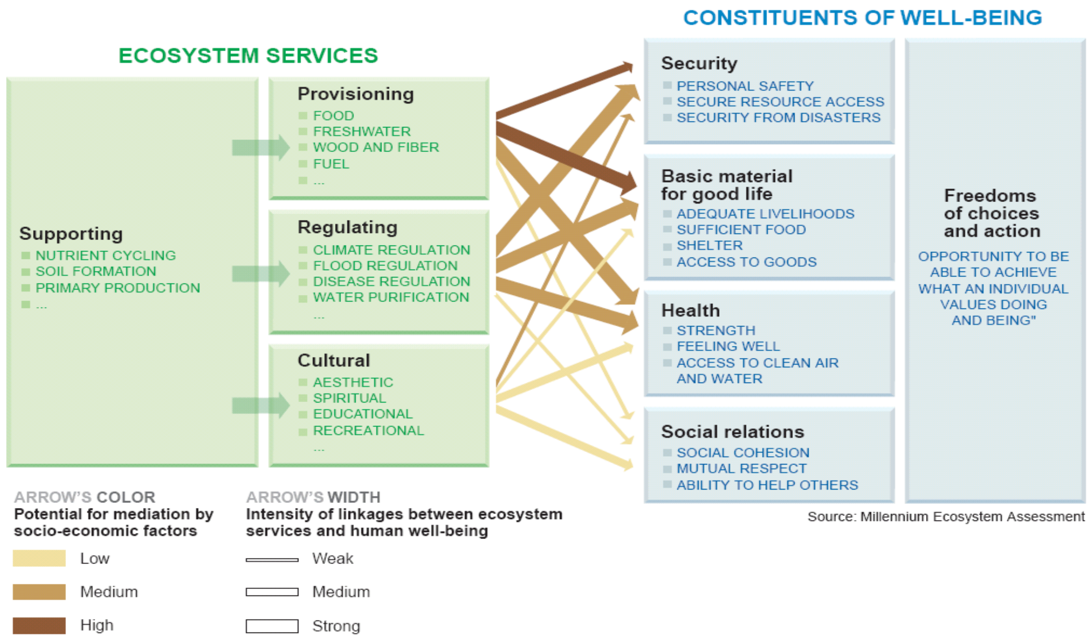


Figure 1.1. The Millennium Ecosystem Assessment Framework indicating the relationships between ecosystem services and constituents of well-being. Source: Millennium Ecosystem Assessment (2005).

1.2.1 Food production

Agriculture is the primary land use in the EU, accounting for approximately 44% of total surface area (Ecologic *et al*, 2007). In 2005, the utilised agricultural area (UAA) in the EU-27 covered around 182 million hectares. In the EU-15, UAA has increased from around 134 million hectares in 1998 to 145 million hectares in 2005 (+ 8%)[9]. Despite this increase in UAA at EU level, land abandonment is widely regarded as a threat to the provision of land services in certain marginal areas where agriculture (or other land uses) is no longer economically viable.

Arable production of cereals and permanent pasture linked to livestock production are the two main land uses in the EU. In 2005, cereal production in the EU-27 accounted for an average of 32.5% of UAA. Arable land accounts for more than 40% of UAA in 8 Member States, namely the Czech Republic, Denmark, Germany, Slovakia, Finland, Hungary, Poland and Romania.

The use of permanent pasture for livestock production is also significant, accounting for more than 40% of UAA in a number of Member States including Greece, Ireland, Luxembourg, the Netherlands, Austria, Slovenia and the UK, based on estimates for 2006, and accounting for at least 20% of UAA in another 10 Member States including France, Germany, Italy and Spain (Alliance Environnement, 2007). Recent data suggest that permanent pasture levels have been relatively stable in the EU-25 since 2003 (Alliance Environnement, 2007). Semi-natural

[9] Figures taken from 'Agriculture in the European Union - Statistical and economic information' http://ec.europa.eu/agriculture/agrista/index_en.htm

grasslands are of particular importance in Central and Eastern European Member States, the largest areas being located in Romania and Poland (Veen Ecology, 2001)[10].

The analysis of past and future drivers of land use change conducted as part of Task 1 underpins projections of the impacts of drivers, such as rising commodity prices, market forces and changing consumer demands, policy interventions arising under the CAP and through energy policy, and pressures on the land uses. Chapter 3 provides a more thorough analysis of recent changes in land use and food production capacity in the EU.

1.2.2 Biodiversity

Biodiversity is not in itself a service, but an integral component of ecosystems and therefore underpins all ecosystem services, such as pollination, primary production, and the aesthetic and educational benefits of wild nature. However, for the purposes of this study we treat biodiversity as a distinct and measurable ecosystem service in itself as well as indirectly taking into account its contributions to other services (e.g. soil carbon cycles).

The wider importance of biodiversity beyond traditional nature conservation concerns is now being increasingly widely recognised, for example in the MEA. Recent studies have also attempted to measure this in monetary terms, for example the recent initiative on *The Economics of Ecosystems and Biodiversity* (TEEB, 2008) and its supporting studies (Balmford *et al,* 2008; Braat and ten Brink, 2008; Markandya *et al*, 2008). However, this study does not require an economic valuation of biodiversity; it focuses instead on biodiversity values related to EU biodiversity conservation objectives, and in particular on the EU objective of halting the loss of biodiversity by 2010 and actions in the related EU Biodiversity Action Plan (including the implementation of the Birds and Habitats Directives).

The importance of habitats varies considerably in the EU with respect to their biodiversity conservation importance, with near natural and rare habitats generally being of highest concern. Natural habitats that are dominated by native plants and have near-natural vegetation communities are typically of highest biodiversity value (though not necessarily the most species-rich). These include some forests, bogs and grasslands grazed by livestock (or in some cases semi-domesticated species, such as Reindeer *Rangifer tarandus*) often under traditional low intensity systems. However, such habitats are now largely confined to remote areas, wetlands, mountains and the far north.

Most areas of native vegetation have at the very least been affected by centuries of forest management and grazing (and in some cases burning) that have resulted in significant changes in vegetation composition and structure. Nevertheless, such semi-natural communities are often species-rich and include a range of High Nature Value (HNV) habitats (Baldock *et al,* 1993; IEEP, 2007). Semi-natural permanent grasslands are still widespread in parts of Europe, particularly in the east and especially in hilly and mountainous regions, arid regions and on areas with poor or wet soils.

However, most semi-natural grasslands have been lost as a result of agricultural improvements such as drainage, fertilisation and re-sowing with species-poor agricultural mixes (Stoate *et al*, 2009). Such grasslands are generally of low plant conservation value, but can still support some wildlife of significant conservation importance. For example,

---

[10] Veen Ecology (2001) http://www.veenecology.nl/index.php?id=5

productive permanent grassland can support important populations of invertebrate feeding birds, especially in winter (Tucker, 1992).

In contrast to permanent grasslands, short-term sown grass monocultures (e.g. *Lolium* spp) are often used as silage rather than being directly grazed. The rapid and dense growth of fertilised grasslands and arable crops combined with the use of herbicides precludes the growth of other plants in the crop. The regular tilling of the soil also reduces organic matter and disrupts the soil ecosystem. Consequently intensive grasslands and arable crops are typically of relatively low biodiversity conservation value.

Furthermore, intensive systems tend to increasingly specialise in growing grass (especially in milk production systems) or crops. Crop rotations are also simplified or abandoned (Stoate *et al*, 2009). As a result vegetation and structural diversity in intensive farmland landscapes is greatly reduced. Studies in the UK have found that the separation of pastoral and arable farming systems has led to declines in bird populations through reduction in habitat diversity in arable (Atkinson *et al*, 2002) and grassland landscapes alike (Robinson *et al*, 2002). Furthermore, such declines are likely to be widespread as agricultural specialisation is a common trend across much of Europe.

Forest, heathland and wetland habitats also similarly vary considerably in biodiversity importance. The most valuable are those that have retained large-scale intact ecosystems with near-natural vegetation communities and associated animal assemblages; such habitats are, however, now rare in the EU.

1.2.3 Water retention and quality

The supply of sufficient water of adequate quality for its intended purpose is a key requirement for many important ecological services and other human uses. The three main human uses of water in the EU are for agriculture, industry and the domestic sector (e.g. households). According to the EEA, the overall abstraction and consumption of water resources is currently sustainable in the long-term[11]. However, some areas may face unsustainable trends, especially in southern Europe where much improved efficiency of water use, especially in agriculture, is needed to prevent seasonal water shortages. In addition, climate change may affect water resources and water demand.

To met these demands the main EU policy objectives for water resources are:

- to ensure that the rates of abstraction from water resources are sustainable over the long term, and to promote sustainable water use based on the long-term protection of available water resources; and
- to ensure a balance between abstraction and recharge of groundwater with the aim of achieving good groundwater status by 2015.

1.2.4 Soil organic matter (especially carbon sequestration)

The presence of organic matter in soils is particularly important for the maintenance of several environmental and ecological functions of soil, such as fertility, biological activity and gas exchanges with the atmosphere and leaching losses to water. Soils hold large amounts of carbon as organic matter as well as inorganic Carbon. Historically, soils have lost carbon through cultivation and disturbance due to land use change. The size of the pool of soil

[11] http://www.eea.europa.eu/themes/water/water-resources

organic matter (SOM) is large compared to gross and net annual fluxes of carbon to and from the terrestrial biosphere (Smith, 2004). Small changes in the SOM pool can therefore have dramatic impacts on the concentration of CO_2 in the atmosphere. To mitigate the increase in concentration of greenhouse gases in the atmosphere, and its effects on global warming, terrestrial ecosystems can be used as carbon sinks. And more importantly, the conservation of (organic) carbon in soils to prevent emissions of CO_2 is highly relevant to both the climate change debate and to the EU's thematic strategy on the protection of soil.

The most recent estimate is that the technical potential for SOC sequestration globally is around 1.3 billion tonnes (Pg) C year–1, but this is very unlikely to be realised. Economic potentials for SOC sequestration estimated by Smith (2008) were 0.4, 0.6 and 0.7 Pg C year–1 at carbon prices of 20, 50 and 100 USD t CO2-equivalent^{-1} respectively. Schulp *et al*, (2008) modelled the effect of land use change on carbon sequestration for the four IPCC SRES scenarios. Carbon sequestration rates are expected to decrease by 4% in 2030 relative to 2000 if land use remains unchanged. Land use change causes an additional decrease in sequestration rate in the IPCC A2 scenario of 2% in 2030, while in the other three scenarios an increase in sequestration rate of 9 to 16% is predicted in 2030.

1.3 HOW ARE LAND SERVICES AFFECTED BY LAND USE PRESSURES?

As described above, this study is particularly concerned with the impacts of four land uses, processes and features on land services. We therefore treat these as pressures and define them as below.

- **Soil sealing** (as described in the technical specification) is "the impermeabilisation of the upper layer of soil through the use of asphalt, concrete or artificial impermeable membranes (e.g. to seal land-fill sites) etc, which prevents the exchange of water and gases between the soil and the atmosphere".
- **Habitat fragmentation** (i.e. the break-up of habitat patches) as a result of the loss of biodiversity corridors. The study specification does not refer directly to fragmentation, but instead refers to biodiversity corridors, which are landscape-scale features that aim to maintain vital functional ecological connections (such as the ability for plants and animals to move or disperse) between otherwise isolated habitat areas (core areas). These are often continuous physical linkages, and may vary from narrow linear corridors (such as watercourses or hedgerows) to broad landscape corridors. They may also consist of functionally connected corridors of habitat patches that act as stepping stones in the wider landscape (habitat matrix). Biodiversity corridors are therefore features that maintain biodiversity and are not generally conceived of as pressures (though they may exert some on food production and some elements of biodiversity). It therefore seems more logical to refocus this element of the study on habitat fragmentation as a result of the loss of biodiversity corridors.
- **Land intensification and marginalisation**. Intensification is the process of increasing agricultural productivity through increased inputs such as fertiliser, pesticides, cultivations and irrigation etc. strictly speaking marginalisation is a process driven by a combination of social, economic, political and environmental factors, by which certain areas of farmland cease to be viable under existing land use and socio-economic structures (see Section 7.2.1). This can in fact lead to intensification or extensification and abandonment. However, marginalisation is often considered to be the reverse of intensification, leading to extensification and sometimes full land abandonment and vegetation succession. The latter narrow definition matches that used in this study's technical specification, and is therefore followed in this report.

- **Permanent grassland**. For this study permanent grassland is defined according to relevant components of the EU's Common Agricultural Policy, in particular standards for farmers and Member States' obligations to maintain permanent pasture under Regulation 793/2009 (see Section 7.3.1). However, this definition is very broad as it includes all farmland used for grass or other herbaceous forage that has not been included in the arable rotation for 5 years or more. It therefore captures a very wide range of grazed land from biodiversity-rich HNV grasslands of Natura 2000 quality at one extreme, through other semi-natural grasslands, to cultivated grasslands (which may be less than 5 years old, if ploughed up and immediately reseeded as grassland). For clarity, permanent grassland is recast as a pressure by focusing on the loss of permanent grassland, which may arise from the intensification and marginalisation of agricultural land use.

These land use pressures are known to have a range of impacts on the land services that are the subject of this study, and these are summarised in Table 1.2 and described further below.

Table 1.2. The impacts of land use related pressures on land services

Land services	**Soil sealing**	**Intensification**	**Marginalisation (i.e extensification and abandonment)**	**Loss of permanent grassland**	**Fragmentation (absence of biodiversity corridors)**
Food production	Sealed areas cannot produce food under conventional soil based agriculture. But new agro-technology can produce food using other growing media.	Production levels / yields generally increase with intensification (within limits). Excessive intensification may be unsustainable.	Marginalisation reduces food production, especially if soils have been damaged by intensive practices.	Loss of products associated with high animal welfare and high quality meat / milk.	Loss of woodlands, hedges and other habitats that support farming by providing habitat for pollinators, natural predators of crop pests, wind-breaks; and some may produce non-crop foods (e.g. berries).
Biodiversity	Sealed areas have minimal biodiversity value	An overall decline in biodiversity (species and community richness and habitat condition).	Much marginalisation affects HNV farmland, which is often of detrimental, but impacts vary according to context and time-scale specific.	Reduced biodiversity value, especially on unimproved grasslands. Increased threat to many EU protected habitats and species.	Reduces the size of habitats patches and connectivity between habitat patches, which can lead to species loss, but impacts depend on landscape structure and species concerned.
Water retention	Water run-off is increased substantially. Groundwater recharge is reduced.	Intensification can lead to increased run-off where grassland and permanent crops are converted to arable, or where drainage occurs.	Usually increased water retention, especially where arable systems are abandoned.	Loss of dense grass sward and organic matter etc that absorbs and retain water in the soil.	Loss of habitats (e.g. grasslands and forest corridors) that help absorb and retain water.
Water quality	Pollutants are often associated with sealed areas. Increased run-off also increases erosion of soils increasing nutrient enrichment.	Intensification normally leads to reduced water quality due to nutrient rich run-off (especially on land used for arable crops or pig production), fertiliser applications and spray drift alongside water courses.	Usually increased water retention, especially where arable systems are abandoned. But detrimental impacts possible, e.g. where terraces fall into disrepair.	Loss of vegetation and SOM that can take up nutrients and absorb some pollutants. Also increased pollution from increased run-off.	Loss of hedgerows, shelter belts and forests that act as barriers to erosion of nutrient-rich soils and sprayed fertilisers and pesticides.
Soil organic matter	The normal cycling of organic matter is prevented by sealing, and SOM levels decline.	Intensification reduces SOM where synthetic fertiliser replaces organic manures, and where arable fields are annually deep-ploughed.	Normally increases in SOM, especially where arable farming is abandoned.	Loss of carbon stores in ancient permanent grasslands.	Loss of grassland corridors etc that can help increase and maintain SOM.

1.3.1 Food production

Increased intensification and regional specialisation of agricultural systems has been a notable long-term trend throughout the EU, particularly in relatively productive areas (as a result of drivers as summarised in Section 2.1). This together with technological advances has led to substantial increases in food productivity.

For example, between 1990 and 2000 average cereal yields increased by 16% whilst milk yields per cow increased by 16% (EEA, 2005a)[12]. More recent figures indicate that milk yields per cow have continued to increase in all Member States, linked to long term trends of increasing farm size and regional concentration but with relatively stable volumes of milk production (as a result of the EU milk quota regime). In the EU-15, annual milk yield increases averaged 2.3% between 1996 and 2006 (2.9% in the EU 25 between 2000 and 2006).

In the arable sector, EU-15 cereal yields have been relatively stable in recent years at around 5.6 tons per hectare[13], with significant variations between Member States and regions. This recent stability is an indication of the relatively intensive techniques, associated with modern arable production, which have been developed over the past few decades. In the new Member States yield intensities can be expected to continue observed trends linked to the modernisation and intensification of production methods (relative to the EU-15).

However, at the same time there has also been a tendency towards the withdrawal of management and possible land abandonment in more marginal areas, where traditional agricultural practices and associated biodiversity are more commonplace (Anon, 2005). Average fertiliser per hectare of agricultural land is often used as an indicator of intensification, however, there has been a noticeable decline in fertiliser use in the EU-15 since 1990, linked to more efficient nutrient management, new crop varieties and technological developments. This trend is reversed in the new EU Member States where significant increases in fertiliser use have been observed (EEA, 2007). Another noticeable indicator of agricultural intensification has been the expansion of irrigated land in the southern EU-15 and south eastern Europe (EEA, 2007).

Another relevant issue is the loss of agricultural land due to developments that can cause soil sealing, for example, where agricultural land, is replaced by roads, buildings, urban development etc. Due to the nature of such development, this issue is most likely to be associated with agricultural land in close proximity to urban centres. Where soil sealing occurs, a decrease in water permeability is also likely, which has implications for water resources and flood management, with potentially indirect impacts on food production.

---

[12] Figures quoted based on FADN in *Agriculture and environment in EU-15 – the IRENA indicator report* (EEA, 2005a).

[13] Total cereal yields (excluding rice): 5.58 tons per hectare in 1996 and 5.60 tons per hectare in 2006 based on Eurostat figures quoted in 'Agriculture in the European Union - Statistical and economic information' available at: http://ec.europa.eu/agriculture/agrista/index_en.htm

1.3.2 Biodiversity

Agricultural intensification / marginalisation and the use of permanent grassland

The biodiversity value of agricultural habitats, including grasslands is highly dependent on the extent to which it has been modified as a result of grazing, agricultural improvements (e.g. drainage and reseeding) and intensive use of fertilisers and pesticides. In general, biodiversity value (e.g. the diversity of characteristic species and rare species) declines with increasing agricultural improvement and intensification (Aebischer, 1991; Billeter *et al,* 2007; Donald, 1998; Donald *et al,* 2001).

The widespread intensification of agriculture across Europe has had well documented impacts on biodiversity, including birds since the 1970s, particularly in western Europe (Newton, 2004; O'Connor and Shrubb, 1986; Pain and Pienkowski, 1997; Tucker and Evans, 1997, Wilson *et al*, 2009; Stoate *et al*, 2009). Non-crop plants and invertebrates have declined massively, primarily as a result of the use of fertilisers and pesticides (Aebischer 1991; Donald 1998). As a result, many of the remaining species-rich agricultural habitats are now rare or much reduced. Consequently a high proportion of rare and vulnerable species of EU conservation importance are associated with these threatened semi-natural habitats and agricultural landscapes (Robinson and Sutherland, 2002).

Despite the trends towards intensification in most parts of Europe, some farming systems that are of marginal economic value and are subject to reduced inputs and management and sometimes abandonment. The impacts of such marginalisation and abandonment are complex and diverse, depending very much on context; consequently they can be positive or negative.

In general, the cessation of agricultural management enables natural processes to take over leading to successional habitat changes. These habitat changes vary but typically start with the growth of rank grassland and shrubs, followed by scrub and eventually forest. Land abandonment results in a reduction in grassland and arable habitats (particularly in low intensity marginal farming areas) and an increase in scrub and forest in the landscape. This can be beneficial in terms of increasing habitat connectivity (see below) or habitat diversity in intensively farmed landscapes.

On the other hand, large scale abandonment can lead to declines in habitat heterogeneity and species diversity across the landscape. Furthermore, HNV farming systems are particularly prone to marginalisation and the abandonment and such areas (e.g. upland grasslands) are often key habitats for some species of high biodiversity importance in the EU (including many listed in the EU Habitats and Birds Directives). Thus, although abandonment of some HNV farming areas may increase species richness amongst generalist species in some situations (e.g. by creating new habitats in otherwise open habitats) it may be detrimental in terms of EU biodiversity conservation objectives. But abandonment may provide opportunities for large-scale managed habitat restoration projects that in the long-term may produce high value habitats. These large-scale habitats may be more resilient to climate change and could significantly contribute to climate mitigation through carbon sequestration. These issues are further discussed in Chapter 8.

Fragmentation and the loss of biodiversity corridors

Habitat fragmentation (i.e. the break-up of habitat patches) is one of most significant threats to habitats and species in the EU (Kettunen *et al,* 2007). Fragmentation exacerbates habitat loss (because some patches may be too small for some species), increases the proportion of habitat edge and increases the isolation of remaining habitat patches. Isolation between patches is a function both of the distance between habitat patches and the permeability of the landscape matrix to the movement of species. At the species level, fragmentation impacts include reduced population density, reduced population persistence, reduced reproduction, reduced individual fitness and increased disease incidence (Fahrig, 2003).

Biodiversity corridors are landscape-scale features that aim to mitigate the impacts of habitat fragmentation. Biodiversity corridors aim to restore functional connectivity by providing continuous strips of habitat or suitably placed patches of habitat that are sufficiently close to allow movements between otherwise isolated habitats. Such corridors often form part of a broader ecological network, typically consisting of core areas (large areas of good quality habitat e.g. protected areas), buffer zones around core areas and corridors (Bennett and Mulongoy, 2006; Jongman and Pungetti, 2004).

However, despite the development of many plans for national, regional and local ecological networks there appear to be few cases where they have been adequately implemented. There is also debate over the value of some existing habitat corridors. For example, many narrow habitat corridors and linear features, such as hedgerows, may provide valuable habitat but probably have limited value in terms of increasing connectivity to mitigate habitat fragmentation and aid climate change adaptation (Davies and Pullin, 2007; Dawson, 1994; Donald, 2005; Donald and Evans, 2006; Hobbs, 1992; ITE, 1994; Spellerberg and Gaywood, 1993). There is also concern over the potential risks of increasing connectivity through the creation of new corridors, for example through facilitating the spread of alien invasive species (Crooks and Sanjayan, 2006).

Progress with the creation of new corridors, through for example habitat restoration and creation appears to have been particularly limited (see Chapter 6). This appears to be often due to the large scale of proposed networks and the consequent need for very high levels of public investment in land purchase and/or management agreements with landowners or large areas of interconnected land. These problems seem to be further exacerbated where proposals for ecological networks have been developed without sufficient empirical evidence to determine the circumstances under which they reduce fragmentation (Van Der Windt and Swart, 2008).

1.3.3 Water retention and quality

Water retention, water quality and land use and land cover change

Among the major processes influencing water quantity and quality at the river basin scale are changes in land use intensity and land cover. Land use changes affect evapotranspiration, infiltration rates, and runoff quantity and timing.

The general impact on local water budgets of changes in land cover are well documented in the hydrological and ecological literature and can be summarised as:

- Change from natural forest to managed forest slightly decreases the available freshwater flow and causes lower long-term groundwater recharge in most temperate and warm humid climates, but is highly dependent on dominant tree species.

- Change from forest to pasture or cropland leads to strong increases in the amount of superficial runoff with associated increases in sediment and nutrient flux, and reduced long-term groundwater recharge. Impacts will depend on the percentage of catchment area covered and the consequences are less severe if conversion is to pasture instead of crops. It is most critical for areas that are prone to high precipitation over short time-periods.
- Change from forest to urban causes strong increases in runoff with the associated increases in pollution loads, strong decreases in groundwater recharge, with impacts dependent on percent of catchment area converted. The effects are stronger when the lower reaches of a catchment is transformed.
- Replacement of tree species with those with higher evapotranspiration rates leads to strong decreases in runoff and groundwater recharge. This is highly dependent on the characteristics of dominant tree species.

There has also been acceleration in the loading of pollutants, including nutrients in the second part of the 20th century onto the land mass associated with industrial agriculture, urbanization and grazing. These inputs are translated into greatly elevated fluxes to and transport through inland water systems, the effects of which pass in many cases fully to the coastal zone.

Intensive agricultural and urbanised areas have expanded rapidly in the last 50 years together with increasing demands for water (Box 1.1). The current extent of cultivated systems provides an indication of the location of freshwater ecosystems that are likely to experience water quality degradation from pesticide and nutrient runoff as well as increased sediment loading.

Box 1.1. The impacts of urbanisation on water demand in Europe

The geographic location of many of the large and growing cities, such as close to coastal areas, and their rapid pace of growth has encouraged the over-tapping of water resources that are not necessarily renewable, such as coastal aquifers. In Europe, for instance, nearly 60% of the cities with more than 100,000 people are located in areas where there is groundwater over-abstraction (EEA 1995d). High levels of water-extraction in many cases are accompanied by water quality degradation and land subsidence. Groundwater over-extraction in such areas can reverse the natural flow of groundwater into the ocean, causing saltwater to intrude into inland aquifers.

Industrial processes, which include withdrawals for manufacturing and thermoelectric cooling, today use about 20% of the total freshwater withdrawals, which has more than doubled between 1960 and 2000. Even though this global use remains small in comparison to water used for agriculture, the current trend in shifting the manufacturing base from industrial to developing countries, due to globalization and international trade, is of concern for future water security.

One significant challenge to both scientific understanding and sound management of water resources is that multiple processes control water quantity, quality, and flow regimes. The pattern and extent of cities, roads, agricultural land, and natural areas within a watershed influences infiltration properties, evapotranspiration rates, and runoff patterns, which in turn affect water quantity and quality. Thus, there remains substantial uncertainty about the effects of management on different components of the hydrological cycle arising from the unique combinations of climatic, social, and ecological characteristics of Europe's watersheds.

Despite this uncertainty it is likely that many impacts of land use change on water resources will be exacerbated by climate change. The changing climate will modify all elements of the water cycle, including precipitation, evapotranspiration, soil moisture, groundwater recharge, and runoff. It can also change both the timing and intensity of precipitation, snowmelt and runoff.

Two issues are critical for water supply: changes in the average runoff supply and changes in the frequency and severity of extreme events, including both flooding and drought. The effect of increased precipitation extremes on floods is still debated because flood response is influenced by many interacting factors, such as basin geology, terrain, and land cover as well as basin size and rainfall patterns. Also, the natural variability of flood flows can mask small changes in precipitation inputs. Although there is considerable variation in the projections for the effects of climate change on precipitation (see Box 2.1 for further discussion), there is broad agreement that overall rainfall will decrease in much of southern Europe and increase in parts of northern Europe, and the frequency of extreme weather events will increase (Christensen and Christensen, 2007; IPCC, 2007).

1.3.4 Soil organic matter

The level of soil organic matter (SOM) in a particular soil is determined by many factors including climatic factors (e.g. temperature and moisture regime) and soil-related factors, e.g. soil parent material, clay content, cation exchange capacity (Dawson and Smith, 2007). Organic matter inputs to the soil are largely determined by the land use, with forest systems tending to have the largest input of carbon to the soil. Grasslands also tend to have large inputs, though the material is often less recalcitrant than forest litter. The smallest input of organic matter is often found in croplands which have inputs only when there is a crop growing and where the carbon inputs are among the most labile. When soils are no longer covered by living vegetation, but rather 'sealed' by asphalt or concrete, the input is reduced to zero.

The small inputs of organic matter to the soil in croplands can be further exacerbated by crop residue removal, and by tillage which increases SOM loss by breaking open aggregates to expose protected organic carbon to weathering and microbial breakdown (Six *et al*, 1998). Consequently, it has been observed that ploughing grassland for conversion to arable land and for grassland renovation is responsible for considerable N_2O and CO_2 emissions in the Netherlands (Vellinga *et al*, 2004). In fact croplands are considered to be the largest biospheric source of carbon lost to the atmosphere in the EU, with estimated losses of 78 (S.D. 37) Mt C per year (Smith, 2004).

Conversely converting arable cropland to permanent grassland typically results in an increase in soil carbon because of lower soil disturbance and reduced carbon removal in harvested products. The soil carbon sequestration potential for the conversion of cropland to grassland in Europe is estimated at 1.2-1.7 t C ha-1 year-1 (Smith, 2004). Carbon losses can also be reduced by changes in farming practices (which increase organic matter inputs to the soil and/or reduce soil disturbance), including organic farming (Hillier *et al*, 2009). Similarly extensification and abandonment can reverse the impacts of intensification on soil carbon stores. There is therefore significant potential within Europe to decrease the flux of carbon to the atmosphere from cropland, and for cropland management to sequester soil carbon, relative to the amount of carbon stored in cropland soils at present. As further discussed in Section 8.2, this could have the potential to make significant contributions to reducing overall green house gas emissions.

1.4 OUR OVERALL APPROACH TO THE STUDY

On the basis of the above considerations and the study specification a logical structure was established for the study based on the well known Driver-Pressure-State-Impact-Response (DPSIR) framework. The key tasks within the study are set out according to their position in the DPSIR framework and the land use interrelationships in Figure 1.2.

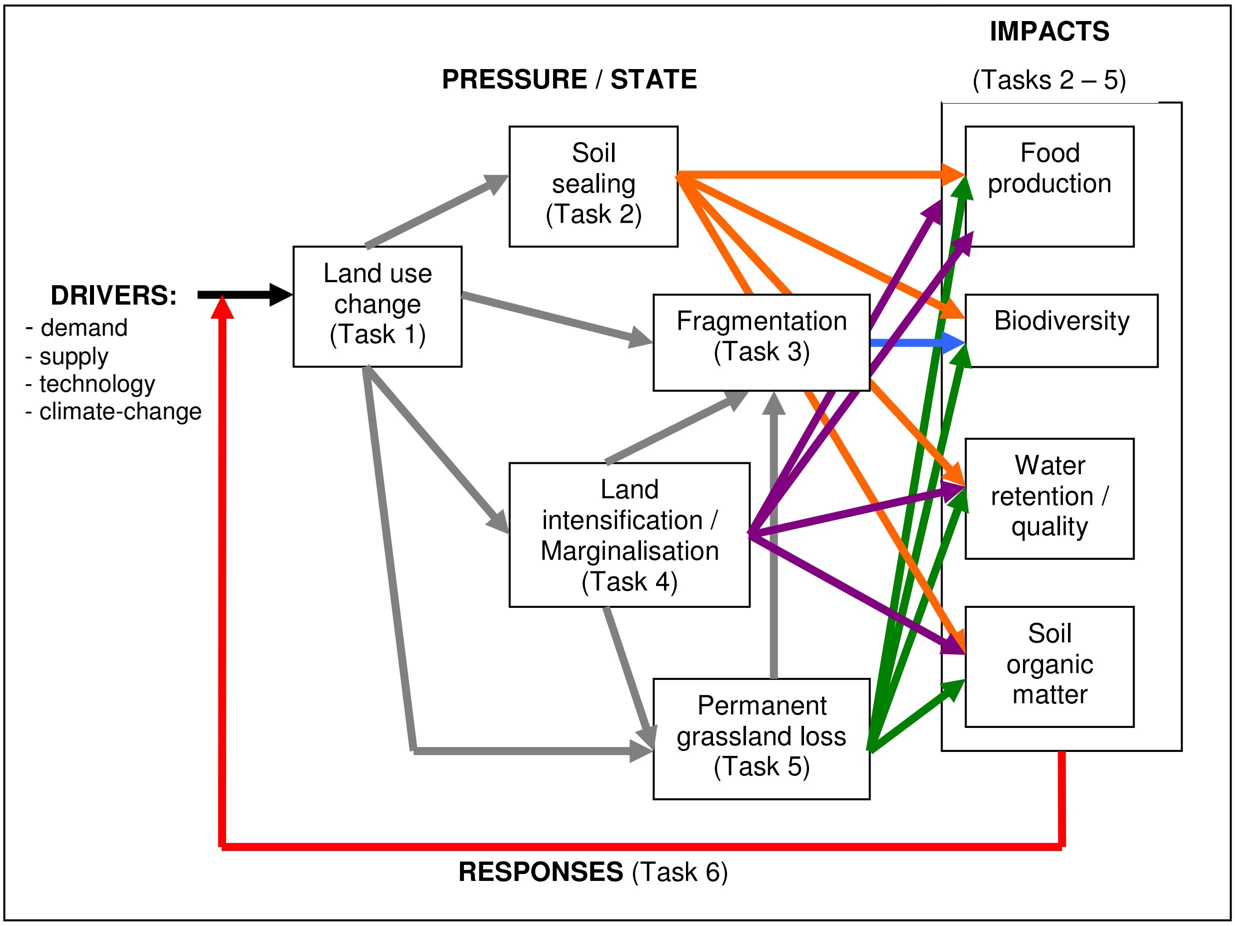


Figure 1.2. Study framework, showing the key interrelationships between tasks

The four land services of that are the focus of this study are (1) food production, (2) biodiversity, (3) water retention and water quality and (4) soil organic matter (in particular carbon stores). The provision of these land services are impacted upon by changes in the state of the environment, including soil sealing, fragmentation of habitats, intensification of agriculture/marginalisation and the loss of permanent grassland (which form the focus of Tasks 2 – 5)[14]. These changes in state are caused by land use change pressures that are in turn the result of exogenous drivers (or indirect pressures in the terminology of the MEA). However, it is important to note that some changes in state exert new indirect pressures on

[14] As discussed in Section 1.3, for clarity, permanent grassland is recast as a pressure by focusing on the loss of permanent grassland, which may arise from the intensification and marginalisation of agricultural land use. Similarly, the subject of biodiversity corridors is recast as habitat fragmentation resulting from the loss of existing corridors and other features that enhance ecological connectivity.

components of the environment (such as the loss of permanent grassland, which contributes to habitat fragmentation).

Our initial focus in this study is therefore a quantitative assessment of the dynamic interplay amongst these elements of the framework, as observed over the past 25 years and according to modelled projections for the next 25 years. All of these factors have a critical influence on the four land services and are incorporated into the modelling approaches that underpin much of this study (as described further in Chapters 3, 4 and 5).

The close interrelationships between the land use related pressures and the subsequent provision of land services forms the focus of the synthesis stage of the analysis (Task 6). Finally the study identifies existing and new policy measures that may be used to respond to changes in the provision of land services, by influencing drivers of change and / or particular pressures.

1.5 TASK CONSOLIDATION AND THE STRUCTURE OF THIS REPORT

The analytical tasks undertaken in this study have been carried out according to our interpretation of the overall aims and rationale for the project (as described above) and the interrelationships between the tasks outlined in the specification (as summarised in Figure 1.2). As a result some of the tasks have been combined where they are closely interrelated (agricultural intensification and loss of permanent grassland) or divided where they are particularly large and complex (e.g. analysis of fragmentation impacts and effectiveness of existing corridor measures). The tasks are therefore now described in the following chapters.

Chapter 2: Overview of drivers affecting land use change.

Chapter 3: Analysis of land cover trends and projections of land use trends for the next 25 years (on the basis of the study's baseline reference scenario) (Specification Task 1).

Chapter 4: Analysis of the effects of projections of land use change on soil sealing and its likely impacts on the provision of land services, and an assessment of policy instruments related to soil sealing (Specification Task 2).

Chapter 5: Analysis of the effects of projections of land use change on habitat fragmentation (and habitat corridors as mitigation) and its subsequent impact on the provision of land services (Specification Task 3).

Chapter 6: Assessment of policy instruments that may stop or reverse habitat fragmentation, and an assessment of the implementation of ecological networks (Specification Task 3).

Chapter 7: Assessment of drivers of land intensification (and marginalisation) and the loss of permanent grassland and policies that may affect these processes (Specification Tasks 4 and 5).

Chapter 8: Analysis of the effects of projections of land use change on land intensification (and marginalisation) and the extent of permanent grassland, and impacts on land services (Specification Task 4 and 5).

Chapter 9: Synthesis of the combined impacts of drivers and pressures on the four land services (Specification Task 6).

Chapter 10: Assessment of existing policy instruments and a blueprint of measures to protect and enhance land services (Specification Task 6).

The specific tasks carried out in this study are described at the beginning of each chapter. Further details of the analyses are also provided in the accompanying Technical Annex.

2 OVERVIEW OF DRIVERS AFFECTING LAND SERVICES

Graham Tucker, Andrew McConville and Clunie Keenleyside (IEEP)

The key drivers of agricultural land use change are of particular importance to this study and are therefore described in detail in Chapter 7. However, in order to set the context for the modelled projections of land use change (carried out in Task 1 and described in Chapter 3) a brief overview of the key drivers of general land use change is provided below.

2.1 THE MAIN DRIVERS OF LAND USE CHANGES OVER THE LAST 25 YEARS

Although the situation has varied between regions of the EU, the principal drivers of land use change over the last 25 years (and especially as the EU-15) have included:

- Market and direct support for farmers, driving agricultural intensification, specialisation, concentration of production and a decline in mixed farming systems.
- EU set-aside policy linked to arable CAP payments (suspended in 2008).
- Uncompetitiveness and shortage of successors in marginal farming systems leading to agricultural abandonment in marginal areas.
- Growing environmental awareness and concern over the environmental degradation arising from an intensification in agricultural production, leading to the introduction of agri-environment measures in 1985, followed by the successive integration of environmental objectives in the CAP.
- Rises in agricultural commodity and input prices (particularly since CAP decoupling) with direct implications for the production of arable crops including biofuels).
- Afforestation on agricultural land driven by public subsidies (national and EU), whilst natural regeneration is linked to land abandonment. Conversion of forestry to agricultural land, though deforestation is an issue in some New Member States (NMS).
- Demographic changes (with population growth and immigration) and economic development, leading to direct increases in demand for food products, demand for space for housing, work facilities and transportation, and recreation.
- EU enlargement and globalisation of the economy, leading to direct demand for land for agricultural and forestry products for export markets, but also increased competition from outside the EU (e.g. reducing timber prices).
- Social changes, and migration from certain areas, alongside counter-urbanisation in others, leading to a change in the social fabric of rural areas and patterns of land use.

In addition to these, other drivers are likely to be important at regional levels and local levels. These include trends in migration, national land use policies and regulations concerning the expansion of urban areas into agricultural areas and pressures on land use related to recreation and tourism.

All the drivers and resulting land use changes over the past 25 years have led to the current distribution of land use across Europe, maps of which will form the starting point for this study's projections of land use change, based on the business as usual scenario. The next section introduces the expected changes in the main drivers of land use change over the next 25 years.

2.2 THE EXPECTED PRINCIPLE DRIVERS OF LAND USE CHANGE AND LAND SERVICES OVER THE NEXT 25 YEARS?

2.2.1 Socio-economic drivers

The key drivers of land use change in the EU over the next 25 years to 2030 are likely to primarily be the following socio-economic drivers:

- Full decoupling of direct payments for farmers, transfer of funding from Pillar 1 to Pillar 2, and the reorientation of CAP support towards the provision of environmental public goods and ecosystem services.
- Changes in the supply and prices of agricultural commodities.
- EU Energy policy and a new post Kyoto climate policy, stimulating action on the sequestration and carbon in soils and biomass, forestry measures, adaptation and mitigation.
- An increase in the global demand for bioenergy feedstocks.
- An expanding global population, leading to an increase in the demand for food, and the demand for housing and built infrastructure.
- Concerns over food security and the availability of food, leading to some increases in production and yields, facilitated by technological advances and high commodity prices.
- Changing consumption patterns, including an increase in the share of meat and dairy products in the diets both in Europe and in developing nations such as India and China.
- International commitments on biodiversity and the implementation of the MEA Framework.
- Implementation of the Water Framework Directive and the introduction of a Soil Thematic Strategy Forestry.
- Possibly some increase in the area under natural regeneration of woodland in marginal areas, arising from agricultural land abandonment.

These factors may therefore lead to significant changes in the balance of land uses, especially between agriculture, forestry and the built environment (Figure 2.1). With recent increases in agricultural commodity prices, it seems likely that agricultural drivers will have particularly important impacts on future land use. These were recently reviewed by IEEP as part of the ongoing Unfarmed Features project for DG Environment (Farmer *et al*, 2008), which concluded that in the absence of policy intervention, it is likely that agricultural drivers will lead to either an intensification in production on the more competitive farms, or could further undermine the economic viability of more marginal farms across the EU. Both have the potential to have an adverse impact on permanent grasslands, existing biodiversity corridors and other landscape features of biodiversity importance, increasing the pressure to remove landscape features or leading to a cessation in their management, respectively.

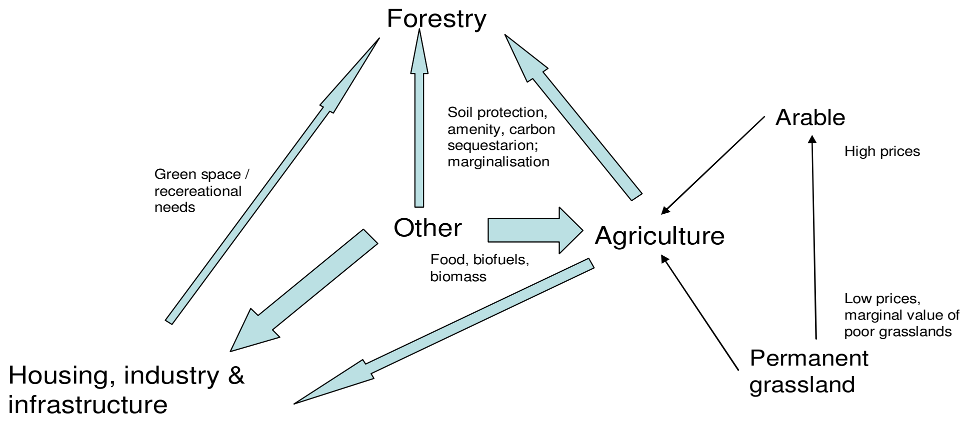


Figure 2.1 Indicative strengths and directions of land use drivers in the EU

2.2.2 Climate change drivers

All of the key socio-economic drivers described above will also be increasingly influenced by climate change, initially as a result of the indirect effects of mitigation and adaptation measures (e.g. biofuels). Direct impacts from higher temperatures, rainfall changes and more frequent extreme weather events, as well as many of the changes in natural vegetation will become more significant later this century (see Box 2.1). The impacts of climate change on agriculture and potential adaptation measures will be of particular significance, and will have knock-on impacts on other land services. These are therefore described further below.

The potential impacts of climate change on agriculture

The changes in weather patterns due to climate change on a European scale are difficult to predict; in a recent study (Ciscar *et al*, 2009) two global models made significantly different predictions about the likely changes in temperature and precipitation (see Box 2.1). Despite this, some generic assertions can be made. In all cases, northern, central and, in particular, southern regions can expect high increases in temperature (between 2°C and 8°C). Central and southern Europe experience substantial annual decreases in precipitation (from 10 to 40%) while other regions, particularly northern Europe, will experience annuals gains (from 10 to 40%), with high seasonal variation. The Atlantic regions experience the smallest increases in temperature but will lose agricultural land to sea-level rise.

All agricultural systems across Europe are likely to be affected to some extent by the projected changes in the coming decades. Climate-related increases in crop yields are expected in the short term due to longer growing seasons and the impact of rising concentrations of CO_2 (Alcamo *et al,* 2007); overall by 2020 gains in yield of 17% are possible (Ciscar *et al*, 2009) particularly of C3 crops such as wheat, potato and rice. However, there will be a likely shift of crops to the north with decreases in yield the south due to higher summer temperatures and drought (Alcamo *et al*, 2007). Technology such as new crop varieties and cropping practices might outweigh negative effects; yield increases of wheat by 2050 could increase from 37% to 101% (Ewert *et al*, 2005; cited in Alcamo *et al*, 2007). However, there is uncertainty to the extent to which these gains will be affected by the increase in extreme weather events, with expected increased yield variability (Jones *et al*, 2003; cited in Alcamo *et al*, 2007) and reduced average yield (Trnka *et al*, 2004; cited in Alcamo *et al*, 2007). Agricultural systems based on traditional farming and quality foods which depend on favourable climatic conditions are most at risk (Parry, 2000; cited in EEA, 2005d).

There are many other impacts on agriculture. The wetter winters and drier summers will put an additional strain on water resources, notably in southern regions, leading to conflicting demands between agriculture and other users. Furthermore, drought conditions alter the structure of agricultural soils, rendering the soil 'strong' and impenetrable to roots, further exacerbating the impacts of drought (Whalley *et al*, 2006; cited in Cooper and Arblaster, 2007). In northern regions, soil structure may be adversely altered by the thawing of the permafrost (EC, 2007). Adverse impacts can also be expected from the likely rise in the spatial distribution and intensity of pests and weeds (EC, 2007). As the efficacy and duration of pesticide control is also affected by environmental conditions, there may be an increase in the use of pesticide use with negative environmental effects.

Livestock will be impacted in a number of ways; both directly (e.g. by the increases in temperature) and indirectly (e.g. through the variability in the price of feedstock). Longer warm seasons may reduce the need for winter housing of animals, although wetter winters may increase the risk of soil poaching. An increase in severe heat stress could enhance the mortality of intensively-reared pigs and chickens (Turnpenny *et al*, 2001; cited in Alcamo *et al*, 2007) and require additional ventilation mechanisms in animal housing. Increased frequency of droughts along the Atlantic coast may reduce forage crop productivity such that they are no longer sufficient at current stocking densities without irrigation (Holden and Bereton, 2002; cited in Alcamo *et al*, 2007). Increasing temperatures may also increase the risk of livestock diseases by supporting the dispersal of insect vectors of diseases (such as bluetongue) and enhancing the survival of viruses from one year to the next (Alcamo *et al*, 2007).

Agriculture will be affected both directly from the effects of climate change and indirectly through attempts to mitigate greenhouse gas emissions and to provide adaptation services. The indirect effects include the increased shift towards the production of bio-energy crops (to meet the EU's bio-energy targets set out in the 2009 Renewable Energy Sources Directive), reduced tillage in farming practices, improvement of flood management capacity, and restoration of multifunctional landscapes such as high nature value grassland that provide habitat and assist migration for numerous species. The impact of these measures on agriculture and its related biodiversity could be mixed. For example, efforts to meet the bio-energy targets may lead to some further intensification of agricultural land in western Europe, but in eastern Europe it could cause further conversion of natural lands into production areas.

Box 2.1. Climate change projections for Europe

A recent study for the European Commission (Ciscar *et al*, 2009) used two global models with embedded regional models (HadAm3h with HIRAM; ECHAM4 with RCAO) to analyse the impacts of climate change on Europe under the SRES scenarios A2 and B2 by 2080, and delivered quite different results. Under A2 and B2 scenarios respectively, temperature rise for Europe is predicted to be 3.9°C and 2.5°C under the HadAm3h model suite and as much as 5.4°C and 4.1°C under the ECHAM4 model suite. On a regional basis, HadAm3h is more optimistic about temperature changes, with maximum increases in southern and northern Europe of between 4°C to 5°C, while ECHAM4 sees large parts of southern and central Europe increasing to between 7°C and 8°C (both under A2 scenario). With regards to the British Isles, HadAm3h predicts a reduction in overall rainfall (of 5% to 10%) while ECHAM4 predicts on overall increase in rainfall, particularly in the northern parts (of 5% to 40%).

Despite these differences, there are certain patterns in common between the model suites. Very large temperature increases are expected for both the southern and northern countries with relatively lower temperature increases in the British Isles. Significant reductions in precipitation are expected in southern and central Europe (from 10% to 40%) and as much as 60% in Cyprus, with extended droughts and water shortages expected in areas already experiencing water scarcity. Northern Europe will see substantial increases in precipitation (from 10% to 40%) with as much as 80% in parts of Norway which are likely to be very seasonal causing wetter winters and drier summers.

Understanding the differences between these predictions, how regions will be affected and what seasonal changes are expected is vital to planning adaptation strategies. For instance, the study suggests that the lower warming scenarios under the HadAm3h would lead to small changes in yields for the EU, while the 5.4°C scenario could mean a fall in crop yields of 10% (Ciscar *et al*, 2009). Agriculture is also likely to be highly sensitive to extreme climatic events such as hot spells, heavy storms, intense rainfall or droughts (Parry, 2000; cited in EEA, 2005d). Overall, it is likely that intensive farming systems in western Europe have a lower sensitivity to climate change and are generally well resourced to cope with changes. It is farmers in southern and, to a certain extent, eastern countries that may be among the most vulnerable (EEA, 2005d).

2.2.3 Adaptation measures

The most important adaptation measures for agriculture and related land management needs are described in Box 2.2 and can be summarised as:

- Water conservation and protection;
- Altering planting dates and cultivars;
- Changes in land use;
- Alterations to livestock management;
- Improved pest control; and
- Ecosystem and biodiversity protection (ecosystem–based adaptation).

There is the potential for many of these measures, especially ecosystem-based measures, to provide wider benefits for land services. Ecosystem-based adaptation identifies and implements a range of strategies for the management, conservation and restoration of ecosystems to provide services that enable people to adapt to the impact of climate change. It aims to increase the resilience of ecosystems and people in the face of climate change (AHEWG, 2009; CBD AHTEG, 2009). On the other hand, the implementation of some adaptation measures to climate change could cause significant adverse effects if not coordinated and developed carefully. For instance, increased irrigation in southern countries has already been shown to affect biodiversity adversely through the deterioration of habitat such as the reduction of the water table and river flows, drainage of wetlands and the salinisation and contamination of groundwater (Baldock *et al*, 2000). The increase risk of damage from pests and diseases could lead to an uncoordinated increase in pesticide use. Substantial land use changes will have implications for the natural environment as they would disrupt relationships between farmland species, their habitats and land management practices over long periods of time (Bignal and McCracken, 1996; cited in Cooper and Arblaster, 2007). This has been demonstrated for British BAP species, a majority of which are likely to experience changes in their range or suitability of their habitats by 2020, 2050 and 2080 (Walmsely *et al*, 2007). This will require the development and maintenance of an interlinked network of habitats to ensure species survival (Opdam and Wascher, 2004; Chambers and Ball, 2007; cited in Cooper and Arblaster, 2007).

While farmers are already making adjustments to changes in climate, such as altering the times of sowing, conditions are likely to reach a point after which small scale changes will no longer be sufficient. Some of the ad-hoc responses are likely to have adverse environmental impacts such as increased water use and application of fertiliser and pesticides. This suggests that a co-ordinated response at national and EU level may be required. Capital investment may be needed to make changes from one land use type to another or to adjust existing infrastructure such as animal housing or irrigation systems. Support under the CAP may be needed to address the increased costs of farming, such as the cost of diversifying crop rotations to reduce farm vulnerability. Also, the use of Pillar II spending through modulation can encourage the use of small-scale water conservation measures such as water collection from farm buildings and the construction of on farm water reservoirs.

There will certainly be a role for the European Commission to co-ordinate adaptation strategies and to oversee consultation of stakeholders at all levels. While certain issues will be adequately dealt with at a national level, there are many issues which will require pan-European co-operation. This response will have to include excellent communication to the farming community and other land use stakeholders of the likely impacts of climate change and associated risks and opportunities.

Box 2.2. Potential measures to facilitate adaptation of agricultural systems to climate change

Water conservation and protection

Expanding the area under irrigation and increases in the intensity of water use is a likely response to changes in precipitation and drier summers, in particular in southern Europe. However, this will likely have adverse effects such as the deterioration of habitat by the reduction of the water table and river flows, drainage of wetlands and the salinisation and contamination of groundwater (Baldock *et al*, 2000). In addition, higher use of agricultural inputs in order to increase returns can increase pollution incidents and contamination of water courses. The EC Green Paper on Adaptation emphasises that the role agriculture should play through efficient use of water in dry regions and protection of water courses against excessive nutrient flow.

Methods of adapting to low water availability will become increasingly important. Existing irrigation systems can be made more efficient by reducing leaks and improved timing and volume of water distribution to make irrigation more precise. Conservation tilling, the practice of leaving some of the previous year's crop residues on the soil surface, may protect soil from erosion and maintain moisture and infiltration, but as it requires heavy machinery, is unlikely to be suitable in large parts of Europe where fields are sloping (Cooper and Arblaster, 2007). Protection of upland bogs, forests and floodplains could be a key strategy to protect catchments and ensure water retention. The construction of small-scale water conservation measures such as water collection from farm buildings and the construction of on farm water reservoirs to store increased winter rainfall for drier summers is likely to become important, and has recently been recommended by the National Farmers Union in the UK (West and Gawith, 2005a, b; cited in EEA, 2005d).

Altering planting dates and cultivars

Changes to the seasonal timing of life cycle events due to changes in mean weather conditions are already observable in Europe, although attributing these to climate change directly is not yet possible. Sowing dates for maize have advanced 10 days in Germany and up to 20 days in France (EC, 2007), which suggests that farmers are already adapting to new climate conditions. There are some opportunities to be exploited. Increased temperatures will mean longer growing seasons which will allow crops to be sown earlier. In southern states, this could mean crops reaching maturity earlier in the season and avoiding the extreme hot temperatures of mid-summer. Elsewhere, it could increase the output of long season cultivars. This could be enhanced by using strains of crops from different regions more suitable to the new conditions. Biotechnology offers the opportunity to develop crops that are more resistant to more difficult growing conditions and to diseases and pests.

Changes in land use

A comprehensive response to climate change will ultimately result in more substantial changes to the type of agriculture and where it is practiced. Crops will have to be selected that are best adapted to the new growing conditions, such as those less dependent on irrigation or deep-rooted crops such as Lucerne that survive better in hot and dry conditions. In central Europe, optimal land use may see the reduction of crops less suited to increased temperatures and lower water availability such as spring wheat, barley, potato and increasing the area of winter wheat, maize and vegetables (Olesen and Bindi, 2002; cited in Cooper and Arblaster, 2007). In the long-term, certain water-intensive crop growing activities may have to cease in vulnerable areas; the rice sectors in Spain, Portugal and Greece are thought to be particularly at risk (Agra Europe, 2007; cited in Cooper and Arblaster, 2007).

Diversifying the crop rotations and maintaining a combination of crop types can be an effective way of limiting farm vulnerability to climate change. However, this remains costly as it is more labour intensive and can affect farm profitability.

Alterations to livestock management

Changes to temperature may reduce the need for winter housing of animals although this could be affected by the increased risk of soil erosion and poaching due to increased rainfall in northern countries. For animals that remain indoors ventilation systems may have to be improved or temperatures reduced through the use of sprinkler systems. In areas of much hotter climates, additional shade could be provided for livestock through the restoration of hedges and planting of trees, which would also be beneficial for biodiversity. There may need to be more wholesale changes to the type of stock to allow for breeds that are more resistant to new climates. It is important to note that the increased risk of disease may result in the rise of chemical and medicinal use, with potential adverse environmental impacts.

Improved pest control

Changes in temperatures are likely to increase the ability of pests to spread and persist over the winter, resulting in a corresponding increase in pesticide use. Pest and disease control can be improved through better monitoring of pest movements, diversified crop rotations or integrated pest control methods (AEA, 2007).

Ecosystem –based adaptation

According to the EC Green Paper on Adaptation, agriculture will become increasingly important in the provision of ecosystem services including the management of multifunctional landscapes. However, the protection of these services will also be an important part of any agricultural adaptation programme. For example, in upland areas the restoration of peatlands or the regeneration of tree cover could help water retention and help even the distribution of water between the seasons. Hedges and trees also reduce surface water run-off and act as wind breaks and provide shade cover in warmer climates. In addition, the genetic diversity present in the wild could be an essential component to developing climate resistant crop and livestock varieties. In some cases biodiversity can help with pest control, such as the population control of insects carrying bluetongue disease by bats in Ireland (Catherine Connolly, pers. comm.). Improved soil management options, such as reducing tillage and disturbance could provide benefits of reducing moisture loss and reduce their vulnerability to drought, flooding and water-logging, which would also have benefits for wildlife and soil quality.

3 ANALYSIS OF LAND COVER TRENDS AND PROJECTIONS OF LAND USE FOR THE NEXT 25 YEARS

Marta Pérez-Soba, Gerard Hazeu, Peter Verburg, Michiel van Eupen, Matthijs Danes and Laure Roupioz (Alterra)

3.1 INTRODUCTION

Specification description
The contractor shall collect and analyse relevant data concerning land cover and, to the extent possible, land use and land use changes in the past 25 years on the basis of European and national statistics, research projects, CORINE Land Cover data, etc. In particular, the contractor shall also gather relevant information concerning current and prospective trends in spatial distribution, such as habitat fragmentation and existing or planned biodiversity corridors at various scales across EU, on farmland intensification/marginalisation (including land abandonment) and on permanent grasslands to show the evolution of the amount and status of permanent grasslands across the EU.

On the basis of past trends, the contractor shall provide a reasonable estimate of how land cover and, to the extent possible, land use will evolve in the next 25 years in the EU, assuming a "business as usual" scenario, but taking into account existing data which indicate how the key trends in climate change are likely to impact on different parts of the EU.

On the basis of this and our interpretation of the overall goals of this study, this task was divided into the following sub-tasks:

- Task 1.1 Collection and review of land cover/land use change data in the past 25 years
- Task 1.2 Identification of main trends and patterns in land cover/land use change
- Task 1.3 Estimate the future trends in land cover/land use following a 'business as usual scenario' considering climate change

The methods, results and conclusions from each of these sub-tasks are described below, with further detailed data provided in the Technical Appendices to this report and as separate Excel files.

3.2 COLLECTION AND REVIEW OF LAND COVER/LAND USE CHANGE DATA IN THE PAST 25 YEARS

3.2.1 Review of existing data sources and selection of appropriate sources for the land cover/land use change assessment in the last 25 years

In the review of state-of-the-art information on land cover/land use changes in the last 25 years the following datasets were taken into consideration:

- Corine Land Cover (CLC) 1990 and 2000[15];
- BIOPRESS (Gerard, *et al*, 2006 and Thomson *et al*, 2007);
- Pan-European Land Cover database (PLCM)(Hazeu *et al*, 2008a,b), including PELCOM and GLC2000
- Historical land cover dataset for 1960 (HISLU60)(Kramer and Mucher, 2006);
- High resolution soil sealing layers produced by a consortium of European service providers under contract with EEA[16];
- Land and Ecosystem Accounts (LEAC)[17] for Europe 1990-2000
- Farm Structure Survey (Eurostat)
- Permanent grassland database (DG Agri)
- High Nature Value (JRC/IES)

In the following sections, these selected datasets are described in detail, including an estimation of their accuracy regarding the objectives of the spatial analysis of land cover/use changes in this project. The information presented is mostly based on the projects FP6 Echochange, FP6 NitroEurope, and FP5 Biopress.

The farm structure, permanent grassland and High Nature Value (HNV) datasets were reviewed as well in order to check if they could contribute to a better "snapshot picture" of a given land use in the past, to improve the information derived from the CLC data sets.

CORINE Land Cover 1990 and 2000

Description

The CORINE (CO-oRdination of INformation on the Environment) programme was initiated by the EU in 1985. A number of databases were created within this framework with the aim to give information on the status and changes of the environment. One of these databases is the CORINE Land Cover database 1990 (*CLC1990*). The IandCLC2000 project resulted in an update of the CLC1990 database, the so-called *CLC2000* database. Besides the CLC2000 database, the project delivered also a revised version of the CORINE Land Cover database 1990 (*CLC1990rev*) and a change database (*CLC-change 90-00*) containing all land cover changes larger than 5ha between 1990 and 2000.

---

[15] CLC 2006 will only be available for some of the EU27 countries at the end of 2009 (based on ETC LUSI Pers. Communication)

[16] http://etc-lusi.eionet.europa.eu/CLC2006/FTSP/built-up_areas

[17] Land Accounts for Europe 1990-2000. Towards integrated land and ecosystem accounting. EEA report 11/2006, ISSN 1725-9177.

The CLC2000 database has an extended geographical coverage (36 countries) compared to CLC1990 (26 countries) (Figure 3.1 bottom and top respectively). For that reason the change database has also a limited geographical coverage[18].

The land cover information is derived from high resolution satellite data (Landsat-TM/ETM) by computer assisted visual interpretation in combination with ancillary data. The final CLC database consists of a geographical database describing land cover/use in 44 classes grouped into a three level hierarchical structure. The CORINE land cover nomenclature has 5 major categories at the first level, 15 land cover categories at the second level and 44 categories at the third level (see Table 3.1). The land cover classes are extensively described in Bossard *et al* (2000). Other technical specifications are a minimum mapping unit of 25ha and a minimum width of 100m for line elements. The scale of the land cover database is 1:100.000 (Heymann *et al*, 1994). See also Büttner *et al* (2004) and Feranec *et al* (2007a,b) for more details on the computer aided visual interpretation, geometrical and thematic correction/revision of CLC1990, and the change detection methods.

Accuracy
An assessment of the thematic accuracy of CLC2000 by using LUCAS (land use/cover area frame statistical survey) revealed that the accuracy requirement of 85% was fulfilled. At individual class levels there were differences ranging from > 95% (rivers, lakes, industrial and commercial units and discontinuous urban fabric) to < 70% (sparse vegetation) (Büttner and Maucha, 2006).

Currently, the CLC2006 programme is running with the focus on land cover changes between 2000 and 2006. The methodology is comparable with the CLC2000 update; computer aided visual interpretation of changes larger than 5ha (Büttner *et al*, 2007). The integration of land cover changes with CLC2000 will result in CLC2006. The CLC2006 will extend the spatial and temporal coverage for land cover/use change analysis, but is not yet available. The CLC-change 00-06 database and CLC2006 is expected to be ready at the end of 2009, but not in time for inclusion in this study.

Appropriateness for this project
The CLC1990 and CLC2000 datasets are selected to be used in this project because they are the most complete, detailed and consistent datasets regarding land cover for EU27. The CLC1990 and CLC2000 databases have a different extent so the land cover/use changes are only known for a limited number of countries (28 countries of which 23 belong to the EU27[19]).

[18] Although CLC90 is not available for the United Kingdom and Serbia and Montenegro these countries are included in the land cover accounting (LEAC).

[19] Cyprus, Finland, Malta and Sweden are the missing countries regarding a CLC change analysis for EU27.

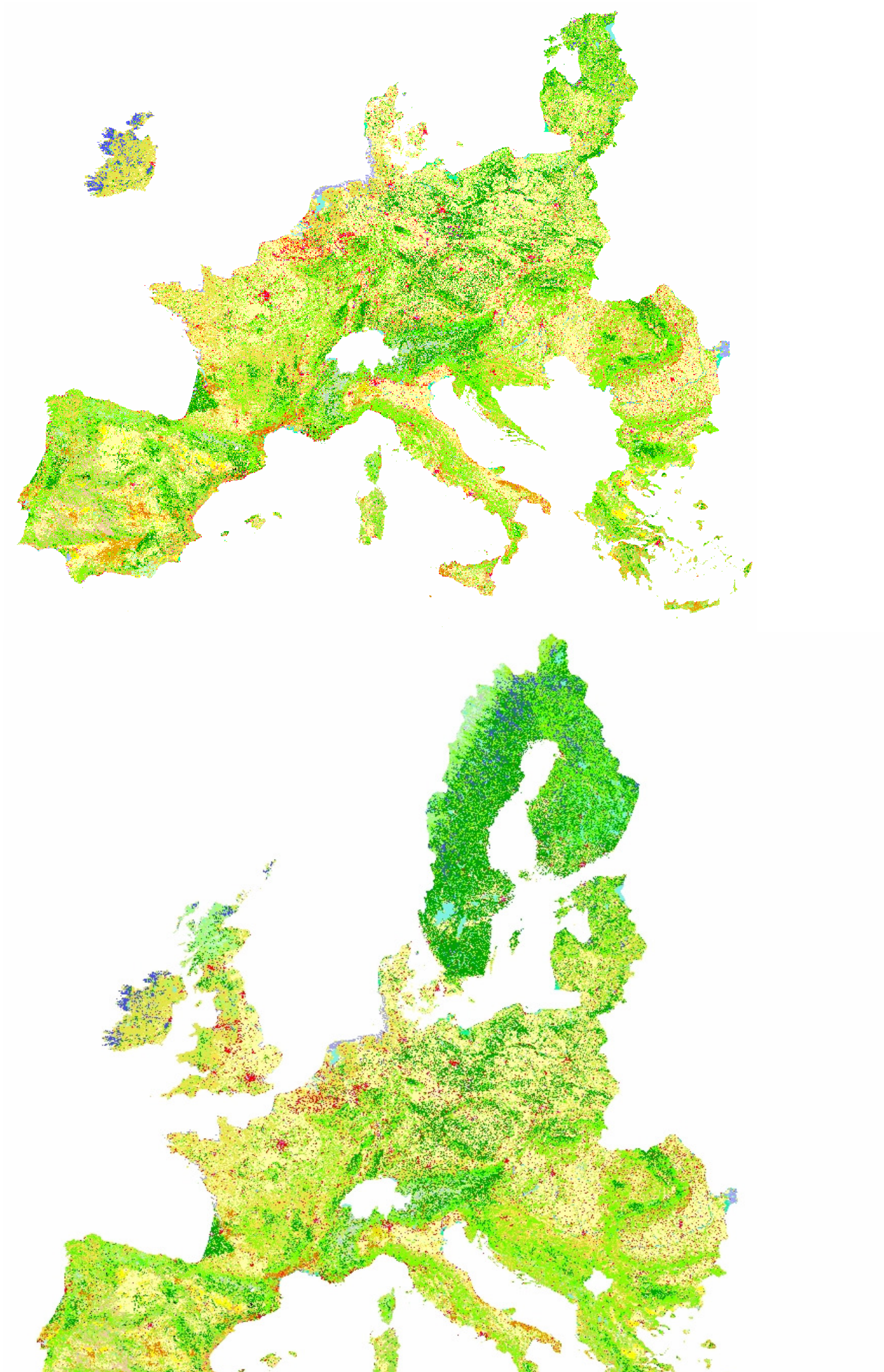


Figure 3.1. The geographical extent of CLC1990 (top) and CLC2000 (bottom).

BIOPRESS

Description

BIOPRESS[20] ('Linking Pan-European land cover change to pressures on Biodiversity'), is a FP6 European Commission funded 'Global Monitoring for Environment and Security' project. It produced land cover change information (1950–2000) for Europe from aerial photographs and tested if this information was suitable for monitoring habitats and biodiversity. BIOPRESS was strongly linked to CLC1990 and 2000. Changes in land cover were established through 73 window and 59 transect samples distributed across Europe. Although the sample size was too small and biased to represent the spatial variability observed in Europe, the work highlighted the importance of method consistency, the choice of nomenclature and spatial scale.

Appropriateness for this project

The BIOPRESS dataset contains historical land cover changes (CLC compatible) for the period 1950-1990 for a limited number of windows across EU. The methodology is suitable to detect historical land cover changes. However, the spatial distribution makes it difficult to use the data for deriving EU wide figures, and therefore this dataset was not considered to be suitable for this study.

Pan-European Land Cover Mosaic (PLCM)

Description

Since the CORINE Land Cover data covers only a limited number of European countries, high resolution land cover information is still lacking for countries as Switzerland and Norway. Therefore, the best available land cover databases were integrated to compile Pan-European land cover databases. Against this background two new Pan-European land cover databases are created for the years 1990 and 2000.

The PLCM datasets are composed through integration of the following data sources:

- CORINE Land Cover databases (CLC1990, CLC2000 and CLC-changes) (Heymann *et al* 1994; Bossard *et al* 2000; Feranec *et al* 2007a,b; Buttner *et al* 2004).
- Pan-European Land Cover database (PELCOM) (Mücher *et al* 2001).
- Global Land Cover database for the year 2000 (GLC2000) (Di Gregorio 2005; Bartholomé and Belward 2005).
- National land cover databases for Switzerland and Norway.

The compilation of the PCLM1990 and 2000 databases by integrating several data sources on thematic and spatial content resulted in homogeneous Pan-European land cover databases. All databases have the same geographical extent, i.e. EU27+2 (Norway, Switzerland), Albania, Andorra, Belarus, Bosnia-Herzegovina, Croatia, Iceland, Kosovo, Liechtenstein, Macedonia, Moldavia, Monaco, San Marino, Serbia and Montenegro, part of Russia, Turkey, Ukraine and Vatican. More details on the datasets are provided by Hazeu *et al* (2008a,b).

[20] http://www.creaf.uab.es/biopress/index2.htm

Appropriateness for this project
The PLCM datasets are CLC datasets for 1990 and 2000 extended with national datasets (Switzerland and Norway) and GLC2000/PELCOM conform to the CLC legend. The national datasets. PELCOM and GLC2000 are used to fill the holes in the CLC datasets for the Pan-European coverage. However, the national datasets, PELCOM and GLC2000 datasets have a different and limited number of land cover classes at lower resolutions. Furthermore, the land cover changes between 1990 and 2000 can not be monitored. Therefore, the PLCM datasets are not used in this project since it does not provide the land cover information at the spatial resolution required.

HISLU60

Description
There is no historical Europe wide land cover information available for the sixties with a reasonable resolution. Therefore, it was decided to construct an historical land cover database based on information from the World Atlas of Agriculture published in 1969 that contains maps based on land use surveys from the fifties and sixties on a scale of 1:2.500.000 for most maps. The methodology used for the construction of the historical land use database is described by Kramer and Mücher (2006).

The following 7 classes are discerned in the HISLU60 database: urban, arable land, grassland, forest, non-agricultural land, inland water and sea (Figure 3.2). The database has a spatial resolution of 250 by 250 m and is based on the integration of different map sheets out of the World Atlas of Agriculture.

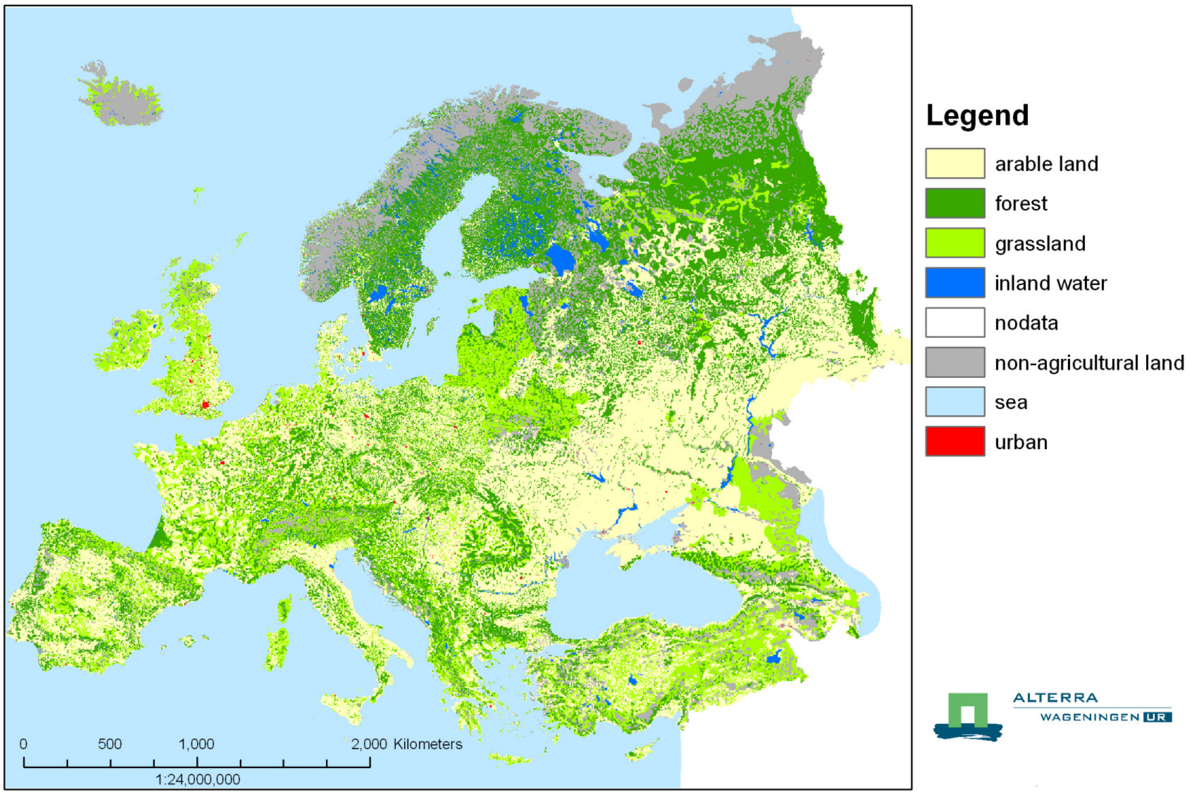


Figure 3.2. Historical Land use database for the reference year 1960 (HISLU60). Source: derived by digital processing from the World Atlas of Agriculture.

Accuracy
The accuracy assessment of the HISLU60 dataset is based on the three independent data sources, i.e. two national assessments (Dutch and Swiss) and one pan-European (BIOPRESS). For all three data sources the land cover classes are converted into the seven HISLU classes. The Dutch assessment (HGN1960) covers the Dutch territory and bordering sea (totalling 41739 km^2). The Swiss assessment deals with 41366 km^2 (national territory) and the BIOPRESS assessment covers 59304 km^2 across Europe.

The overall accuracy of the HISLU60 database ranges from 38.4 – 58.1% depending on the used reference dataset. The accuracy assessment with the Swiss data resulted in the lowest overall accuracy while the BIOPRESS assessment took an intermediate position with 48.1%. These low accuracies give a clear indication to restrict the land cover/use change analysis to only large spatial units (NUTS0 and NUTS1). A more detailed analysis of changes does not make sense as the pixel (1 km x 1 km) or geographical locational accuracy is very low for all three assessments (Hazeu *et al*, 2008a,b).

Appropriateness for this project
The HISLU60 dataset has a different thematic content, spatial detail and the processing of the dataset is quite different from the CLC databases. Therefore the assessment of historical land cover changes (1960-1990) is difficult for the following reasons:

1. The comparison of CLC and HISLU60 datasets is difficult due to differences in thematic and spatial detail.
2. The objectives, methodology and production is different for historical land cover datasets (i.e. HISLU60) and not comparable with more recent datasets (i.e. CLC).
3. HISLU60 is produced with the best available data sources. However, one dataset is often a combination of different data sources and therefore, the temporal (and thematic) variation within one dataset can be large.
4. Validation of a historical dataset such as HISLU60, is difficult as independent reference data sources are very limited. Collection of 'new' data is not possible.

The HISLU dataset is the best available for the historical analysis required across the EU. But, for the reasons outlined above and its limited accuracy, the assessment of 1960-1990 land cover changes in this project is limited to large spatial units based on regional statistics. A pixel to pixel validation is not valid. In addition, the interpretation of the differences in land cover stocks between 1960 and 1990 at NUTS0 level has to be carefully interpreted. Historical change analysis remains difficult and needs to be further explored in new projects. Results of a historical land cover change analysis needs to be validated and interpreted in relation to the way they are produced and used. However, lack of independent (spatial) historical data hamper the validation of historical land cover changes.

High Resolution Soil Sealing data

Description

Soil sealing data have been produced by a consortium of European service providers under contract with EEA (GMES project land monitoring fast track service precursor or CLC2006) and are based on the classification of the IMAGE2006 satellite data. The overall objective is the production of a seamless European high resolution core land cover dataset of built-up areas, including degree of soil sealing, for the reference year 2006. Built-up areas are characterized by the substitution of the original (semi)-natural cover or water surface with an artificial, often impervious, cover. This artificial cover is usually characterized by long cover duration (FAO Land Cover Classification System, 2005). Impervious surfaces of built-up areas account for 80 to 100% of the total cover. A per-pixel estimate of imperviousness (continuous variable from 0 to 100%) is provided as index for degree of soil sealing for the whole geographic coverage. The data are produced in full spatial resolution, i.e. 20 m by 20 m, which provides the best possible core data for any further analysis.

Accuracy

The classification accuracy per hectare (based on a 100 m x 100 m grid) of built-up and non built-up areas should be at least 85%, for the European product. A qualitative assessment for each country is carried out by the National Reference Centers. A quantitative assessment for the European product is foreseen in 2009.

Appropriateness for this project

The High Resolution Soil Sealing layer was not used in this project in this study for the analysis of soil sealing (Task 2), because of (i) the different reference time (2006) from the other land cover datasets (1990, 2000, 2025); (ii) the different legend, which does not allow differentiation in types of built-up area, but differentiation in % built up area; and (iii) the different resolution from the other land cover datasets and the soil maps used (1 km^2).

LEAC

Description

The Land and Ecosystem Accounts (LEAC) for Europe 1990-2000 produced by the EEA, consists of a detailed analysis of land cover changes between 1990 and 2000. The main goal of LEAC is to provide easy and comprehensive access to land cover data showing the ‘stock’ available for each land cover class in different years, and providing also the changes occurring in the periods between the different years. The accounts are limited to 28 countries for which CLC1990 and CLC2000 are both present. For four of the EU27 member states, the land cover flows are unknown as the CLC1990 database is lacking (Weber, 2007 and Haines-Young and Weber, 2006).

Accuracy

The LEAC system is a framework for systematically analyzing land cover changes between 1990 and 2000 and grouping them into land cover flows. The data used are CLC1990, CLC2000 and in the near future CLC2006. The accuracy is similar to the CLC datasets.

Appropriateness for this project

The LEAC methodology was considered to be suitable for the same reasons as the CLC datasets. However, it was necessary to restrict the change analysis to the aggregated land cover classes and land cover flows as defined in the LEAC methodology.

Farm Structure Survey

The Farm Structure Survey (FSS) is conducted by Eurostat and forms part of the Eurostat database. This source of information provides data (from 1975) on structural characteristics of agriculture in the EU, classified by farm type, farm size and region.The statistical unit is the agricultural holding, which is a single unit, both technically and economically, having a single management, producing agricultural products, and having either (i) a utilised agricultural area of 1 ha or more; or (ii) a utilised agricultural area less than 1 ha, provided it produces on a certain market scale or that its production units exceed certain natural thresholds.

Data are collected in the agricultural census surveys every ten years (1990 and 2000), with intermediate sample surveys every two years (1993, 1995, 1997, 2003 and 2005). Standard survey data are available in a three level geographical breakdown of the whole country (FSS-0), the regions (FSS-1), and the sub-regions (FSS-2). However, data for intermediate surveys are only available for FSS-0 and FSS-1 levels. The calendar for the basic and intermediate surveys is broad, the time intervals being, respectively 27 and 15 months. An interesting point is that organic farming is now also covered by the FSS as well as the Member State returns on production areas and livestock numbers with respect to Regulation 2092/91.

Appropriateness for this project

The FFS database was not appropriate for the analysis in this study for the following reasons:

- The regional divisions of the regions (FSS-1) and sub-regions (FSS-2) do not match with the NUTS divisions, which are the spatial reference units in this project. To harmonise the differences between the NUTS division and FSS will involve expert knowledge rules and loss of regional detail;
- Data reliability. Data are produced from sample surveys, the size of which varies with country and survey year, e.g. the sample size varies between 3% and 40% of the total population of agricultural holdings. In addition, the size of the FSS regions varies strongly between Member States;
- FSS datasets do not cover all land uses in a comprehensive manner that can be used for modelling.

Permanent grassland database (DG Agri)

This dataset is of most relevance to Task 5 regarding permanent grassland and is therefore discussed in Chapter 7.

High Nature Value (JRC/IES)

The High Nature Value farming dataset from JRC/IES at 1 km^2 is only available for the year 2000. It is therefore not suitable for the historic assessment of land use changes or the modelling of future projections of change, because they do not have time series data. The HNV map is also a derived dataset based on the predicted occurrence of HNV from broad scale data sources (including CORINE landcover) rather than actual field surveys. It is therefore an indicative map and cannot be used to provide reliable assessment so of the status or change in HNV farmland.

3.2.2 Distribution of land cover/use changes data into appropriate territorial units

The first stage of the analysis of land cover change for this study was carried out by distributing the land cover data into three levels of territorial units, i.e. NUTS0 (EU member states), NUTS1 and NUTS2. The results are presented in the separate Technical Annexes to this report and provide information on the surface occupied by the relevant types of Land

Cover and the changes that occurred in these surfaces between 1960 -1990 and 1990 – 2000. The following information is presented at the NUTS0 level:

- Land cover/use aggregated into CLC level 1 for the HISLU60, CLC1990 and CLC2000 datasets (Annex 1.1(a-c).
- Land cover/use for the 31 classes defined for the specific needs of this project at NUTS0 level (Annex 1.2(a and b). These 31 classes result from the thematic aggregation of 44 CLC classes as shown in Table 3.1. The data presented in the are based on the CLC 100m*100m resolution data of 1990 respectively 2000.

The land cover/use data distributed according to NUTS1 and NUTS2 territorial units are available in an Excel table with worksheets for CLC2000, CLC1990 and HISLU60 data at different thematic aggregation levels (CLC level 1, level2, level 3 and the aggregation defined for the land use services).

Table 3.1. Thematic aggregation of 44 CLC classes into 31 LC classes for this project

Level 1		Level 2		Level 3			DG-ENV
1	Artificial surfaces	1.1	urban fabric	1.1.1	Continuous urban fabric	1	1
				1.1.2	Discontinuous urban fabric	2	2
		1.2	industrial, commercial and transport units	1.2.1	Industrial and commercial units	3	3
				1.2.2	Road and rail networks and associated land	4	4
				1.2.3	Port areas	5	5
				1.2.4	Airports	6	6
		1.3	mine, dump and construction sites	1.3.1	Mineral extraction sites	7	7
				1.3.2	Dump sites	8	8
				1.3.3	Construction sites	9	9
		1.4	artificial non-agricultural vegetated areas	1.4.1	Green urban areas	10	10
				1.4.2	Port and leisure facilities	11	11
2	Agricultura l areas	2.1	arable land	2.1.1	Non-irrigated arable land	12	12
				2.1.2	Permanently irrigated land	13	13
				2.1.3	Rice fields	14	14
		2.2	Permanent crops	2.2.1	Vineyards	15	15
				2.2.2	Fruit trees and berry plantation	16	15
				2.2.3	Olive groves	17	15
		2.3	Pastures	2.3.1	Pastures	18	16
		2.4	heterogeneous agricultural areas	2.4.1	Annual cops associated with permanent crops	19	17
				2.4.2	Complex cultivation patterns	20	17
				2.4.3	Land principally occupied by agriculture with significant natural vegetation	21	17
				2.4.4	Agro-forestry areas	22	18
3	Forests and semi-natural Areas	3.1	Forest	3.1.1	Broad-leaved forest	23	19
				3.1.2	Coniferous forest	24	20

Level 1	Level 2	Level 3			DG-ENV
		3.1.3	Mixed forest	25	21
	3.2 shrub and/or herbaceous	3.2.1	Natural grasslands	26	22
	Vegetation associations	3.2.2	Moors and heath lands	27	23
		3.2.3	Sclerophyllous vegetation	28	24
		3.2.4	Transitional woodland-scrub	29	25
	3.3 open spaces with little or no vegetation	3.3.1	Beaches, sand, dunes	30	26
		3.3.2	Bare rocks	31	26
		3.3.3	Sparsely vegetated areas	32	26
		3.3.4	Burnt areas	33	26
		3.3.5	Glaciers and perpetual snow	34	26
4 Wetlands	4.1 inland wetlands	4.1.1	Inland marshes	35	27
		4.1.2	Peat bogs	36	28
	4.2 coastal wetlands	4.2.1	Salt marshes	37	29
		4.2.2	Salines	38	29
		4.2.3	Intertidal flats	39	29
5 Water bodies	5.1 inland waters	5.1.1	Water courses	40	30
		5.1.2	Water bodies	41	30
	5.2 marine waters	5.2.1	Coastal lagoons	42	31
		5.2.2	Estuaries	43	31
		5.2.3	Sea and ocean	44	31

3.3 IDENTIFICATION OF TRENDS AND PATTERNS IN LAND COVER/LAND USE CHANGE

3.3.1 Land cover in 1960, 1990 and 2000

Annex 1.1 presents the stocks of land cover/use at NUTS0 level for CLC level 1 and HISLU60 classes and Annex 1.2 aggregates the 1990 and 2000 data into 31 classes for the purposes of this study (which are referred to as DG-ENV classes). From these data, as summarised in Table 3.2[21] and the analysis of Hazeu *et al* (2008b) the following overall EU trends are apparent:

- increase of urban area
- decrease of grasslands
- increase of forest area

However, these trends are not apparent in some countries and some areas within countries, and in some cases are different. Similarly the BIOPRESS study's results suggested that different processes are taking place in different parts of Europe: with the Boreal and Alpine regions dominated by forest management; abandonment and intensification mainly occurring in the Mediterranean; and urbanisation and drainage being more characteristic of the Continental and Atlantic regions. As already mentioned these figures have to be interpreted with care due to missing 1990 data, inconsistencies in land classification between years, use the low accuracies of HISLU60 and assumptions made regarding the comparison of different types of datasets.

3.3.2 Land cover flows

This study is also concerned with flows of land cover (i.e. the dynamics and patterns of change from one use to another), particularly relating to urbanisation and changes in the use of agricultural land. These flows were assessed using the 'Land accounts for Europe 1990-2000' stock and change accounts for the EU24 (1990-2000) as reported by Haines-Young and Weber (2006). The report contains data for the different LEAC classes (aggregation of 44 CLC classes into 8 main LEAC classes) regarding nine land cover flows and other more detailed land cover flows. Special focus is given to some geographical regions (mountains, bio-geographical and coastal zones) and special themes including urbanization, agricultural change and changes in forest and semi-natural habitats. The following data are included:

- Land cover starting year of account (i.e. 1990)
- Losses (consumption) of initial land cover
- Gains (formation) of new land cover
- Net formation of land cover (gains- losses)
- Net formation as % initial year
- Total turnover of land cover (losses+gains)
- Total turnover as % of initial year
- No land cover change
- No land cover change as % of initial year
- Land cover final year of account (i.e. 2000)

The most important LCF between 1990-2000 at NUTS0 level are presented in (Table 3.2). These indicate that the most important land cover flow (LCF) between 1990-2000 in artificial

[21] Taking into account countries with missing 1990 data.

areas is LCF1 urban land management. For arable land and permanent crops (2A)_and pastures and mosaics (2B) the most important flow is LCF4 agricultural conversions, while LCF2, LCF3 and LCF6 are in second place. Forested land (3A) and semi natural vegetation (3B) are most influenced by LCF5 conversion from other land cover into agriculture and LCF7 forest creation and management. The area with open spaces and/or bare soils (3C) is mainly affected by LCF7 and LCF9 changes of land cover due to natural and multiple causes. Most important land cover flow in the wetlands and water body areas is LCF9 changes of land cover due to natural and multiple causes.

Overall it can be concluded that urban expansion takes place at the expense of agricultural land. In addition, agricultural land is also prone to a lot of internal conversions and abandonment of activities. Forested land and land with semi-natural vegetation is a source for new agricultural land.

It is important to note that within countries there are large regional differences which are reflected at different NUTS levels. Per country the largest LCF is shown in bold. LCF7 forest creation and management is most important in most countries, LCF4 agriculture internal conversions is the most important flow in Czech Republic, Germany, Ireland, Estonia and Lithuania, while LCF2 urban residential sprawl and LCF3 sprawl of economic sites and infrastructure are the most important flows in Monaco respectively the Netherlands. Agricultural conversions (LCF4) occupy large areas in Czech republic, Germany, Spain and Ireland (>300,000 ha). As shown in Figures 3.3 and 3.4, LCF7 forest creation and management has large contributions from Spain, France and Portugal (> 600,000ha).

Table 3.2. Land cover flows (hectares) in Europe Source: Haines-Young and Weber (2006)

NUTS 0	LCF1 Urban land management	LCF2 Urban residential sprawl	LCF3 Sprawl of economic sites and infrastructures	LCF4 Agriculture internal conversions	LCF5 Conversion from other land cover to agriculture	LCF6 Withdrawal of farming	LCF7 Forests creation and management	LCF8 Water bodies creation and management	LCF9 Changes of Land Cover due to natural and multiple causes	No Change	Grand Total
Austria	425	3263	8941	1109	1186	1817	8941	490	**10472**	8351472	8388116
Belgium	2447	5467	13669	8727	761	1651	**18356**	844	1702	3012961	3066585
Bulgaria		177	3339	44672	1329	2630	**68727**	134	1439	10974658	11097105
Czech Republic	4317	4058	7799	**298711**	2797	6857	181316	1757	1443	7379045	7888100
Germany	10023	96938	109882	**387969**	15923	24042	157892	18789	49972	35298458	36169888
Denmark	296	4117	9172	1531	276	9273	**28250**	338	3558	4350722	4407533
Estonia	92	1400	1126	**66115**	333	1534	48024	5	1514	4416142	4536285
Spain	15573	67425	106598	651057	311335	125898	**867460**	37733	199486	48240503	50623068
France	10643	53432	88847	162488	37715	18677	**697522**	12745	34102	54067377	55183548
Greece	2055	4977	30927	56331	13170	569	**125530**	4218	32732	12930001	13200510
Hungary	585	1444	8997	141910	4923	39004	**211689**	3039	3646	8886716	9301953
Ireland	2525	15561	15612	**303136**	4624	15740	201733	58	2163	6503696	7064848
Italy	1618	49816	34071	54909	10079	84221	**129175**	2404	27979	29734280	30128552
Lithuania	711	155	576	**95304**	507	768	57861	332	207	6361066	6517487
Luxembourg	95	1062	722	234	119	57	1982			255429	259700
Latvia			117	125142		99	**126055**		225	6204263	6455901
Netherlands	11542	40509	**43679**	29280	1189	21052	3574	3588	13476	3820466	3988355
Poland	5197	4160	15720	44599	5661	20221	**143241**	5636	11340	30999342	31255117
Portugal	3948	38370	29094	122165	47943	81825	**601225**	6678	44750	7948175	8924173
Romania	994	3024	5658	101392	7596	19537	**166143**	1250	4164	23506597	23816355
Slovenia	382	27	276	27	317	49	**1125**	84	195	2025783	2028265
Slovakia	560	2878	2469	40626	5659	26322	**114063**	3341	3962	4700641	4900521
United Kingdom	3967	14120	23201	1	4437	8533	**308313**	533	859	24408849	24772813
TOTAL	**77995**	**412380**	**560492**	**2737435**	**477879**	**510376**	**4268197**	**103996**	**449386**	**344376642**	**353974778**

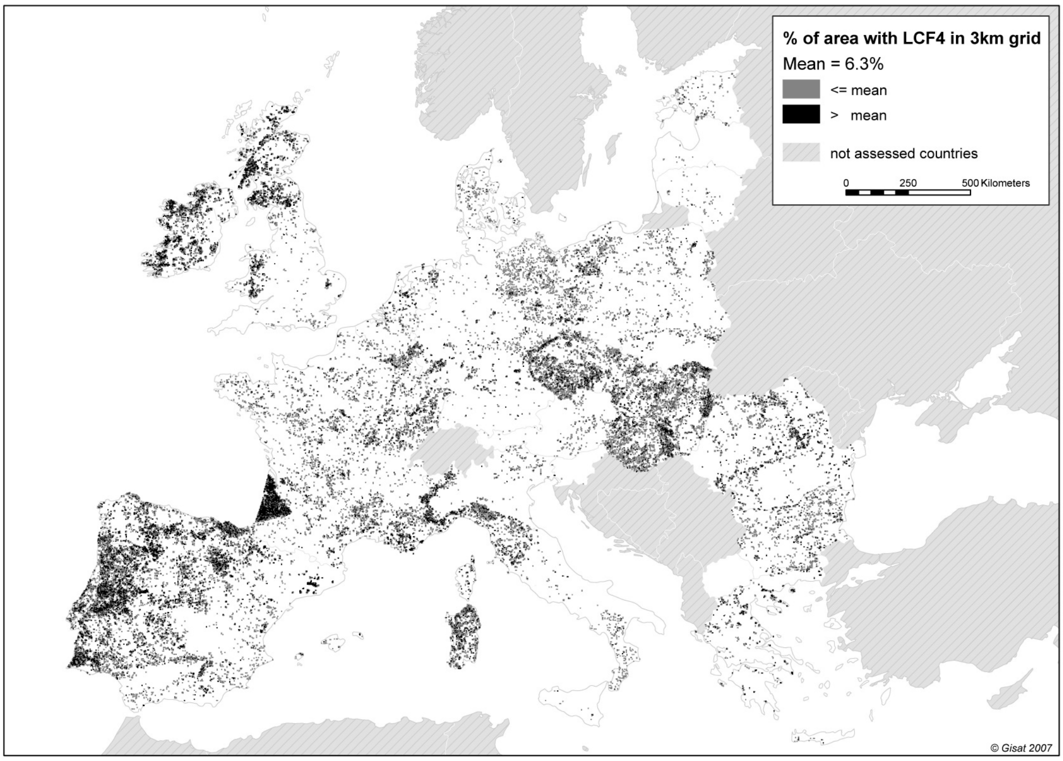


Figure 3.3. Spatial distribution of afforestation (LCF4)[22] **in 24 European countries (1990-2000)**. Source: Feranec *et al*, (2009).

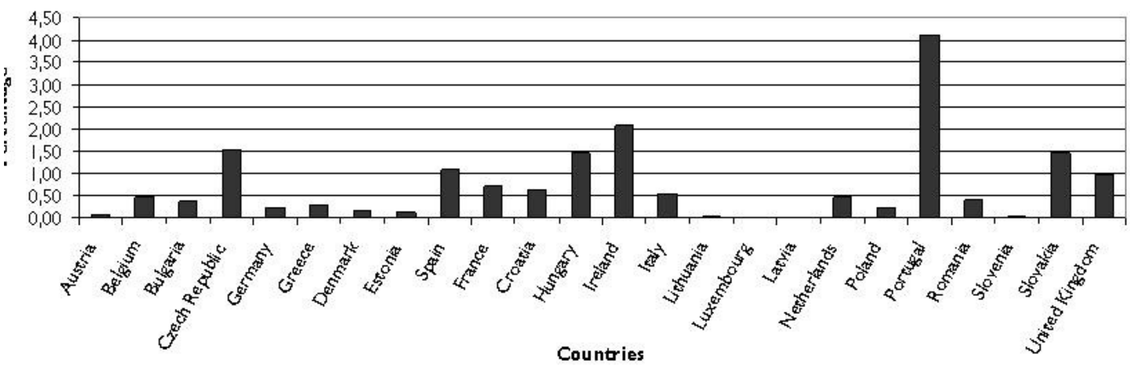


Figure 3.4. Percentage of the total country surface affected by afforestation (1990-2000). Source: Feranec *et al*, (2009).

Urban land management (LCF1) is important in Germany, Spain, France and the Netherlands with more than 10,000ha involved. Next to the countries with large LCF1 flows, Italy and Portugal have more than 35,000ha of area with changes that are characterized as urban residential sprawl (LCF2). These 6 countries are also characterized with high land cover flows defined as sprawl of economic sites and infrastructures. In relation to the size of the countries

[22] LCF4 is the abbreviation for a land cover change flow which describes a process (in this case afforestation) while LCF7 (forest creation and management) in the LEAC means a land cover flow. Both definitions are different from each other.

it can be stated that the percentage of area affected by urbanization is highest in the Netherlands (see Figures 3.5 and 3.6).

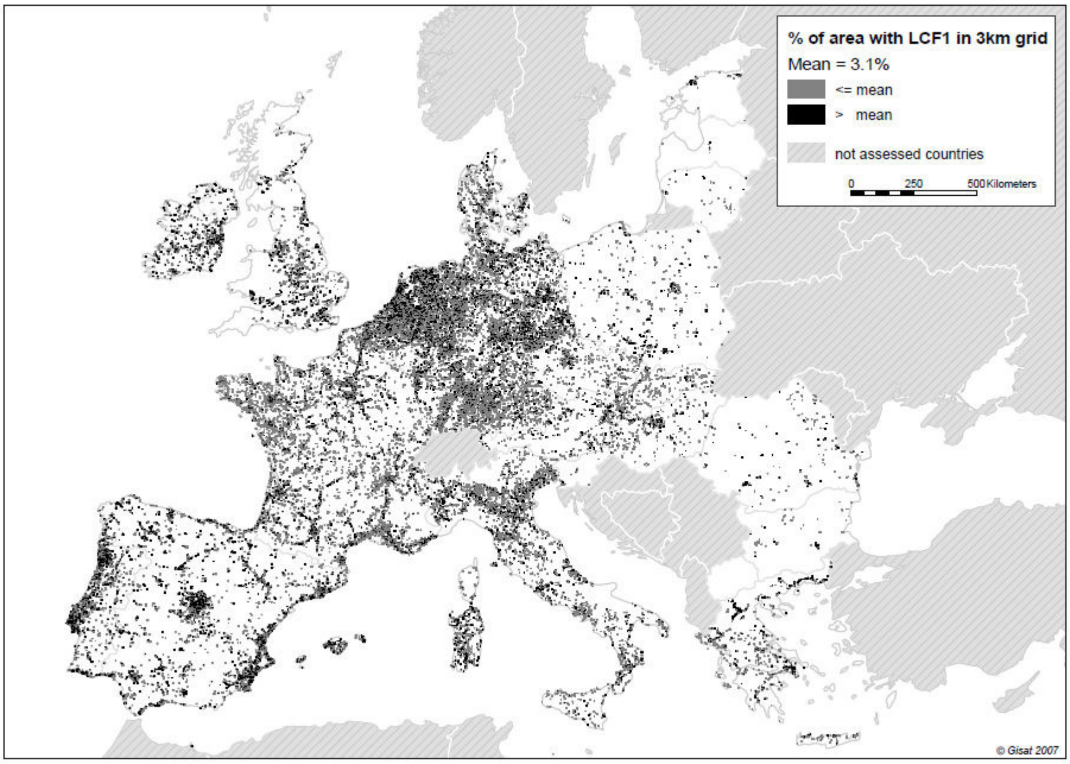


Figure 3.5. Spatial distribution of urbanisation (LCF1) in 24 European countries (1990-2000). Source: Feranec *et al*, (2009).

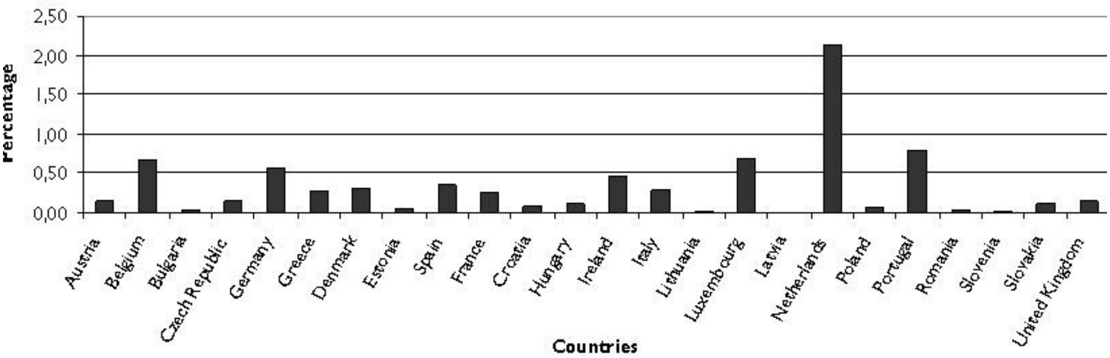


Figure 3.6. Percentage of the total country surface affected by urbanisation (1990-2000). Source: Feranec *et al*, (2009).

Another striking land cover flow at NUTS0 level is the conversion from other land cover to agriculture (LCF5) in Spain (see Figures 3.7 and 3.8). Withdrawal from farming (LCF6) is important in the countries with high urbanization rates and in most former Eastern European countries with the Mediterranean countries leading. Water body creation and management (LCF8) is a relatively small land cover flow. Changes of land cover due to natural and multiple causes are especially important in Austria, Germany, Spain, France, Greece, Italy, the Netherlands, Poland and Portugal (>10,000ha).

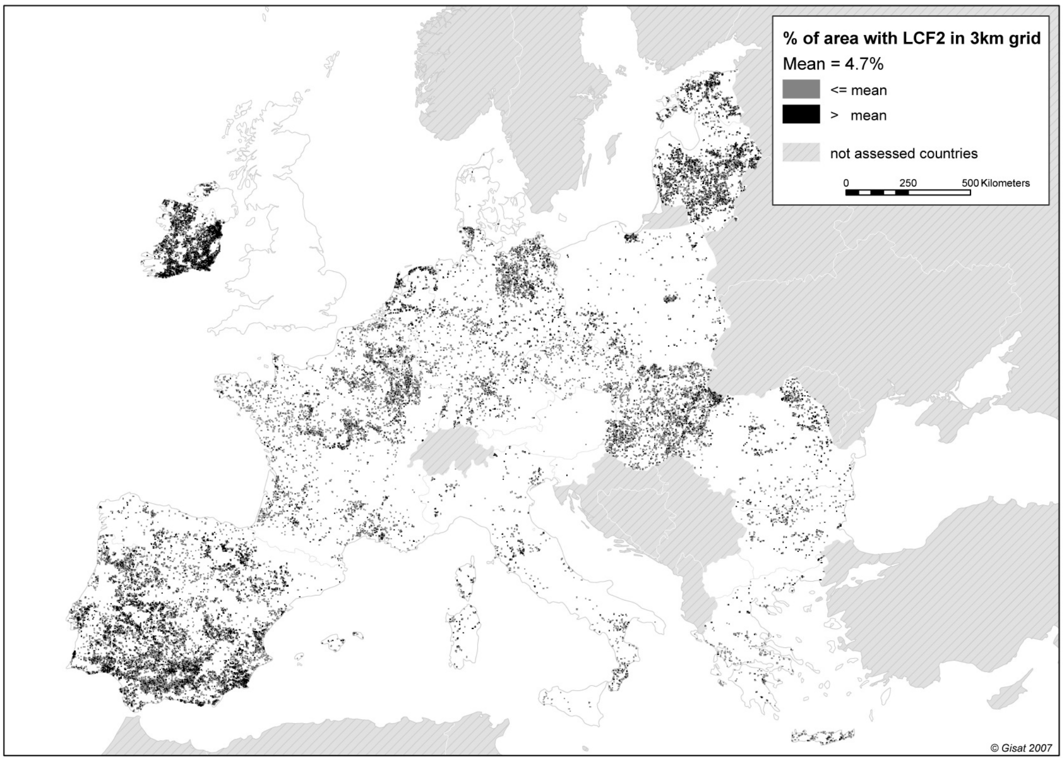


Figure 3.7. Spatial distribution of intensification of agriculture (LCF2) in 24 European countries (1990-2000). Source: Feranec *et al*, (2009).

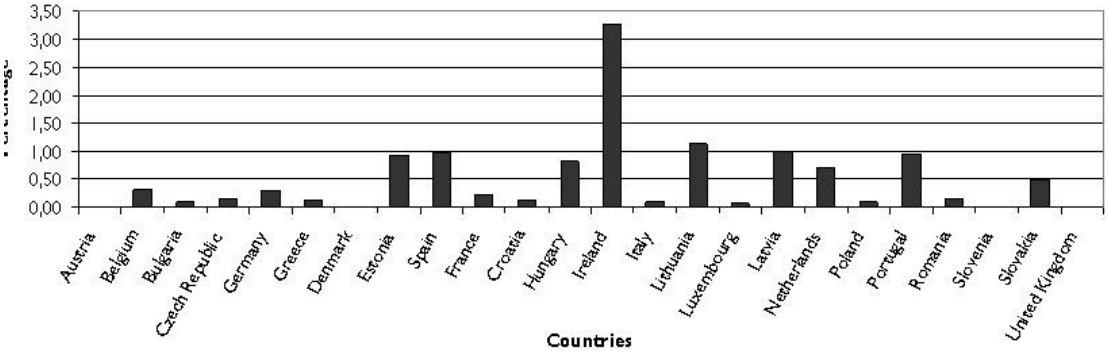


Figure 3.8. Percentage of the total country surface affected by intensification of agriculture (1990-2000). Source: Feranec *et al*, (2009).

Similar figures and tables on extensification of agriculture and deforestation are published (see Feranec *et al*, 2009). The definition of the processes urbanisation, intensification or extensification of agriculture, afforestation and deforestation are re described as well in this article.

Lastly, it is important to note, although some countries validated their changes, validation of land cover changes between 1990-2000 has not been considered at a European scale. The changes have only been verified by a external team during the production of CLC2000. The comparison between 1960 and 1990 might not be therefore be consistent since the methodology to produce the datasets was different.

3.4 ESTIMATION OF THE FUTURE TRENDS IN LAND COVER/LAND USE FOLLOWING A 'BUSINESS AS USUAL SCENARIO'

3.4.1 Methods

A high spatial resolution assessment of possible land use changes for the period 2000-2030 is made. Such an assessment is necessary because land use change is not likely to continue trends of the past given the many non-linear interactions and thresholds in the system. Moreover, many policies relevant to land use are changing. Especially the reform of the Common Agricultural Policy is expected to affect large areas. The assessment of future land use in this project is based on the EURURALIS study (WUR/MNP, 2008) which is one of the most recent, well documented assessments of land use change at the European scale (Meijl *et al*, 2006; Eickhout *et al*, 2007; Verburg *et al*, 2006; Verburg *et al*, 2008).

A further assessment of the impacts of land use change on the provision of ecosystems services necessitates a spatially explicit analysis. The geographical location of land use change will, to a large extent, determine the impact of these land use changes on ecosystem services, e.g., deforestation on flat land will not necessarily lead to soil erosion while on sloping land risk of increased loss of soil are much higher.

The methodology is described below in two parts:

1. Identification and description of the 'reference' scenario, which formed the basis of the modelled projections;
2. Description of the land use model.

Identification and description of the reference scenario

Modelled projections of land use change are based on scenarios that incorporate a number of assumptions with respect to the drivers of land use change. The technical specification for this study requests that the modelling analysis should be based on a "Business as Usual Scenario". However, following our recommendations in our technical proposal and agreement at the Inception Meeting, we identified a set of scenario's which could be used as a reference scenario for the study's projections of land use changes. They follow the concept storylines of the IPCC Special Report on Emission Scenarios (SRES; IPCC, 2001a,b) which are structured along two axis distinguishing globalisation from regionalisation; and development pursuing narrowly defined economic objectives from more broadly defined economic, social and environmental objectives.

However, the focus of these scenarios is much broader than land use, agriculture and rural development and lacks the regional disaggregation needed for this study. Therefore the scenarios have been elaborated for land use issues and agricultural policies typical for Europe (Westhoek *et al*, 2006). This has resulted in a series of four scenarios distinguished by different degrees of global (market) integration and different levels of (policy) regulation. The regulation level is indicative of the ambition of governments in pursuing their goals with ambitious regulation, e.g., to obtain equity or environmental sustainability. Scenarios with a relatively low level of regulation include the Global Economy (A1) and Continental Market (A2) scenarios. The other two scenarios: Global Co-operation (B1) and Regional Communities (B2) assume a relatively high level of regulation, including specific spatial and agricultural policies.

The elaboration of the scenarios also included the quantification of variables exogenous to the simulation models representing the developments assumed in the scenarios. These exogenous variables include demography, institutions, trade barriers and technology parameters. A selection of the assumptions made in the four scenarios that are explicitly accounted for in the simulations is provided in Table 3.3. For the quantification use was made of a number of existing scenario studies and models. In addition a number of sessions with policy makers was held to check the credibility and consistency of the story lines and model input (Klijn *et al*, 2005; Westhoek *et al*, 2006).

Following further consideration by the project Steering Committee, it was agreed that the B1 Global Cooperation scenario should be used as the basis of the model projections in this study.

Table 3.3. Selection of assumptions underlying policy measures in the four scenarios

Source: Westhoek *et al* (2006)

Aspect	Model where aspect is implemented	Global Economy (A1)	Continental Markets (A2)	Global Co-operation (B1)	Regional communities (B2)
Trade of agricultural products	GTAP	Export subsidies and import tariffs phased out	Export subsidies kept in place but volumes reduces. Import tariffs kept in place	Export subsidies and import tariffs phased out. Slight increase in non-tariff barriers	Export subsidies phased out. Import tariffs maintained. Sharp increase in non-tariff barriers
Farm payments	GTAP	Phased out; abolished by 2030	Basically unaltered	Fully decoupled and gradually reduced (by 50% in 2030	Increase in agri-environmental payments; other payments reduced
Intervention prices	GTAP	Phased out; abolished by 2030	Maintained, but maximum guaranteed areas/quantities are reduced	Phased out; abolished by 2030	10% increase, but maximum guaranteed areas/quantities reduced
Less favoured areas	CLUE-s	Concept abolished by 2020	Maintained	Concept merged with Natura 2000	Maintained; no intensive agriculture allowed
Nature conservation	CLUE-s	Existing areas protected	Existing areas protected	Existing areas protected; abandoned areas within Natura 2000 sites managed for nature development	Existing areas protected; abandoned areas managed for nature development
Urban development	CLUE-s	No restrictions	No restrictions	Restrictions on urban sprawl; i.e. incentives for compact cities	Restriction on urban sprawl; incentives to prevent desertion of rural villages

Out of the series of IPCC SRES scenarios, the B1 scenario was selected as a reference by the members of the steering committee of this project. The B1 scenario is called Global Co-operation following the nomenclature of the EURURALIS study. It includes assumptions for specific changes and policies in EU27, which are consistent with the global narrative. The Global Co-operation scenario combines a global orientation with a preference for social, environmental and more broadly defined economic values. Economic profit is not the only objective here. Governments are actively regulating, ambitiously pursuing goals related to, for example, equity, environmental sustainability and biodiversity. The main assumptions of this scenario are as follows:

- Intensive multilateral international co-operation on many issues.
- Tariff barriers restricting market access are gradually removed but international food safety standards are raised and new mechanisms are introduced to ensure high social and environmental production standards of traded goods.
- Developing regions are supported so as to comply with these standards.
- The current CAP export subsidies are abolished, since these are understood to hamper developing countries in their development.
- Border support is also phased out.
- Income support is reduced to 33%, mainly aiming at maintaining environmental services.
- CAP Less Favoured Area (LFA) / Naturally Handicapped Area payments are maintained, except for arable agriculture in locations with high erosion risk.
- Cohesion policy targeting wealth convergence between EU regions remains a priority policy issue.
- The maintenance (and acquisition) of natural and cultural heritage are mainly publicly funded.
- Restrictions in spatial urban planning lead to relatively compact urban growth.
- Successful climate mitigation strategies are assumed as well. The EU climate stabilization target of 2°C is implemented globally and therefore, global greenhouse gas concentration level is stabilized at 450 ppm CO2-equivalents. Note that given current agreed global commitments this seems unlikely.
- There is a flexible policy with respect to the international mobility of individuals from outside the EU (leading to 2.1 net migrants per 1000 inhabitants in 2030) and no limitation for migration between Member States. In combination with a relatively high fertility rate this leads to an increased population of almost 500 million inhabitants in 2030.
- Globally, the high economic growth stimulates the global demographic transition, leading to a sooner stabilization of global population at around 8 billion inhabitants around 2030/2040.
- Economic growth will be especially high, i.e. 3.4% per year, in the new Member States (EU-12), partly at the cost of the original EU15.
- Human behaviour is also adjusting towards global solidarity, for example leading to changes in diets of people containing less meat than could be assumed based on their economic welfare. In this scenario, people focus more on sustainability, hence the consequential animal welfare and health considerations are assumed to lead to relatively less meat consumption (-5% in 2020 and -10% in 2030 of endogenous outcome based on GDP developments).

The key socio-economic and policy assumptions are summarised in Table 3.4.

Table 3.4. Socio-economic and policy assumptions and indicators for the B1 reference scenario. Source: Westhoek *et al* (2006) and www.eururalis.eu

Aspect	**Global Co-operation (B1)**
Population EU-27 in 2030	500 million
Idem, change since 2000	4%
EU-15 GDP yearly growth	1.3%
EU-12 GDP yearly growth	3.4%
EU enlargement	Turkey enters EU
Trade of agricultural products	Export subsidies and import tariffs phased out. Slight increase in non-tariff barriers
Product quota	Phased out; abolished by 2020
Farm payments	Fully decoupled and gradually reduced (by 50% in 2030)
Intervention prices	Phased out; abolished by 2030
Compulsory set-aside of arable land (excl. organic farms)	Abolished

In addition to the socio-economic and policy assumptions shown in Table 3.4, a number of spatially explicit policies and incentives are accounted for, as described in Table 3.5. These policies either target specific land use types or regions. A full description of all scenario assumptions accounted for is included in Annex 1.3.

Table 3.5. Policies and incentives related to specific locations or regions for the reference scenario

Aspect	**Global Co-operation (B1)**
NATURA2000	Strict protection, no residential development. Incentives to prevent abandonment of extensive farming in NATURA2000 areas (second pillar measure)
Fragmentation of nature areas	Incentives to limit fragmentation of natural areas
Efforts to establish corridors for nature	Incentives to sell agricultural land for nature development in ecological corridor regions as indicated in PEEN map (only eastern European PEEN implemented)
Less Favoured Areas	Compensation maintained at current level except for arable farming on erosion sensitive areas
Permanent pastures	Restrictions on the conversion of permanent pastures to arable land
Soil conservation	Conversion to arable land is not allowed in erosion sensitive areas; incentives are provided to abandon arable land in erosion sensitive areas or to convert arable land to grassland/permanent crops.
Spatial planning urban areas	Strong spatial planning aiming at compact cities, growth mainly in large cities and provincial towns

Model description

The simulation of land use change and associated impacts is based on the use of multiple models to address the different scales of analysis and multiple inputs (Hellmann and Verburg, 2009; Verburg *et al*, 2008). Land use change in Europe is affected both by local conditions, such as topography, accessibility and demographic structure, and global processes, such as global trade of commodities, market-support policies and migration. It is therefore necessary to apply a multi-scale approach accounting for the processes affecting land use change over the whole range of scales.

In this project, a modelling chain consisting of the GTAP, IMAGE and CLUE models was considered. The main external driving factors that are specified as input to the models are demography, overall economic development (GDP), technological change and policies. As described above, the parameters for these factors were set using a scenario approach (i.e. the B1 reference scenario).

At the global level a macro-economic model was used to calculate the land use change response to changes in overall economic development, trade and agricultural policies, technology and demography. An extended version of the Computable General Equilibrium (CGE) model (**GTAP**: Global Trade Analysis Project (Hertel, 1997), was used which combines the advantages of the global CGE approach with specific features of partial equilibrium models concerning land modelling (Meijl *et al*, 2006). The model links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. Extensions of the standard model were used to improve the treatment of agricultural production and land use. The land use structure was extended by accounting for different degrees of substitutability between land use types and an endogenous treatment of land demand and supply through a land supply curve specifying the relation between land supply and land rent (Meijl *et al*, 2006). In addition, biodiesel and bioethanol are separately placed in the GTAP input-ouput structure of the petroleum industry, which means that the petroleum industry can choose between using oil, 'regular' petroleum products, biodiesel or bioethanol as inputs for fuel (Banse *et al*, 2008). The GTAP model distinguishes 36 world regions and the 27 Member States within the European Union. Within these regions the land resources are assumed to be distributed homogeneously. However, land resources often show a high spatial variation and current use is often located in the most productive areas. Changes in land area used for agricultural purposes tend to take place in the more marginal areas with relatively low yields. Therefore, the model may overestimate the production increase upon area expansion. At the same time environmental processes such as climate change may affect production conditions of the different world regions leading to changes in the competitive advantage of regions to produce commodities. In order to account for both effects the **IMAGE** model (Integrated Model to Assess the Global Environment; (Alcamo *et al*, 1998; Strengers *et al*, 2004) was used. The consequences of land allocation and climate change on the average productivity of different regions are input to a new simulation of the GTAP model. An iterative procedure is used until the output of both models is consistent (Eickhout *et al*, 2007).

Within Europe a more detailed assessment is made of the spatial patterns of land use change in order to identify which regions are expected to face specific land use change processes. A spatially explicit land allocation model, **CLUE** (Conversion of Land Use and its Effects, Dyna-CLUE version (Overmars *et al*, 2007; Verburg and Overmars, 2009) was used with a spatial resolution of 1 km^2 for yearly time steps. Seventeen different land use types are distinguished based on the CLC2000/CORINE land cover database (EEA, 2005b; Haines-Young and Weber, 2006) including built-up area, rainfed arable land, pasture, (semi-)natural vegetation, inland wetlands, irrigated arable land, recently abandoned farmland, biofuel crops, permanent crops, forest, and a number of different distinct (semi-) natural land use types such as beaches, glaciers, etc.

The CLUE model is based on the dynamic simulation of competition between land uses while the spatial allocation rules are based on a combination of empirical analysis of current land use patterns (Verburg *et al*, 2006; Wassenaar *et al*, 2007), neighbourhood characteristics (Verburg *et al*, 2004), and scenario specific decision rules. The spatial allocation rules are configured separately for each country to account for the country-specific context and land use preferences. The land requirements for the different land use types to be allocated by the model are specified at the national scale for each country within Europe separately as follows:

- Changes in agricultural land area are based on the results of the combined simulations with the global economic (GTAP) and integrated assessment model (IMAGE).
- Growth in built-up area is based on demographic development, immigration ratios and scenario-specific estimates of change in area used per person.
- Changes in natural vegetation are the result of both net changes in agricultural and built-up area and locally determined processes of re-growth of natural vegetation (Verburg and Overmars, 2009). After abandonment of agricultural land re-growth of natural vegetation is determined by the local growing conditions (soil and climate conditions), population and grazing pressure and management. The possibilities to convert natural vegetation into agricultural land or residential/industrial land depend on the location and the type of natural area. Path-dependent dynamics arise from the combination of top-down allocation of agricultural and urban demand and bottom-up simulation of the re-growth of natural vegetation.

Annex 1.4 describes the legend of the maps presented here and illustrates and describes the land cover classes in detail. Annex 1.5 provides a detailed description of the methods used in the CLUE model.

3.4.2 Results: estimation of the future trends in land cover/use change

General changes

Figure 3.9 presents a synthesis of the modelling results for the B1 reference scenario. This provides a generalised view of the main projected changes in land use/cover over the 2000-2030 period, with the colours indicating the most important process in the region. This map clearly suggests that, under this scenario, there will be widespread abandonment, particularly in Spain and Portugal, parts of Finland and Sweden, highland areas of France, Italy, central Europe, Romania, Bulgaria and the UK, and parts of Greece. However, it is important to note that the green colours do not indicate that all agricultural activities in these locations are likely to be abandoned. In reality finer-scale patterns of change will be more diverse. Nevertheless, the projected magnitude of abandonment is clearly substantial. In general the projections for abandonment match those areas considered to be most at risk of abandonment, according to known drivers of abandonment (as discussed in Chapter 7, see Figure 7.4), and areas that are already undergoing abandonment (see discussion on model validation below). The projections of the areas most likely to be affected by abandonment are therefore probably reasonably reliable, although the projections for parts of central Europe (such as Germany), the UK and Ireland are probably less so as the drivers of abandonment are less apparent in these areas.

Table 3.6 provides a summary of the projected changes for each Member State and for the EU as a whole. These results should be treated with some caution as the spatial distribution of land uses that are used in the model are interpretations based on CORINE data rather than detailed land use statistics. Nevertheless, the results confirm and approximately quantify some of the generalised land use changes illustrated in Figure 3.9. They clearly show that the main changes in land use across the EU are expected to be overall declines in agricultural and semi-natural habitats with increases in forest and, to a lesser extent built up areas. Specifically, the projections are for a 13% loss of arable farmland including biofuels (-177156 km^2), 13% loss of grasslands (-71748 km^2), and 14% loss of semi-natural habitats (-99377 km^2). This is balanced out by a 12% increase in forest cover (165541 km^2) and a 6% increase in built up areas (10261 km^2)[23]. These projected patterns of change are reasonably consistent across the Member States, especially regarding the decline in grasslands (stable or declining in all Member States), the expansion of forests (declining in all but two Member States). Built-up areas are increasing moderately in all Member States.

However, there are significant spatial variations amongst the projections for arable farmland and semi-natural habitats. In particular much of the expected decline in arable farmland is expected in the EU-12, with smaller changes in most other countries. But as also indicated in Figure 3.9, an increase in arable agriculture is expected in the Baltic States, seemingly at the expense of grasslands and semi-natural habitats. In fact many of the most significant declines in semi-natural habitat (in both relative and absolute terms) are expected in eastern Europe, with other substantial declines in Bulgaria, the Czech Republic, Poland, Slovakia and Slovenia. As discussed in Section 8.2, these losses of semi-natural habitat are of particular concern from a biodiversity point of view (potential impacts on HNV farmland is therefore examined in more detail below). Furthermore, it is important to remember that biodiversity losses from declines in semi-natural habitats cannot be balanced out in other areas. Although some countries may expand their area of semi-natural habitat (e.g. Germany, Belgium and the Netherlands) new areas of semi-natural habitat are likely to be of much lower biodiversity value than those lost in other parts of Europe, even if they are the result of intentional restoration management.

Figure 3.10 gives a number of snapshots of the dominant processes in specific areas of Europe. Figure 3.10A and 3.10E illustrate the process of land abandonment and increasing forest areas. Figure 3.10B and 3.10D illustrate the urbanization process while Figure 3.10C illustrates the removal of small forest patches within an agricultural landscape leading to an expansion of the agricultural area.

[23] There are also small increases in the area of recently abandoned arable farmland and pasture in most Members States (not provided in the table), which amount to an overall increase of 4%. Other land classes are assumed to be static in the CLUE model.

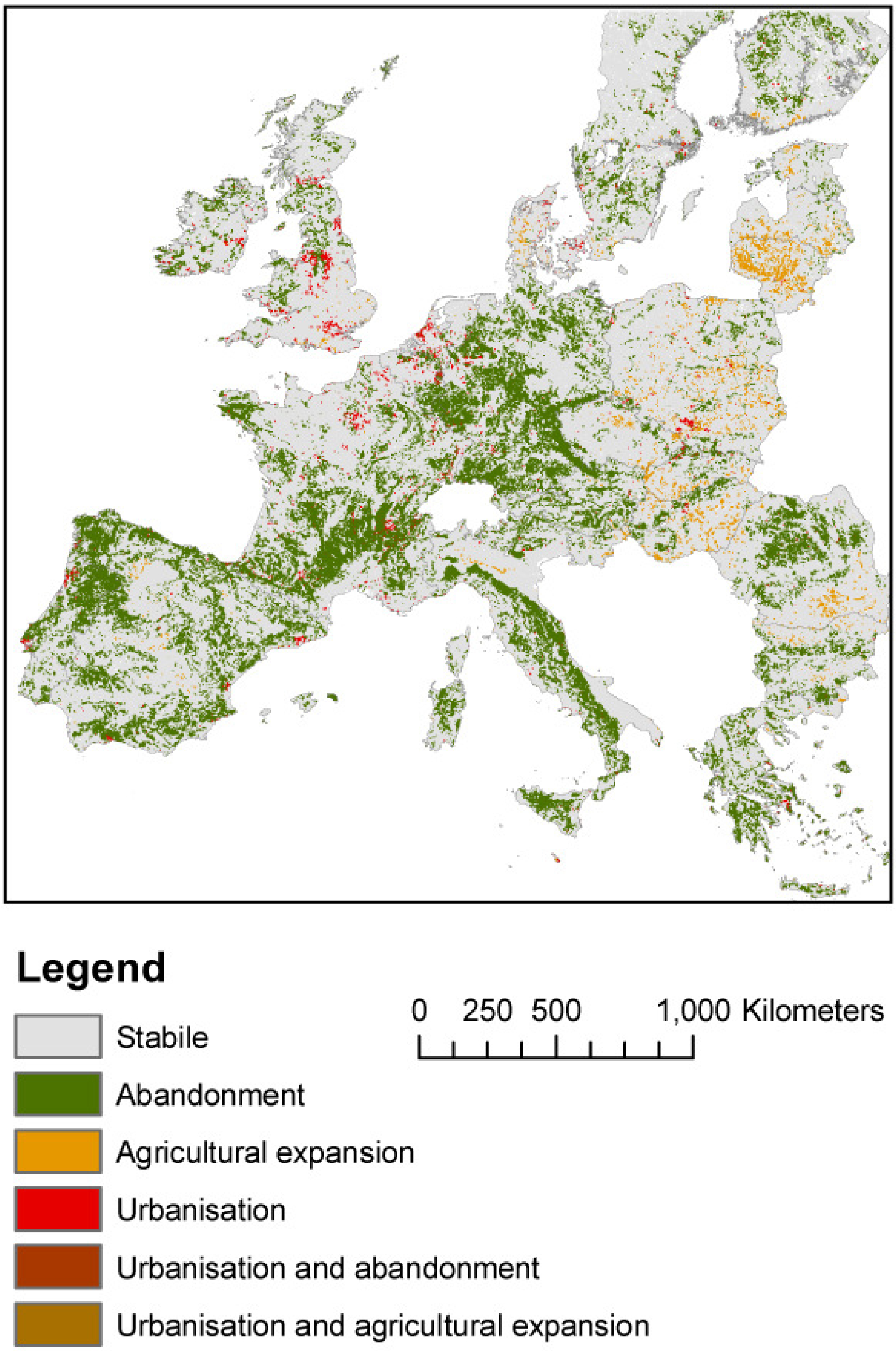
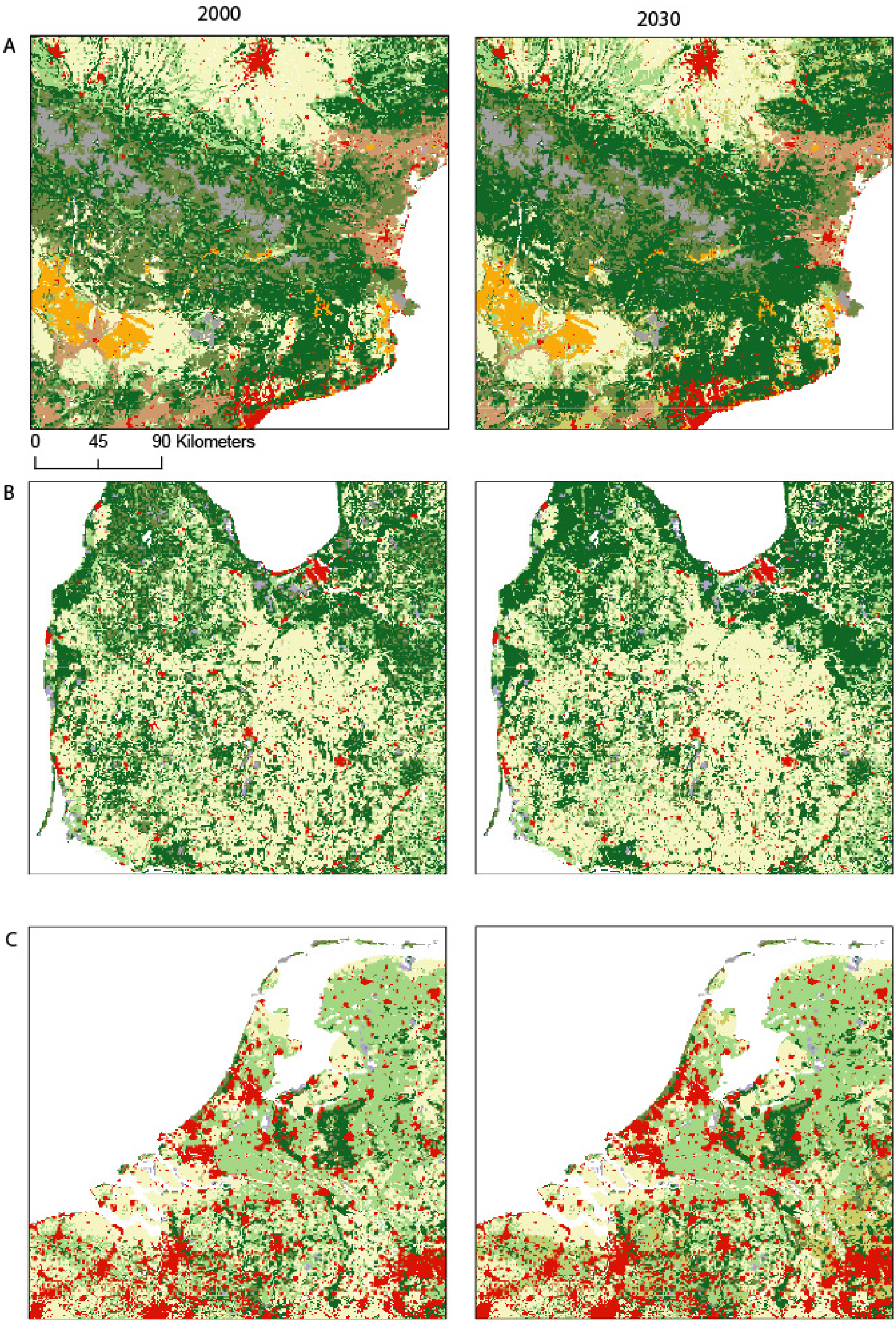


Figure 3.9. Generalised dominant land use / cover change for 2000-2030. Source: this study's modelled projections based on the B1 reference scenario

Table 3.6. Modelled projected changes in CORINE land cover types (km^2) according to the B1 Global Cooperation scenario

	Arable and biofuels			Grasslands			Forest			Semi-natural areas			Built -up areas		
	2000	2030	change	2000	2030	change	2000	2030	change	2000	2030	change	2000	2030	change
Austria	15160	10465	-31%	11908	10079	-15%	37570	38110	1%	14619	17204	18%	3506	3592	2%
Belgium	9960	7474	-25%	7113	6510	-8%	6108	6424	5%	1012	1697	68%	6245	6545	5%
Bulgaria	44736	41764	-7%	9580	8280	-14%	34812	42560	22%	15261	9331	-39%	5406	5462	1%
Cyprus	3767	3779	0%	535	537	0%	1562	1563	0%	2625	2451	-7%	687	831	21%
Czech Rep	34969	35103	0%	8578	7507	-12%	25544	26444	4%	4397	2587	-41%	4810	4901	2%
Denmark	29613	32008	8%	2704	2684	-1%	3709	1868	-50%	3104	2005	-35%	3044	3261	7%
Estonia	8523	8960	5%	5153	3623	-30%	20828	25525	23%	7693	2706	-65%	917	937	2%
Finland	19359	11522	-40%	5969	6044	1%	194095	233882	20%	79685	43342	-46%	4599	4731	3%
France	201465	159427	-21%	123216	113870	-8%	144979	160477	11%	47324	47328	0%	26497	28941	9%
Germany	151892	112303	-26%	59513	52998	-11%	103910	107985	4%	9111	23547	158%	28965	29559	2%
Greece	37548	32279	-14%	11011	5922	-46%	23449	29837	27%	54732	48802	-11%	2790	3096	11%
Hungary	53639	53465	0%	8946	7363	-18%	17348	17463	1%	5997	4993	-17%	5267	5378	2%
Ireland	7129	6923	-3%	38873	36779	-5%	2866	3222	12%	18108	17752	-2%	1322	1769	34%
Italy	126493	99256	-22%	24204	19775	-18%	78865	91245	16%	53131	58031	9%	14183	14569	3%
Latvia	13044	14416	11%	13992	12914	-8%	27016	31562	17%	8446	2514	-70%	850	855	1%
Lituania	27721	31414	13%	10637	10097	-5%	18607	16946	-9%	4378	2255	-48%	2137	2167	1%
Luxembourg	625	227	-64%	723	533	-26%	911	983	8%	104	394	279%	226	228	1%
Malta	46	45	-2%	67	66	-1%	3	2	-33%	104	84	-19%	87	110	26%
Netherlands	10880	9049	-17%	13939	13771	-1%	3138	3146	0%	1571	1926	23%	4524	5123	13%
Poland	153158	154816	1%	43017	39875	-7%	91882	88295	-4%	8817	6857	-22%	10410	11120	7%
Portugal	34053	24947	-27%	6565	2014	-69%	24364	28113	15%	20491	24026	17%	2392	2762	15%
Romania	96520	90254	-6%	34788	30770	-12%	69803	76338	9%	18018	15008	-17%	14898	15097	1%
Slovakia	18221	18759	3%	4962	4081	-18%	19332	20714	7%	3461	1176	-66%	2763	2869	4%
Slovenia	3154	3165	0%	3367	3056	-9%	11372	12184	7%	1732	779	-55%	543	566	4%
Spain	208665	187848	-10%	36590	21030	-43%	91969	110528	20%	149631	130238	-13%	7915	8568	8%
Sweden	32186	17579	-45%	5626	5111	-9%	252527	296450	17%	114783	82581	-28%	5972	6321	6%
UK	67066	65189	-3%	74445	68984	-7%	19839	20083	1%	61727	61071	-1%	18065	19923	10%


2000
2030
A
0 45 90 Kilometers
B
C

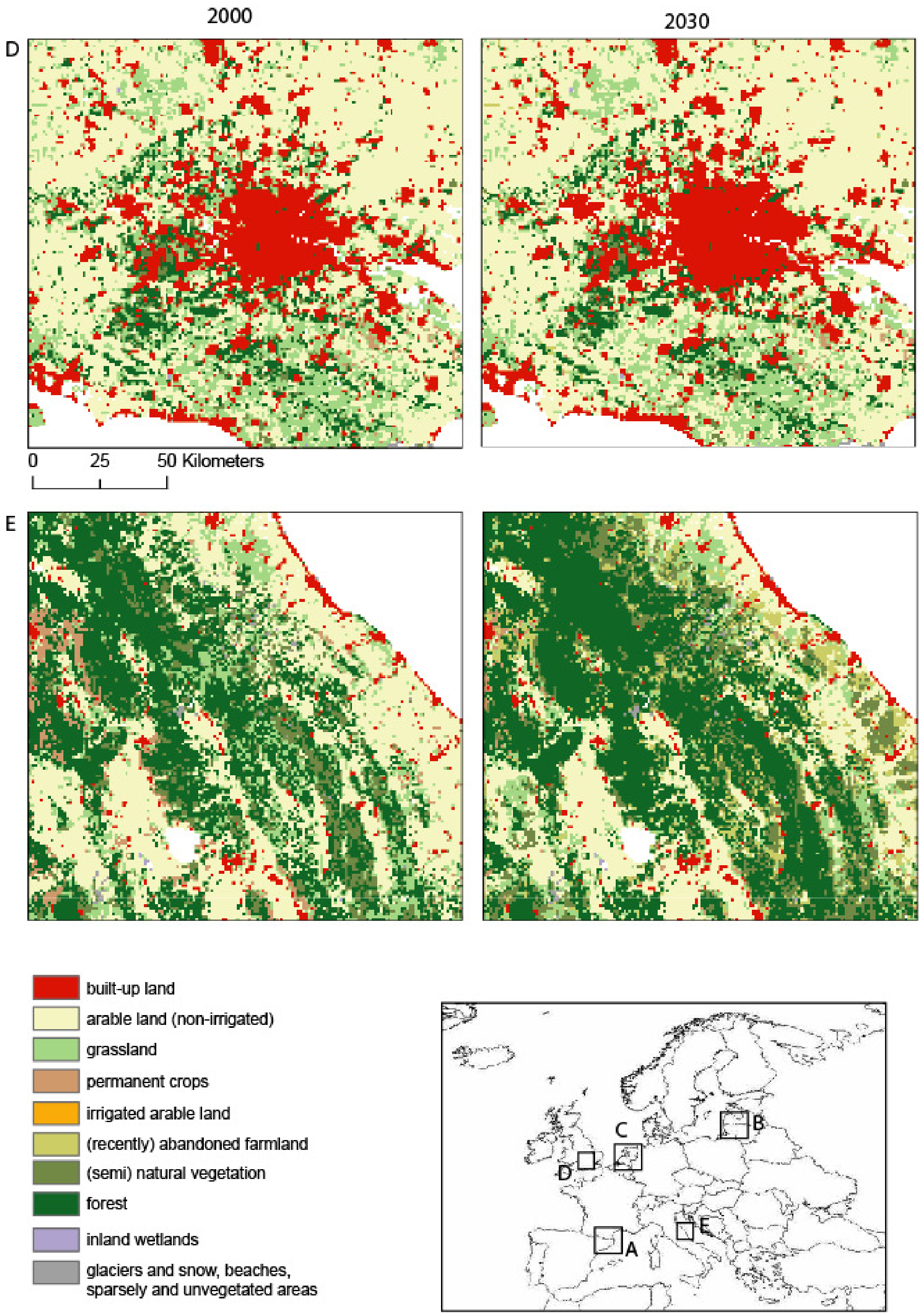


Figure 3.10. Snapshots of the dominant processes of land use change in specific areas of Europe. Source: this study's modelled projections based on the B1 reference scenario

Figure A,B,C are at the regional scale and D, E are enlarged to a high level of detail

Impact of the predicted changes in agricultural land use on High Nature Value farmland areas (HNV)

The impacts of the observed land use changes on soil sealing and habitat fragmentation (and corridors) are described in Chapters 4 and 5 respectively. This section describes an analysis of impacts on High Nature Value (HNV) farmland (see Box 3.1). The main aim of this analysis is to overlay the projected land cover/use changes with the estimated distribution of HNV farmland in Europe, in order to investigate how HNV farmland areas may be threatened by the conversion of land use.

BOX 3.1 The High Nature Value (HNV) Farming concept

The High Nature Value farming concept was established in the early 1990s and describes those types of farming activity and farmland that, because of their characteristics, can be expected to support high levels of biodiversity or species and habitats of conservation concern (Baldock *et al*, 1993; Beaufoy *et al*, 1994; Bignal and McCracken, 2000).

The farming of most value for biodiversity conservation across Europe is the low-intensity raising of livestock on unimproved vegetation that is grazed, browsed, or cut for hay, a fact that is widely supported by the scientific literature (see, for example, Bignal *et al*, 1994; Bignal and McCracken, 1996). This semi-natural farmland is unique in harbouring numerous habitat types from Annex 1 of the Habitats Directive, ranging from hay meadows to wood pastures and heaths. These habitats support communities of flora and fauna that depend on the continuation of low-intensity grazing and/or late mowing for their survival.

In many areas of Europe, semi-natural land cover survives only as smaller patches in a more intensively farmed landscape. These patches may still be of sufficient local value for biodiversity conservation to be considered as HNV farmland. This value normally will be greater where the semi-natural patches exist in a mosaic with low-intensity cultivated land. The biodiversity value of semi-natural elements and a diversity of land cover types is confirmed in many studies (see, for example, Billeter *et al*, 2008).

In most of Europe, arable farming has been intensified to the point where it can no longer be described as HNV, but there are some areas where this is not the case, especially in southern and eastern Europe. These are usually low-yielding, low-input dryland systems retaining a sizeable proportion of fallow and the presence of semi-natural vegetation, including elements such as permanent pasture and features such as field margins, headlands, patches of scrub and/or woodland. Often extensive grazing is part of the HNV land use, exploiting arable stubbles and semi-natural patches (see, for example, Robinson *et al*, 2001).

Permanent crops, particularly the most traditional fruit and nut orchards and olive groves, can be of high nature value. The key characteristics are large old trees and a semi-natural understorey, which is often grazed by livestock. The semi-natural understorey is an essential element in the biodiversity of HNV permanent crop systems, and should be present for all or most of the year. HNV permanent crops are not irrigated and nitrogen fertilisers, biocides or broad spectrum insecticides are not used, or only at very low levels. Significant semi-natural features associated with these systems can include field margins, headlands, patches of scrub and woodland, and dry stone walls (Baldock, 1999; Kabourakis, 1999).

Linear and point features on farmland, such as hedges and ponds, are also significant for other types of HNV farmland, such as in low-intensity bocage landscapes. Where linear and point features survive on intensively managed farmland they are important for conserving vestiges of biodiversity in landscapes that otherwise are of limited nature value.

A systematic presentation of the core characteristics of HNV farming has been developed through projects undertaken for the EEA (Andersen *et al*, 2003) and for the European Commission (IEEP, 2007; Beaufoy and Cooper, 2008). These characteristics are discussed below.

1. Low intensity farming characteristics - biodiversity is usually higher on farmland that is managed at a low intensity. The more intensive use of machinery, fertilisers and pesticides and/or the presence of high densities of grazing livestock, greatly reduces the number and abundance of species on cropped and grazed land.
2. Presence of semi-natural vegetation - the biodiversity value of semi-natural vegetation, such as unimproved grazing land and traditional hay meadows, is significantly higher than intensively managed agricultural land. In addition, the presence of natural and semi-natural farmland features such as mature trees, shrubs, uncultivated patches, ponds and rocky outcrops, or linear habitats such as streams, banks, field margins and hedges, greatly increases the number of ecological niches in which wildlife can co-exist alongside farming activities.
3. Diversity of land cover - biodiversity is significantly higher when there is a "mosaic" of land cover and land use, including low intensity cropland, fallow land, semi-natural vegetation and farmland features. Mosaic agricultural habitats are made up of different land uses, including parcels of farmland with different crops, patches of grassland, orchards, areas of woodland and scrub. This creates a wider variety of habitats and food sources for wildlife and therefore supports a much more complex ecology than the simplified landscapes associated with intensive agriculture.

The dominant characteristic of HNV farming is its low-intensity. A significant presence of semi-natural vegetation is also essential. In situations where the proportion of land under semi-natural vegetation is reduced, a high diversity of land cover (mosaic) under low-intensity farming may enable significant levels of biodiversity to survive, especially if there is a high density of features providing ecological niches. A high diversity of land cover alone does not indicate HNV farming.

In certain situations, it is possible for more intensive farmland, whose characteristics of farming intensity and land cover do not suggest HNV farming, nevertheless to continue to support important populations of species of conservation concern. Generally these are bird populations. Examples include the more intensively farmed cereal steppes in Spain and Portugal which maintain populations of species such as Great Bustard (*Otis tarda*). For these exceptional types of HNV farmland, the presence of one or more species populations may be a sufficient indicator

Source: European Evaluation Network for Rural Development (2009) Guidance Document: The Application of the High Nature Value Impact Indicator 2007-2013. http://ec.europa.eu/agriculture/rurdev/eval/hnv/guidance_en.pdf

The scenario based-outcomes provided by the CLUE model were used to derive land use changes that may occur between 2000 and 2030. The land use flows were overlaid with the potential distribution map of HNV farmland produced by the Joint Research Centre (JRC) - Institute for Environment and Sustainability and the EEA (Paracchini *et al*, 2008).

The mapped estimation of the distribution of HNV farmland at a European level is based on land cover and biodiversity data. The following Corine Land Cover classes were selected for this estimation.

- Arable land (except permanently irrigated land)
- Permanent crops fields
- Pasture
- Heterogeneous agricultural areas
- Scrub and/or herbaceous vegetation associations
- Sparsely vegetated areas
- Inland wetland + salt marshes

These classes can be related to the equivalent land use classes established by the CLUE methodology, and the Clue classes divided in two categories: HNV classes and non HNV classes as shown in Table 3.7.

Table 3.7. Reclassification of CLUE classes according to the HNV potential land cover

Potential HNV classes	**Non potential HNV classes**
Arable land (non-irrigated)	Built-up area
Pasture	Glaciers and snow
(Semi-) Natural vegetation*	Irrigated arable land
Inland wetlands	Forest
Recently abandoned arable land**	Beaches, dunes and sands
Permanent crops	Salines
Arable land devoted to the cultivation of (annual) biofuel crops	Water and coastal flats
Sparsely vegetated areas	
Heather and moorlands	
Recently abandoned pasture land***	

*including natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes
**i.e. "long fallow"; includes very extensive farmland not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30 cm
***includes very extensive pasture land not reported in agricultural statistics, grasses and shrubs below 30cm

The differences between the actual land use (2000) and the projected land use (2030) allows to visualize the changes in land use that may occur during this period. By combining the land use changes with the HNV farmland map (after only considering the cells currently covered by at least 50% of HNV farmland) an assessment of change in HNV areas was generated (Table 3.8).

Table 3.8 presents the percentage of conversion as well as the percentage of permanency for each CLUE land use classes inside potential HNV areas between 2000 and 2030. The land use classes corresponding to potential HNV farmland are highlighted in green (shaded). The projected land use changes indicate a tendency for abandonment of agricultural activities in HNV areas. Indeed, 9.0% of the non irrigated arable land may become (semi-) natural vegetation area, and 10.8% may turn into recently abandoned arable land. The projected abandonment trend for pasture is even greater with 20.4% developing into recently abandoned pasture, and 7.7% into (semi-) natural vegetation areas. Regarding semi-natural vegetation areas, 17.3% is expected to be converted into forest, which confirms the abandonment trend found in the HNV farmlands. Moreover 8.5% of the permanent crops category may also be converted into recently abandoned arable lands.

The projections do suggest that an insignificant area of HNV farmland will be at risk of intensification.

Table 3.9 shows the changes of land use between 2000 and 2030, for each land use class, and indicates if the changes are to other HNV classes or to non HNV classes. The projected trends indicated in Tables 3.9 and 3.10 are generally in line with the abandonment trends observed at an EU level (see discussion of model validation below).

According to Table 3.9, only (semi-) natural vegetation classes change to classes outside the HNV categories, implying a loss of HNV area. In addition, Table 3.8 shows that the changes occurring for the other HNV classes are mainly conversion to (semi-) natural vegetation or abandonment. Although such classes may remain suitable for HNV farmland for a while, eventually it may lead to the loss of HNV farmland.

Table 3.8. Land use flow inside HNV areas between 2000 and 2030. Source: this study's modelled projections based on the B1 reference scenario

Clue class 2030 / 2000	0. Build-up area	1. Arable land (non irrigated)	2. Pasture	3. (Semi-) natural vegetation	4. Inland wetlands	5.Glaciers and snow	6.Irrigated arable land	7. Recently abandoned arable land	8. Permanent crops	9. Arable land for annual biofuel crops	10. Forest	11. Sparsely vegetated areas	12.Beach, dunes and sands	13. Salines	14. Water and coastal flats	15.Heather and moorlands	16. Recently abandoned pasture	17. Perennial biofuel crop
0. Build-up area	100.00%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1. Arable land (non irrigated)	0.26%	68.85%	4.34%	9.05%	0.00%	0.00%	0.00%	10.77%	0.38%	5.42%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.60%	0.00%
2. Pasture	0.46%	0.11%	70.48%	7.73%	0.00%	0.00%	0.00%	0.00%	0.53%	0.02%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	20.44%	0.00%
3. (Semi-) natural vegetation	0.02%	1.76%	0.53%	79.98%	0.00%	0.00%	0.00%	0.07%	0.00%	0.20%	17.35%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%
4. Inland wetlands	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
5. Glaciers and snow	-	-	-	-	-	100.00%	-	-	-	-	-	-	-	-	-	-	-	-
6. Irrigated arable land	-	-	-	-	-	-	100.00%	-	-	-	-	-	-	-	-	-	-	-
7. Recently abandoned arable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Permanent crops	0.11%	0.77%	3.15%	4.14%	0.00%	0.00%	0.00%	8.50%	83.07%	0.08%	0.03%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	0.00%
9. Arable land for annual biofuel crops	0.00%	10.64%	5.45%	1.61%	0.00%	0.00%	0.00%	6.44%	0.00%	75.87%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10. Forest	0.02%	1.44%	0.52%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.17%	97.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%
11. Sparsely vegetated areas	-	-	-	-	-	-	-	-	-	-	-	100.00%	-	-	-	-	-	-
12. Beaches, dunes and sands	-	-	-	-	-	-	-	-	-	-	-	-	100.00%	-	-	-	-	-
13. Salines	-	-	-	-	-	-	-	-	-	-	-	-	-	100.00%	-	-	-	-
14. Water and coastal flats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.00%	-	-	-
15. Heather and moorlands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.00%	-	-
16. Recently abandoned pasture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17. Perennial biofuel crop cultivation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.9. Land use flow summary for CLUE land use classes. Source: this study's modelled projections based on the B1 reference scenario

	No change	Other HNV class	Non HNV class
Built-up area	100.00%	-	-
Arable land (non irrigated)	68.85%	30.57%	0.58%
Pasture	70.48%	28.84%	0.68%
(Semi-) natural vegetation	79.98%	2.65%	17.37%
Inland wetlands	100.00%	0.00%	0.00%
Glaciers and snow	100.00%	-	-
Irrigated arable land	100.00%	-	-
Recently abandoned arable land	-	-	-
Permanent crops	83.07%	16.79%	0.14%
Arable land for annual biofuel crops	75.87%	24.13%	0.00%
Forest	97.80%	2.18%	0.02%
Sparsely vegetated areas	100.00%	-	-
Beaches, dunes and sands	100.00%	-	-
Salines	100.00%	-	-
Water and coastal flats	100.00%	-	-
Heather and moorlands	100.00%	-	-
Recently abandoned pasture land	-	-	-
Perennial biofuel crop cultivation	-	-	-

A more detailed analysis of the projected changes at Member State level in arable land, pasture and (semi-) natural vegetation is provided in Table 3.10. The pattern of abandonment is also evident in this table, where the main trend for arable land and pastures is conversion to other HNV land use types and for (semi-) natural vegetation to turn into non HNV land use class. Most of the countries show the same abandonment trend. The loss of HNV pasture areas in the Mediterranean countries (Greece, Spain, Portugal and Italy) to other HNV classes is particularly significant. Discussion of the potential impacts of these projected changes in HNV farming areas is provided in Section 8.2.

Table 3.10. National level land use flows inside HNV farmlands areas. Source: this study's modelled projections based on the B1 reference scenario

NB. 100% = total HNV area of the country

	Arable land (non irrigated)+ Arable land for annual biofuel crops			**Pasture**			**(Semi-) natural vegetation**		
	Other HNV classes	No HNV classes	No changes	Other HNV classes	No HNV classes	No changes	Other HNV classes	No HNV classes	No changes
Austria	61.0%	2.2%	36.8%	26.9%	0.3%	72.8%	0.3%	7.4%	92.4%
Belgium	56.1%	1.5%	42.4%	15.6%	0.8%	83.5%	0.0%	55.9%	44.1%
Bulgaria	29.2%	0.5%	70.3%	36.1%	0.3%	63.6%	1.8%	57.9%	40.4%
Cyprus	1.6%	3.2%	95.2%	2.8%	10.7%	86.4%	6.3%	0.3%	93.4%
Czech Rep.	11.5%	0.0%	88.5%	24.8%	0.3%	74.9%	2.7%	46.8%	50.5%
Denmark	6.1%	0.0%	93.9%	1.5%	0.0%	98.5%	19.9%	6.2%	73.9%
Estonia	0.6%	0.0%	99.4%	31.1%	0.5%	68.4%	2.2%	88.5%	9.3%
Finland	51.4%	0.8%	47.8%	18.0%	0.5%	81.5%	0.0%	95.9%	4.1%
France	63.6%	2.1%	34.3%	22.4%	0.7%	76.9%	0.0%	37.3%	62.7%
Germany	50.5%	0.8%	48.7%	18.1%	0.7%	81.3%	0.1%	61.3%	38.6%
Greece	58.9%	0.5%	40.7%	63.7%	0.3%	36.0%	2.7%	8.4%	88.9%
Hungary	2.2%	0.0%	97.8%	21.8%	0.5%	77.7%	20.4%	12.7%	66.9%
Ireland	13.9%	0.0%	86.1%	41.0%	0.6%	58.3%	0.0%	19.1%	80.9%
Italy	49.1%	1.2%	49.7%	47.3%	1.1%	51.6%	0.0%	18.6%	81.3%
Latvia	0.0%	0.0%	100.0%	10.5%	0.0%	89.5%	6.1%	77.6%	16.2%
Lithuania	0.2%	0.0%	99.8%	6.3%	0.2%	93.6%	28.8%	32.0%	39.2%
Luxembourg	14.3%	21.4%	64.3%	5.9%	0.0%	94.1%	0.0%	87.5%	12.5%
Malta	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Netherlands	43.5%	0.0%	56.5%	0.3%	1.0%	98.7%	1.8%	15.9%	82.3%
Poland	4.9%	0.2%	94.9%	14.6%	0.8%	84.5%	2.8%	48.0%	49.3%
Portugal	24.5%	0.1%	75.4%	63.8%	1.1%	35.0%	0.0%	9.7%	90.3%
Romania	25.8%	0.5%	73.7%	22.0%	0.3%	77.7%	4.6%	61.1%	34.4%
Slovakia	21.6%	1.0%	77.4%	28.6%	1.1%	70.4%	6.7%	49.4%	43.9%
Slovenia	14.9%	1.6%	83.5%	7.3%	0.4%	92.4%	4.1%	87.7%	8.2%
Spain	16.0%	0.2%	83.9%	56.3%	0.6%	43.1%	4.0%	11.9%	84.0%
Sweden	45.7%	12.0%	42.4%	35.5%	4.2%	60.3%	0.0%	63.5%	36.5%
UK	6.8%	1.7%	91.5%	29.3%	0.6%	70.1%	0.1%	5.3%	94,6%

Validation of the Dyna-CLUE model results

The validity of land use change models should be judged with respect to the intended use of the model results. In this respect it should be noted that the simulation results of Dyna-CLUE are not meant as predictions of future land use but rather as projections based on the assumed scenario conditions, or as a quantified visualization of the qualitative scenario descriptions. However, validation could still contribute to an assessment of the validity and uncertainty in the modelling procedure.

Different versions of the CLUE model have been validated with good results in different applications across the world (Kok *et al*, 2001; Verburg *et al*, 2002). The validity of a model is mainly determined by specific case studies and the quality of the input data. This is also the result of an independent validation conducted by Gil Pontius (Clarke University, US) of a series of eight different land use models. For the evaluated applications CLUE was amongst the best performing land use models in this domain over a wide range of scales (Pontius *et al*, 2008).

To assess the validity of the specific model application at the European scale, consistent European land use data area needed for at least two years. A calibrated model could simulate change in this period and be validated. However, consistent European land use data over such a time span are scarce. The best source of such data is the CLC 1990-2000 land use change dataset, used in this project, which reports observed changes in land use between 1990 and 2000 for the European territory. Levels of correspondence between the observed data and simulated data are low. However, it is unclear to what extent this low level of correspondence can be attributed to model inaccuracy. Observed areas of land use change within the CLC 1990-2000 land cover change dataset do not correspond with reported 'hot-spots' of change from case studies. Figure 3.11 indicates the areas of agricultural abandonment in Europe based on land cover data (derived from remote sensing interpretation of the CORINE database (EEA, 2005b; Haines-Young and Weber, 2006)).

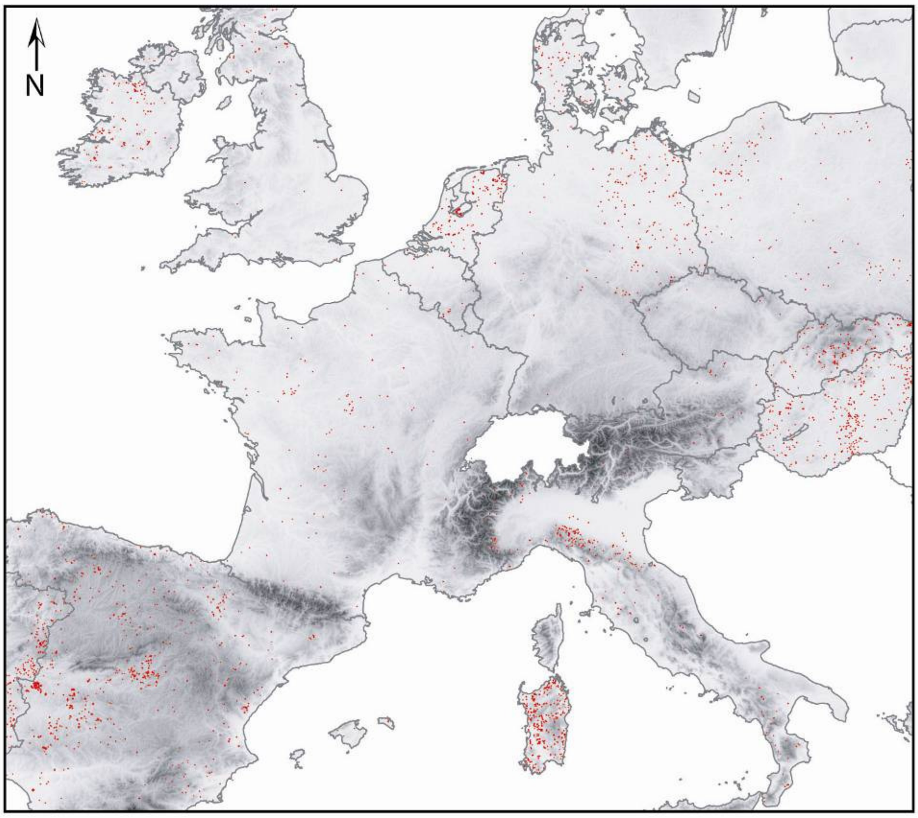


Figure 3.11. Areas of land abandonment (red) according to the CLC1990-2000 dataset

In a small number of countries the 'hot-spots' of land abandonment on the land cover map correspond to areas frequently cited in literature as facing abandonment (e.g. the Italian mountain areas (Falcucci *et al*, 2007). However, the mountain areas that are mentioned in literature as 'hot-spots' of agricultural abandonment do not appear in this map for the larger part of Europe; examples include the French and Spanish Pyrenees (Poyatos *et al*, 2003; Mottet *et al*, 2006), Massif Central area in France (Etienne *et al*, 2003), Austrian alps (Tasser *et al*, 2007), German mountain areas (Reger *et al*, 2007) and most of the 24 mountain areas reported by (MacDonald *et al*, 2000). These large differences can (partly) be attributed to the inability to distinguish land cover based on remote sensing based land cover maps and other land use/land cover discrepancies.

In contrast the projections indicated in Figure 3.9 from this study do have a high level of correspondence with the above case study evidence and risk areas identified according to drivers of marginalisation, as discussed in Section 7.3.2 (see Figure 7.4). But the findings of the recent DG ENV study on Green Infrastructure[24] do not match the observations from these case studies. This may be because the LUMOCAP model has been calibrated towards the CLC 1990-2000 change maps.

In addition to the data-driven and case-study evidence validation, the results of the model have also been subjectively evaluated by experts from different Member States. In general the

[24] http://green-infrastructure-europe.org/index.php?option=com_content&task=view&id=166&Itemid=376

overall patterns of change matched the expectations of the experts (or could otherwise be explained), which provides another level of confidence in the model results.

Nevertheless, despite the encouraging results of the diverse validation exercises, it should be noted that land use changes are the results of complex interactions between multiple drivers and individual farm-level decisions, and therefore modelled projections have high levels of inherent uncertainty. This uncertainty should be taken into account when drawing conclusions and considering potential policy responses.

Another current study for DG Environment on Land Use Modelling Implementation is currently underway, and this may provide more certain estimations of likely land use change. But the results are not yet available and therefore cannot be taken into account in this study.

3.4.3 Conclusions

The structure of agricultural production and spatial patterns of agricultural land use in Europe are expected to face major changes over the next decades due to changes in global trade, technology, demography and policies. Busch (2006) studied 25 scenarios comprising information on quantitative land use changes in Europe, including the scenarios from the EURuralis study that have been applied in the present study. These studies had different foci, operating on both different spatial scales and different time horizons. Given the diversity of quantitative scenarios, Busch illustrated in his review the scenario design and its quantification, and evaluated the results of land use/cover changes on a European level. He focused on the comparison of selected driving forces on agricultural land use/cover change in 'Western Europe' (i.e. EU-15 plus Switzerland and Norway for some studies). Results show large differences in future land use/cover changes ranging from moderate decreases (15%) to large increases (30%) depending on the assumptions about global trade, increase in agricultural productivity and biofuel production. Domestic demand is a minor factor of land use/cover change since populations are only changing slightly, and consumption levels are stable and decoupled from economic growth. Scenarios show that the rate and direction of land cover change differ over time. Considerable shifts towards grassland abandonment in many scenarios reflect changes in agricultural management. Increasing biofuel production as a result of both increasing energy demand and pro-active climate policies takes up considerable areas in many scenarios and prevents substantial abandonment of agricultural land. Although comparable quantitative results concerning European agricultural land use/cover change are only available at a highly aggregated level, the results are relevant to discussions on future challenges in rural areas.

Cropland change

In the 'Global Society' scenario category (corresponding to the B1 reference scenario selected in this study), the divergence of decreases and increases in cropland area is smaller than shown for the scenarios of the 'Global Markets' category. The IPCC-SRES 'B1' scenario and the GEO-3/ RIVM 'Sustainability First' scenario show an increase of cropland area due to highest crop production combined with lowest increase in crop yields. The two scenarios with moderate to high increases in yields but reduced growth in crop production (ATEAM 'B1' and EURuralis) show a decrease in crop area.

Pasture change

Diverging pathways of pastureland are characteristic for all scenario categories. In the two global-oriented categories, the development of pastureland varies between slight and considerable decreases in area. In the two regional oriented categories, the divergences range between slight increases and considerable decreases in pasture area. The rate at which pastureland decreases and its trend reflect both the different assumptions on intensification in livestock production (e.g. increasing productivity, less grazing) and a shift from grass-based production systems towards fodder crops. This shift in turn results from two changes in animal production (1) change in feed composition and (2) preference change in meat consumption from ‘‘red meat’’ (beef) towards ‘‘white meat’’ stemming from pork and poultry production. The results of the B1 scenario reflect assumptions on grassland preservation as part of both environmental policy goals and restrictive planning.

4 SOIL SEALING: TRENDS, PROJECTIONS, POLICY INSTRUMENTS AND LIKELY IMPACTS ON LAND SERVICES

4.1 INTRODUCTION

The specification for the tasks described in this chapter is provide below.

On the basis of the information gathered under task 1, the contractor shall:
- *assess the role of the drivers that cause sealing, of current (EU) legislation favouring or hindering sealing and of the current instruments used by Member States to avoid or limit this process (e.g. land planning, legal and financial instruments, but also other types of instruments, such as strategies for the protection of good agricultural soils;*
- *assess the likely impacts of (trends in) soil sealing on the land services. To the extent it is feasible, this assessment should be quantitative.*

In practice, these components of the study were divided into the following three sub-tasks:
- Task 2.1. Assessment of drivers causing soil sealing and likely trends.
- Task 2.2. Assessment of legislation and instruments related to soil sealing.
- Task 2.3. Estimation of impacts of soil sealing on land services.

The analysis of drivers and trends was carried out in the first task, because information on land cover flows and trends gives insights into the land use change drivers of soil loss (in accordance with the methodology proposed by Huber *et al*., 2008). The methods, results and conclusions from each of these sub-tasks are described below.

4.2 ASSESSMENT OF DRIVERS CAUSING SOIL SEALING AND LIKELY TRENDS

4.2.1 Introduction

Internationally recognized definitions of soil sealing are scarce. The definition put forward by the Working Group on Research, Sealing and Cross-cutting issues contributing to the Soil Thematic Strategy (EC, 2006c) reads: "Soil sealing is the separation of soils from other compartments of the ecosystem, such as biosphere, atmosphere, hydrosphere, anthroposphere and other parts of pedosphere". The definition employed by the ENVASSO project is: "the destruction or covering of soil by buildings, constructions and layers of completely or partly impermeable artificial material (asphalt, concrete)" (Burghardt *et al*., 2004, in: Huber *et al*., 2008).

Soil sealing occurs as a result of the development of housing, industry, transport and other physical infrastructure, including utilities (e.g. waste disposal and water distribution) and military installations, as a result of the wider process of land consumption (Huber *et al*., 2008). Land consumption is a broader concept, that relates to all land development for settlement-related human activities by which previously undeveloped land, not primarily dedicated for biomass production, is turned into built-up areas. Land affected by land consumption comprises sealed areas (buildings, road surfaces, car parks, etc.) and unsealed areas (residential gardens, residual space between buildings, unsealed parts of transport corridors) (Van Camp *et al*., 2004; Huber *et al*.., 2008).

Soil sealing affects soils by disturbing the hydrological, geochemical and soil-surface energy balances of the soil. This has consequences for the major functions that soils provide to society (Box 4.1), and through these, on the land use services (Figure 4.1). The land use services addressed in this study are facilitated by functions of the different compartments involved in human-environment systems: the human environment, the biosphere, the atmosphere and the geosphere. The soil functions are part of the geosphere compartment. The relationships between soil functions and land use services is illustrated in Figure 4.1. The figure shows that multiple soil functions facilitate each land use service, but that for each land use service, one soil function is dominant.

Soil sealing changes the suitability of soils for certain functions to other functions, and possibly prevents the further use of soils for the functions under the land cover before soil sealing occurred. The negative effects vary from loss of net primary productivity of the landscape and natural habitats to increased floods, pollution and health risks and consequently higher societal costs (Imhoff *et al*., 2004; Scalenghe and Marsan, 2009; Lorenz and Lal, 2009). On the other hand, soil sealing may also be regarded as a tool to protect environmental compartments to soil threats, such as contamination (Scalenghe and Marsan, 2009).

Until recently, soil has predominantly been perceived in the context of its agricultural production function (F1, Box 4.1). Over the last decades, the awareness has grown that soils provide goods and services which are vital for land and aquatic ecosystems, and also has many other important societal functions (Box 4.1) (Tóth *et al*., 2008a; Bouma, 2009). This has resulted in the design of EU's Thematic Strategy for Soil Protection (COM(2006)233 final).

Box 4.1. The seven main functions of soil, as defined in the Soil Thematic Strategy (COM(2002) 179 final).

The seven main functions of soil

F1: food and other biomass production

F2: storing, filtering and buffering of materials

F3: habitat and gene pool of living organisms

F4: physical and cultural environment for humankind

F5: source of raw materials

F6: acting as a carbon pool

F7: archive of geological and archaeological heritage

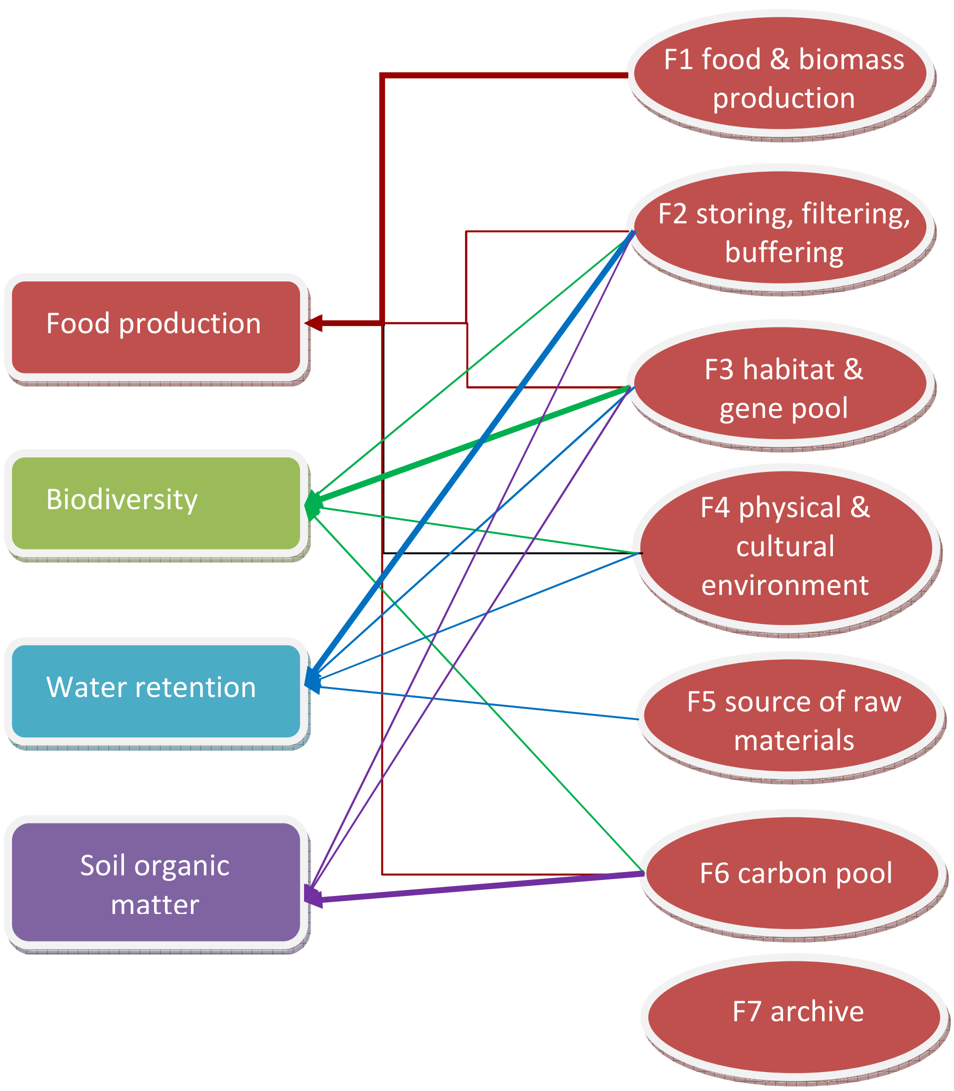


Figure 4.1 Relations between soil functions (see Box) and land use services

Each arrow represents the answer 'yes' to the question: "Does the ability of the soil to provide this function add to the land use service in question?". Most important relationships marked by thick lines.

The performance of soils for the benefit of these functions is determined by amongst others, biological, chemical and physical characteristics, which vary in time and space. Soil classification systems can help to represent these characteristics, although it is not possible to derive performance indicators for soil (or land use) services directly from soil classification systems. The reason for this are that soils may perform multiple functions at the same time, while sets of soil characteristics beneficial for one function may be detrimental to others, and trade-off mechanisms are difficult to establish (Patzel *et al*., 2000; Sojka *et al*., 2003). Secondly, external factors like climate, land use and land management also determine the performance of soils for different soil functions.

4.2.2 Methods

Assessment of trends and drivers in soil sealing

Trends in soil sealing were estimated based on calculations of the extent and growth in built-up areas from the CORINE land cover database (CLC 1990, 2000, supplied by Task 1 as land cover flows) on the basis of satellite images (EC & EEA, 2005; in: Huber *et al.*, 2008). In addition, the Land and Ecosystem Accounts (LEAC)[25] for Europe (1990-2000) were used.

Land cover flows were grouped according to the LEAC Methodological Guidebook (EEA, 2005b). Soil sealing is part of the group of land cover flows leading to the formation of artificial surfaces (Box 4.2). Land cover flows at the first level of grouping were used to analyse trends in soil sealing (LCF1, 2 and 3).

It is also possible that artificial surfaces are converted to other land cover types. The land cover flows expressing these conversions are summarized in Box 4.3. Of these, only the conversion of developed land to agriculture (LCF 54) refers uniquely to artificial surfaces as source land cover types; the other land cover flows may also draw from other source land cover types.

[25] http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=884

Box 4.2. Land cover flows resulting in the formation of artificial surfaces
Source: LEAC Methodological Guidebook (EEA, 2005b).
LCF1 Urban land management: Internal transformation of urban areas.
• **lcf11 Urban development/ infilling**: Conversion from discontinuous urban fabric, green urban areas and sport and leisure facilities to dense urban fabric, economic areas and infrastructures.
• **lcf12 Recycling of developed urban land:** Internal conversions between residential and/or nonresidential land cover types. Construction of urban greenfields is not considered here but as lcf11.
• **lcf13 Development of green urban areas:** Extension of green urban areas over developed land as well as, in the periphery of cities, over other types of land uses.
LCF2 Urban residential sprawl: Land uptake by residential buildings altogether with associated services and urban infrastructure (classified in CLC 111 & 112) from non urban land (extension over sea may happen).
• **lcf21 Urban dense residential sprawl:** Land uptake by continuous urban fabric (CLC 111) from non urban land
• **lcf22 Urban diffuse residential sprawl:** Land uptake by discontinuous urban fabric (CLC 112) from non urban land.
LCF3 Sprawl of economic sites and infrastructures: Land uptake by new economic sites and infrastructures (including sport and leisu4re facilities) from non urban land (extension over sea may happen).
• **lcf31 Sprawl of industrial & commercial sites:** Non urban land uptake by new industrial and commercial sites
• **lcf32 Sprawl of transport networks:** Non urban land uptake by new transport networks (note that linear features narrower than 100 m are not monitored by CLC).
• **lcf33 Sprawl of harbours:** Development of harbours over non urban land and sea.
• **lcf34 Sprawl of airports:** Development of airports over non urban land and sea.
• **lcf35 Sprawl of mines and quarrying areas:** Non urban land uptake by mines and quarries.
• **lcf36 Sprawl of dumpsites:** Non urban land uptake by waste dumpsites.
• **lcf37 Construction:** Extension over non-urban land of areas under construction during the period (note: covers mainly construction of economic sites and infrastructures).
• **lcf38 Sprawl of sport and leisure facilities:** Conversion from developed as well as non-urban land to sport and leisure facilities.

Box 4.3. Land cover flows from artificial surfaces to other land cover types

Source: LEAC Methodological Guidebook (EEA, 2005b).

- **lcf54 Conversion from developed areas to agriculture:** Conversion of urban land to any type of farmland (CLC2)
- **lcf72 Forest creation, afforestation:** Forest creation and afforestation take place on all previously non agricultural landscapes where new forests can be identified. Extension of transitional woodland shrub over non-agricultural land is recorded as afforestation. Conversion from transitional woodland to broadleaved, coniferous or mixed forest are not a creation of forest territory and are therefore registered separately (lcf71).
- **lcf91 Semi-natural creation and rotation:** Changes in natural and semi-natural land cover due to natural factors
- **lcf911 Semi-natural creation:** Natural colonisation of land previously used by human activities.
- **lcf92 Forests and shrubs fires:** Forest and shrub fires. Due to the short cycle of recovery of vegetation from fire, burnt areas (which are well identified on satellite images) cannot be compared in a 10 years interval, except for very aggregated statistics.
- **lcf93 Coastal erosion:** Conversion of all land cover types to intertidal flats, estuaries or sea and ocean. The tide level when the satellite image is shot being unknown of the photointerpretors, the coastal erosion flow has to be used very carefully.
- **lcf81 Water bodies creation:** Extension of water surfaces resulting from the creation of dams and reservoirs

For the time frame 1960-1990, a rough analysis was made of the change in urban area based on a comparison of land cover stocks from the HISLU60 and CLC1990 databases. An analysis of trends in soil sealing from 1960 to 1990 at the level of NUTS0 or higher is not possible based on a comparison of land cover stocks from the HISLU60 and CLC1990 databases, due to the different origin of the datasets and the underestimation of the urban area in the HISLU60 database.

Trends in soil sealing for the period 1990-2000 were analysed for administrative levels at the NUTS0 level. However, tables with land cover stocks for NUTS1 and 2 units in 1990 and 2000 were provided by Task 1 (Annexes 1.2 and 1.3). Stocks of artificial surfaces are represented separately in these tables at the 3 levels of the CLC legend (Table 4.1). For detailed information on these stocks per NUTS unit the reader is referred to these tables.

Table 4.1. CORINE Land Cover 2000 classes for artificial surfaces (based on class 1 at level 1)

Code level 3	Label level 1	Label level 2	Label level 3
111	Artificial surfaces	Urban fabric	Continuous urban fabric
112	Artificial surfaces	Urban fabric	Discontinuous urban fabric
121	Artificial surfaces	Industrial, commercial and transport units	Industrial or commercial units
122	Artificial surfaces	Industrial, commercial and transport units	Road and rail networks and associated land
123	Artificial surfaces	Industrial, commercial and transport units	Port areas
124	Artificial surfaces	Industrial, commercial and transport units	Airports
131	Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites
132	Artificial surfaces	Mine, dump and construction sites	Dump sites
133	Artificial surfaces	Mine, dump and construction sites	Construction sites
141	Artificial surfaces	Artificial, non-agricultural, vegetated areas	Green urban areas
142	Artificial surfaces	Artificial, non-agricultural, vegetated areas	Sport and leisure facilities

Trends in soil sealing for the period 2000-2030 were derived from the simulations with the GTAP, IMAGE and CLUE model chain for global change scenario B1 (source: Tasks 1 results in Chapter 3).The change in built-up area was calculated for NUTS0 units from estimates of the change in built-up area for residential purposes, industrial activities, services and infrastructure. Changes for residential purposes were determined based on demographic projections, and changes in population density as a function of changes in income. The projections of population growth and change in income were based on the model assumptions as described in Task 1. An economic model was used to calculate the changes in the industrial and service sector (Van Meijl *et al.*, 2006). The demand for built-up area was based on these changes.

The assessment of drivers of soil sealing was based on the analysis of land cover flows resulting in the land take for artificial surfaces in the time frames 1960-1990, 1990-2000 and 2000-2030. Land cover flows concerning the conversion of artificial surfaces into other types of land cover were considered. These provide information on the proportion of land take by different types of human activities, giving insight into the processes and drivers underlying soil loss due to soil sealing. Due to the lack of information on source land cover types of land converted to urban area in the available tables with land cover stocks, drivers for soil sealing could not be derived for the time frame 1960-1990.

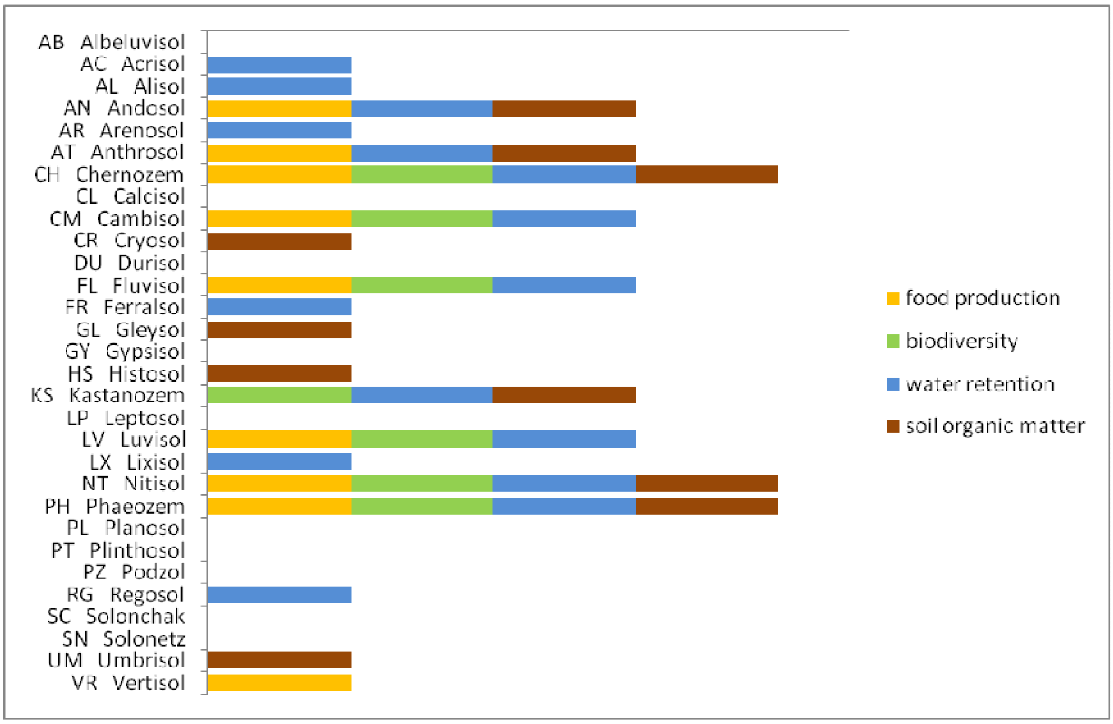
Assessment of impacts of soil sealing on soil resources

Impacts of soil sealing on land use services were partly assessed through an analysis of the impacts on soil resources. Impacts of soil sealing on soil resources in the periods 1990-2000 and 2000-2030 were inventoried by overlaying maps of land cover flows for the periods with the European soil map, derived from the European Soil Database (v2.0) (Annex 2.1).

In order to express the influence of soil sealing on land use services through the analysis of impacts on soil resources, we need a relationship between soil resources and their potential importance for land use services. The soil classification system used in the European Soil Database (v2.0), the World Reference Base for Soil Resources (WRB; IUSS Working Group, WRB, 2006) was used to guide inferences on the performance of land use services as influenced by changes in land use due to soil sealing. The advantage of using this system is that it has a global context, enabling correlations with soil resources outside Europe (Tóth *et al*., 2008a). In order to keep the analysis simple, the soil classification was used in this study at the level of Reference Soil Groups.

The performance of soils – through soil functions - with regard to land use services is difficult to indicate for Reference Soil Groups, even qualitatively, because of the large variation in soils covered by each Reference Soil Group, and due to dependency of land use services on land use and climate change, which are (deliberately) not expressed in the soil classification system. Nonetheless, an attempt was made to give a broad indication of the importance of the Reference Soil Groups (RSGs) in the WRB system (2006) for the land use services (Figure 4.3). The figure indicates the RSGs which are most likely to include soils which are well suitable to facilitate a good performance of the land use services. The figure was based on expert judgement from soil experts.

Figure 4.3. Broad importance of Reference Soil Groups in the WRB soil classification for land use services.



Importance for **food production**: good structure, water holding capacity and nutrient status, good workability and trafficability

Importance for **biodiversity:** deep soils, rich in soil organic matter, without extremely low or high values of pH

Importance for **water retention**: soils easily capable to store water, not shallow or originally wet soils

Importance for **soil organic matter**: soils with by genesis high organic matter contents. Importance depends on the ecosystem of which these soils are part.

Data sources

At the European level, there is a lack of quantitative information on soil sealing, land consumption and response measures. Data are available for some member states, but much of these are not comparable since different methods were used to obtain these data. At the European level, land consumption is assessed by calculating the extent and growth in built-up areas from the CORINE land cover database (1990, 2000, 2006) on the basis of satellite images (EC & EEA, 2005; in: Huber *et al*., 2008).

Within built-up areas, unsealed areas exist in gardens, parks and recreational areas. Although such areas may contain sealed layers at depth, they can have an important influence on soil functions within urban areas, and require appraisal in detailed studies (Verburg and Westhoek, 2006; Law *et al*., 2009). However, information on areas of sealed soil within built-up area is not available at the European level. Under the joint programme GMES (Global Monitoring for Environment and Security of EC and ESA) a European wide soil sealing layer with a resolution of 20 m is under development. However, the dataset does not provide information on the type of artificial surface. This is because currently, there is no information available on the relationships between types of artificial surfaces and the % area sealed (Koomen[26], pers.comm.;Huber *et al.*, 2008).

For use in the analysis of trends for soil sealing, the dataset should be compared with the CLC 2000 and CLUE 2030. For a sound comparison with the CLC2000 dataset, either the % area sealed of the EEA dataset would need to be translated into the types of artificial surfaces defined in the CLC legend (level 2 or 3), or vice versa. Spatially differentiated information is lacking to perform either of these translations.

For a sound comparison with the CLC and CLUE datasets with only one class of artificial surface (CLC at level 1), an argumented analysis is required of a threshold of % sealed area above which the area would be allocated to the land cover category 'artificial surfaces' in CLC2000, and to 'built-up area' in the CLUE land cover map for 2030. Small uncertainties in this threshold may result in large changes in the estimates of land cover flows between the moments in time represented by the datasets.

Other, technical reasons hampering the use of the dataset include:

- the EEA dataset covers only several European countries
- the EEA dataset would need resampling to the resolution of the available CLC and CLUE datasets (1 km). The procedure of aggregating % of sealed areas to larger cells (e.g. average, dominant value) would largely influence land cover flows calculated based on aggregated values.

Due to the lack of information on sealing % within urban areas at the European level, in this study the extent of artificial surfaces (CLC class 1## at levels 1, 2 and 3; CLUE class 0 'built-up area') is used as a proxy indicator to estimate the degree of sealing of the land consumed. In order to keep the analysis simple and feasible in the given resources of time and budget, the extent of artificial surfaces has been analysed up till the level of CORINE 2 (see Table 3.1).

The following data sources were used in Task 2:

1. CORINE Land Cover (CLC) 1990 and 2000
2. Historical Land Cover Dataset for 1960 (HISLU60) (Kramer and Mücher, 2008)
3. Land and Ecosystem Accounts (LEAC) for Europe 1990-2000 (http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=884)
4. Land Accounts for Europe (EEA Report No 11/2006)
5. EEA Core Indicator Set CSI014: Land take by artificial development (http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=2532)
6. The European Soil Database distribution version 2.0, European Commission and the European Soil Bureau Network, CD-ROM, EUR 19945 EN, 2004
7. ESDBv2 Raster Library - a set of rasters derived from the European Soil Database distribution v2.0 (published by the European Commission and the European Soil Bureau Network, CD-ROM, EUR 19945 EN); Marc Van Liedekerke, Arwyn Jones, Panos Panagos ; 2006.
8. 1km Raster version of the European Soil Database (v. 2.0), European Soil Bureau Network & European Commission", EUR 19945 EN ; Marc Van Liedekerke, Arwyn Jones, Panos Panagos ; 2006

[26] Specialist in land use modelling from the VU University, The Netherlands.

9. Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., Van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., Van Lynden, G.J. and Huting, J. (2004). Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73). European Soil Bureau Research Report No.16, EUR 21176, 18pp. and 1 map in ISO B1 format. Office for Official Publications of the European Communities, Luxembourg.
10. S.P.I.04.73. (2004). The PESERA Map: Pan-European Soil Erosion Risk Assessment. Special Publication Ispra 2004 No.73, map in ISO B1 format. Office for Official Publications of the European Communities.SINFO, New soil information for CGMS (Crop Growth Monitoring System), new and extended version of the soil data from the Soil Geographical Data Base of Europe (SGDBE) version 3.1, developed for use in the MARS Crop Yield Forecast Sing System",European Community- DG Joint Research Centre, July 2007
11. Miterra-Europe (Lesschen, 2009; Velthof *et al*., 2009)
12. EU Ruralis (WUR/MNP, 2008)

Datasets 1-3 are described in detail in Chapter 3, including details on spatial coverage, status of validation and an estimation of the accuracy for the spatial land use and cover change assessment in this project.

Limitations with regard to datasets used

- Cyprus is not covered in the ESDBv2.0 and is omitted from the analyses using the ESDBv2.0 for this reason.
- The Canary Islands (Spain) are included in the CLC datasets, but omitted from the maps, because inclusion would deteriorate the visualization of maps at the European level.
- Differences were encountered between areal coverage (%) of Soil Typological Units within Soil Mapping Units on the ESDBv2.0 and the suitability maps for arable cropping and permament grassland derived from the SINFO database. The % of the ESDB were taken as the most reliable data source.
- The representation of artificial surfaces on the HISLU1960 is unreliable. Estimates of the reliability are given by Gerard Hazeu in the report from Task 1.
- Calculation of land cover flows from 2000>>2030 contains uncertainty due to different interpretations of land cover in CLC2000 and CLUE 2030 land cover datasets. The reliability of the changes cannot be determined within the scope of this assignment, as it requires a specialist analysis.
- All maps and tables expressing changes in land cover represent only the European countries that are represented in both layers on which the change calculation is based. This explains why Sweden and Switzerland are not represented in the change maps for 2000>>2030.

4.2.3 Trends in soil sealing from 1960-1990

A rough comparison of the total stocks of urban land in the EU27 in 1960 (HISLU60, 44680 km^2) and artificial surfaces in 1990 (CLC1990, 141830 km^2) would imply an increase of 97150 km^2, or a tripling of the urban or artificial surface. As indicated in the report from Task 1, this trend can be different for countries and within countries.

It should be noted that the urban area in the HISLU60 dataset is largely underestimated (results from the EU FP6 Ecochange Project, Hazeu *et al.*, 2008a). In the framework of the EU FP6 Ecochange project, the estimation of urban areas in the HISLU60 dataset was improved by combining the dataset with the Digital Chart of the World (DCW). However, the urban area remained underestimated. A comparison with the Pan-European Land Cover Mosaic for the year 1990 (PLCM1990) showed that the urban area increased with roughly 62600 km^2 between 1960 and 1990 (Hazeu *et al.*, 2006) (Table 4.2). Considering that the PCLM 1990 database covers more countries than the CLC1990, the increase in urban area would be expected to be larger in the HISLU60 versus PCLM1990 comparison. This illustrates the unreliability of the HISLU60 dataset for assessing historical trends in soil sealing. Overall it can be concluded that the urban area has increased in the EU27 between 1960 and 1990, but that the areal extent cannot be quantified with reasonable reliability.

Table 4.2 Land cover stocks and changes: comparison of HISLU60 and PCLM databases. Source: Hazeu *et al.*, (2008b).

	Stocks						**PLCM1990-**	**PLCM2000-**
Classes	**HISLU60**		**PLCM1990**		**PLCM2000**		**HISLU60**	**PLCM1990**
	km^2	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**km^2**
Urban	87057	0.97	149620	1.67	157924	1.76	62563	8304
Arable land	3432502	38.27	3595102	40.09	3587947	40.01	162600	-7155
Grassland	1716263	19.13	643819	7.18	640629	7.14	-1072444	-3190
Forest	2260972	25.21	2935273	32.73	2935987	32.74	674301	714
Non-agri.land	1205102	13.44	1416475	15.79	1416887	15.80	211373	412
Inland waters	193284	2.15	219111	2.44	219956	2.45	25827	845
Sea	74259	0.83	8786	0.10	8769	0.10	-65473	-17
Total	8969439	100	8968186	100	8968099	100		

4.2.4 Trends in soil sealing from 1990-2000

Trends in soil sealing at the European level (EU24)from 1990 to 2000

Over Europe (24 countries), land take by urban development from 1990 to 2000 (LCF1+LCF2+LCF3, formation) amounted to 9741 km^2, or 6.0% of the stock of urban land in 1990. For the EU-27, this amount was 10.557 km^2 (source data CLC1990 and 2000 from Task 1).

In the following analysis, the data from EU-24 from EEA (2006) were used, because these give insight in the source land cover types from which conversion to artificial surfaces took place. Subtracting consumption of urban land for other land uses, the net change in artificial cover was 8712 km^2, or 5.4% of the artificial cover in 1990 (EEA, 2006). Within the general category of artificial surfaces, the residential and industrial categories exhibited the largest expansion (Figure 4.4).

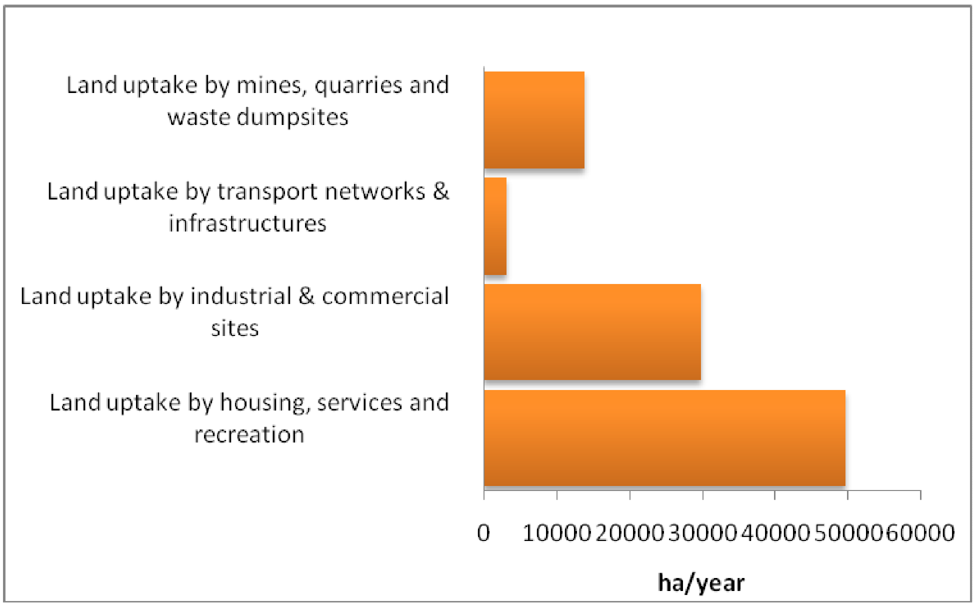


Figure 4.4 Land take by artificial development in Europe (24) from 1990 to 2000. Source: EEA core indicators, CSI014 (dataservice.eea.europa.eu).

When inspecting the source land cover types from which land take for urban development occurred, most of the land 'consumed' came from agricultural land (8,148 km^2)(84% of total uptake), and, to a lesser extent, from forests and semi-natural and natural areas (Figure 4.5). The conversion from agricultural zones to artificial surfaces has been most important in The Netherlands, Belgium and Germany (Figure 4.6).

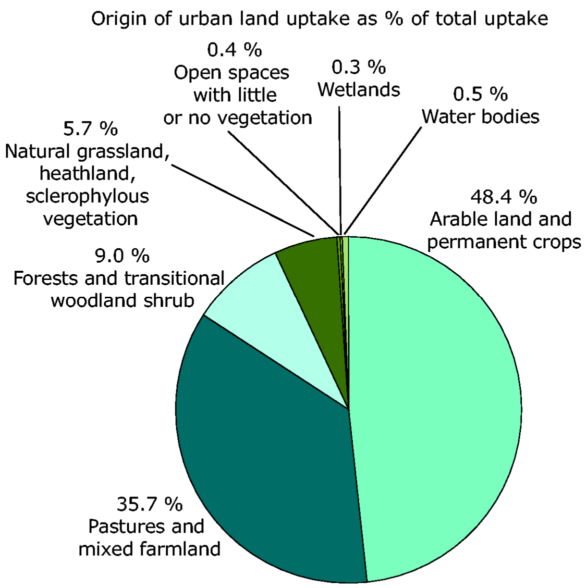


Figure 4.5 Origin of urban land uptake as % of total uptake. Source: EEA core indicators, CSI014 (dataservice.eea.europa.eu).

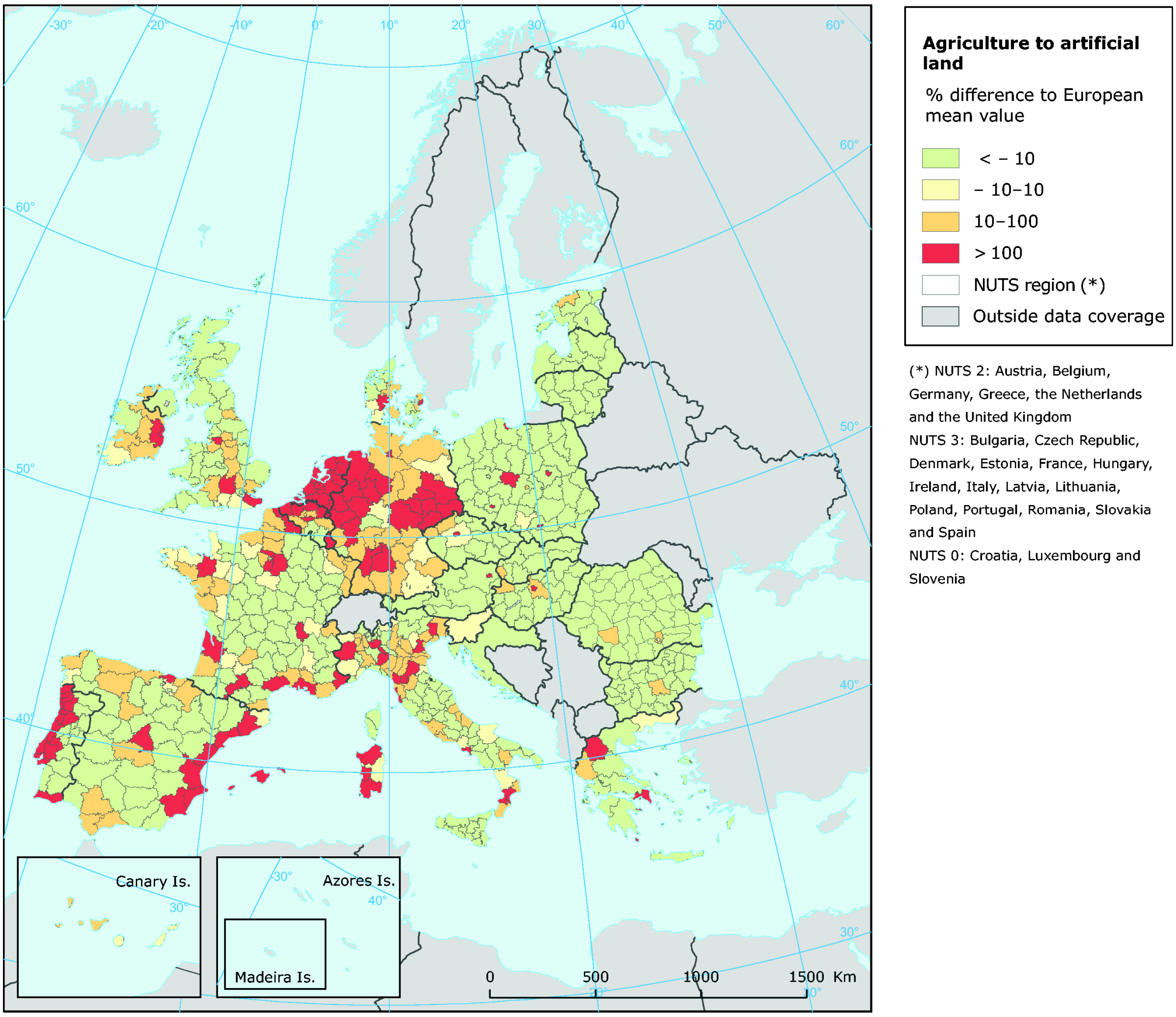


Figure 4.6. Loss of land from agriculture to artificial surfaces by NUTS regions. Source: Land cover accounts (LEAC) based on CORINE land cover changes database (1990-2000)

Trends in soil "de-sealing"

The areal extent associated with the land cover flows including the conversion of artificial surfaces to other land cover types (Box 4.3) amounts to 13263 km^2 from 1990-2000, which is more than the total area converted to artificial surfaces (10557 km^2). The reason for this is that the set of land cover flows listed in Box 4.3 also includes flows from other source land cover types than artificial surfaces. The area converted from developed areas uniquely to agriculture between 1990 and 2000 amounts to 282 km^2, or only 3% of the area converted to artificial surfaces in this period.

Trends in soil sealing at NUTS0 level

The land cover flows resulting in the formation of artificial surfaces in the European countries at NUTS0 level between 1990 and 2000 are shown in Annex 2.2. Internal transformation of urban areas in absolute area are large in The Netherlands, France, Spain and Germany compared to other countries Annex 2.2b. Urban residential sprawl is important in these countries as well, as well as in Portugal and Italy. France, Spain and Germany experienced the largest increase in area for economic sites and infrastructures (Annex 2.2c).

In order to assess trends in soil sealing, the land cover flows from originally non-urban or non-developed land to artificial surfaces (LCF1 and 2) are most relevant. When considering only these land cover flows, and expressing these in % with reference to the total area subject to land cover change (including areas with nu change), land take for artificial surfaces has been most important in small countries like The Netherlands (2.11%), San Marino (1.18%), Luxembourg (0.69%) and Belgium (0.62%). Of the larger countries, land take has been important in Germany (0.57%) and Portugal (0.76%) (Figure 4.7).

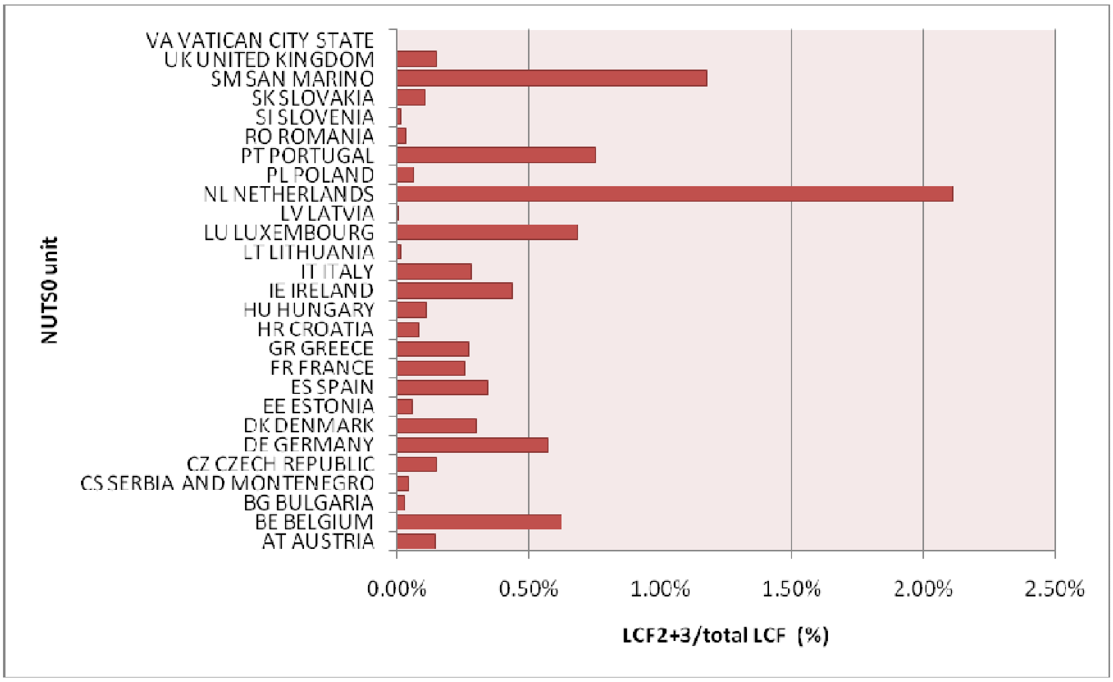


Figure 4.7. Land cover flows indicative of soil sealing (LCF2 and 3) relative to total area subject to land cover flow (including 'no change') in European countries at NUTS0 level between 1990 and 2000.

Source data: LEAC 1990-2000 and Task 1 of this study.

When also internal transformation of urban areas is considered, and the reference is changed from total land area per country to total artificial land in 1990, the variation between European countries becomes different. The average annual increase in artificial land in the 23 European countries covered by CLC2000 between 1990 and 2000 is 0.7%. Land take for urban development compared to the urban area in 1990 was most important in Ireland (3.1% increase in urban area per year), followed by Portugal (2.8%), Spain (1.9%) and the Netherlands (1.6%) (Figure 4.8). Urban sprawl in new Member States has been generally lower than in the other EU countries (CSI-014 Land Take Assessment, EEA, 2005b).

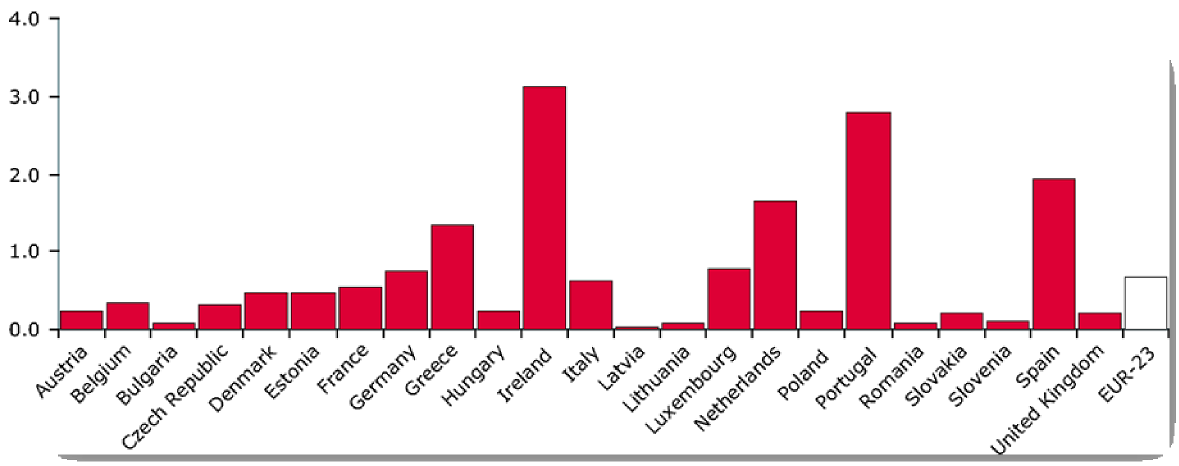


Figure 4.8. Mean annual urban land take 1990-2000 as a percentage of 1990 artificial land. Source: CSI 014 - Land take - Assessment published Nov 2005. Data source: LEAC DB (based on CLC CHANGE DB), CORINE Land Cover (CLC) 1990 and 2000, ETC/TE, http://themes.eea.europa.eu/.

In larger countries spatial patterns of urbanization may vary considerably. These are visualized in Figure 4.9. It shows clusters of urban sprawl (due to expansion of residential and economic sites and infrastructures) around Rome in Italy, in the Algarve in Portugal, around Madrid and along the Mediterranean coast in Spain, and in France along the Mediterranean coast and around Paris. Germany shows concentrations in already densely populated areas in the west and south of the country, but also in former East Germany, showing the effects of the unification. The increase in artificial area in coastal zones in some countries is better visualized in Figure 4.2.

The largest concentration of urban sprawl is observed in a belt extending from the United Kingdom to The Netherlands and Belgium. In Eastern and Central Europe, concentrations of urban development can be seen in the Czech Republic, Slovakia and Hungary, and along the border regions with Germany and Austria.

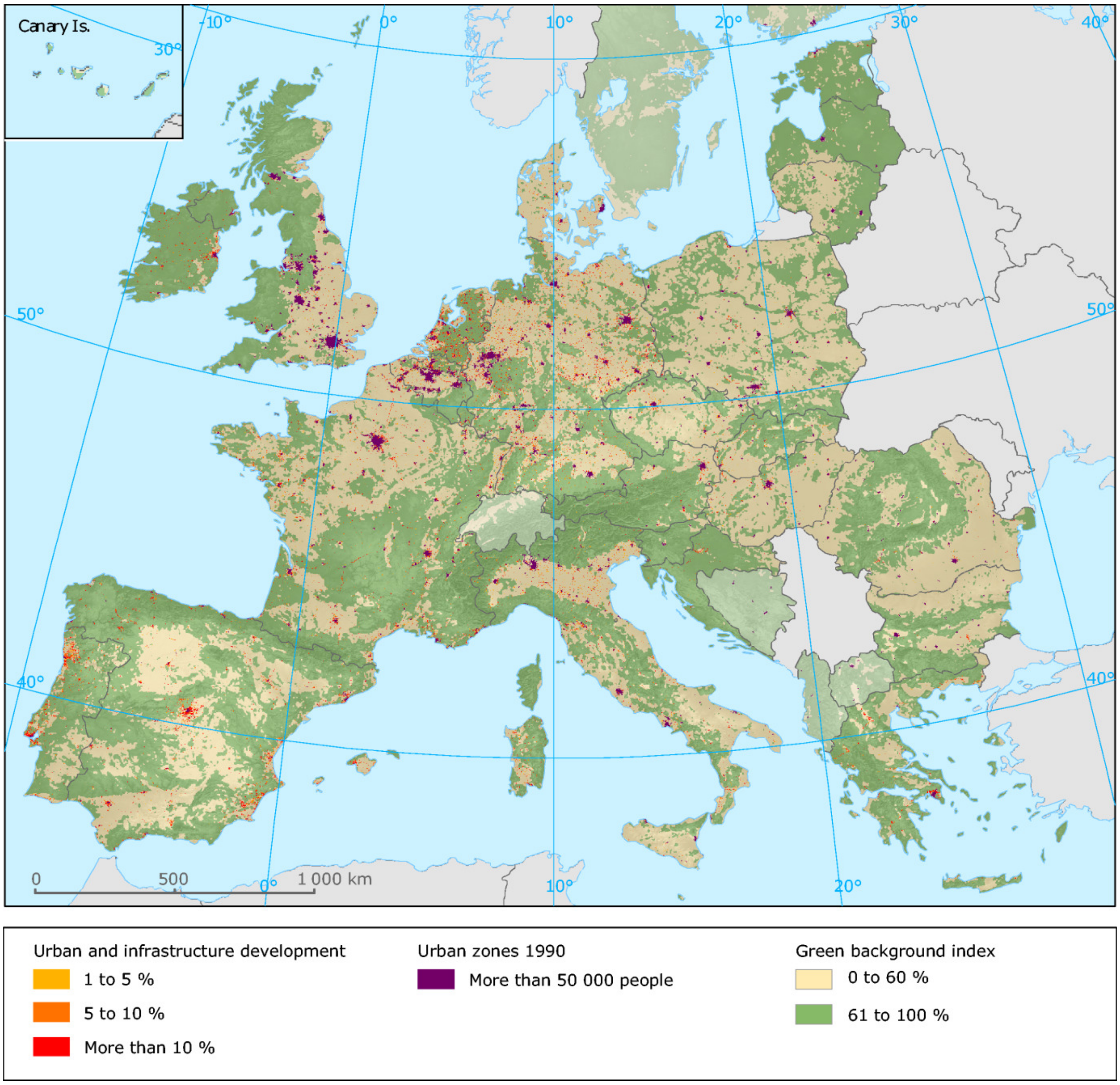


Figure 4.9. Patterns of urban sprawl due to the expansion of residential and commercial sites across Europe, 24 countries, 1990-2000, 1 km x 1 km grid.
Source: dataservice.eea.europa.eu. Published in: Land Accounts for Europe 1990-2000 (EEA, 2006).

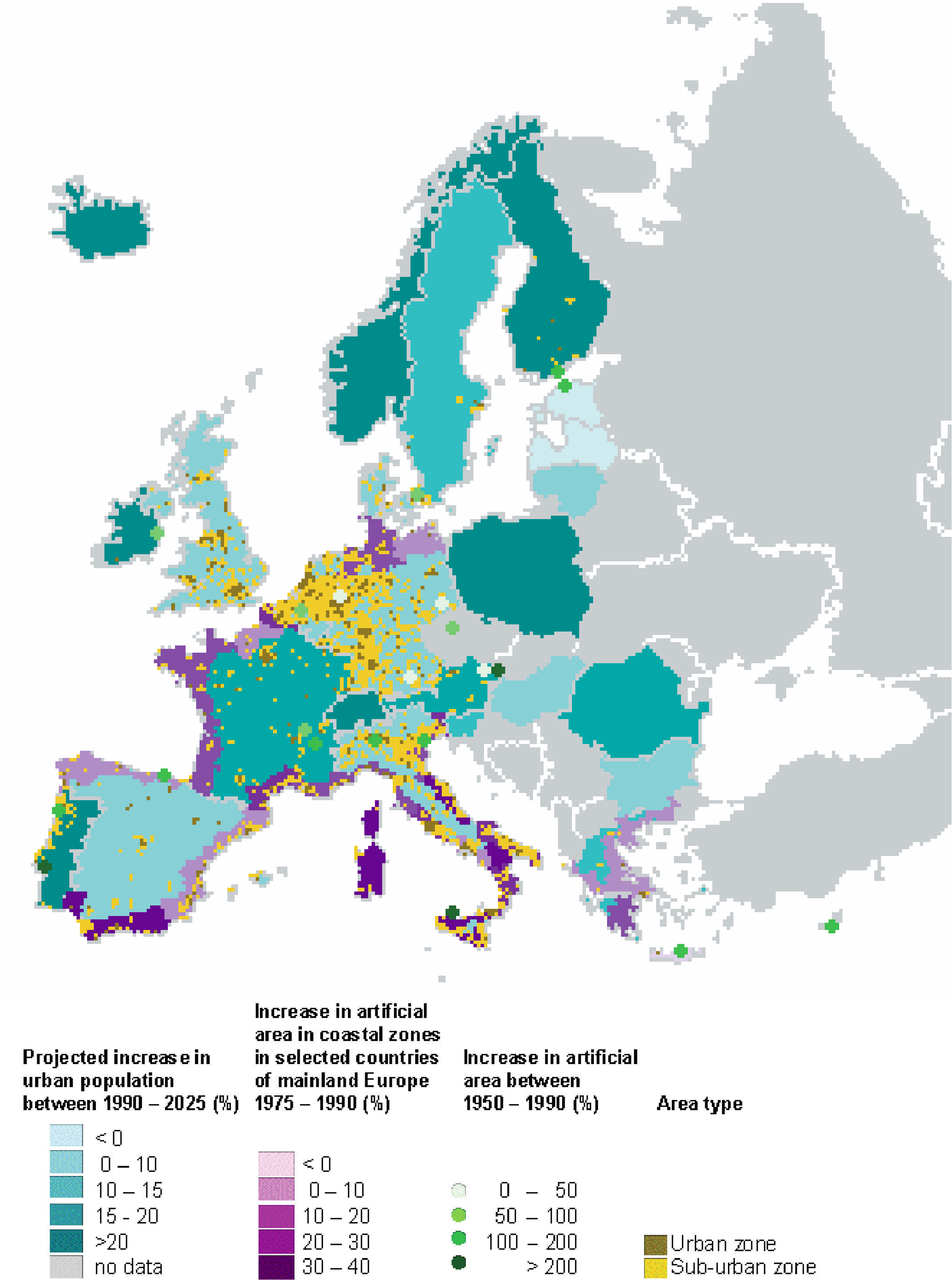


Figure 4.10. Phenomena of soil sealing in Europe. Source: European Environment Agency, in: European Commission, 2005.

4.2.5 Drivers of soil sealing from 1990 to 2000

At the European level, housing, services and recreation make up more than half of the overall increase in urban and other artificial area between 1990 and 2000 (52%) (Figure 4.11). Uptake numbers vary largely between countries. Examples of extreme values are Luxembourg and Ireland, with land take for housing, recreation and services higher than 70%. Small values were observed for Greece (16%) and Poland (22%) where urban development is due mainly to industrial/commercial activity.

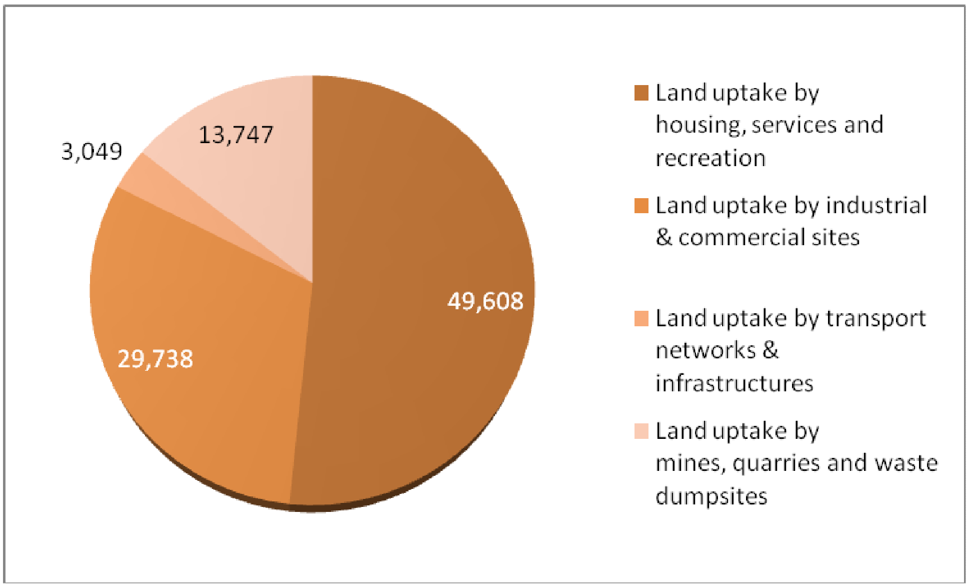


Figure 4.11. Land take (ha/yr) by several types of human activity per year in 23 European countries, 1990-2000. Source data: LEAC 1990-2000, based on CLC CHANGE database. Adapted from: http://themes.eea.europa.eu/.

Land uptake by industrial and commercial sites is responsible for the second largest part of the overall increase in urban and other artificial area (32%). This sector is particularly responsible for land take in Belgium (48%), Greece (43%) and Hungary (32%).

Land take for mines, quarries and waste dumpsites amounted to 14% of total land take from 1990 to 2000. This type of land take was relatively important in countries with low artificial land take during the 1990-2000 period and in Poland (43%), where mines are a key sector of the economy.

Land take for transport infrastructures is reported in the LEAC 1990-2000 database to account for only 3% of the total new artificial cover. This contribution is underestimated, because the source CLC datasets do not include linear infrastructures in the land cover class 'artificial surfaces' (or subcategories). Soil sealing and fragmentation resulting from the laying-out of transport networks and infrastructures therefore need to be determined from other sources.

Considering that the largest uptake of land occurred for the development of housing, services and recreation, it can be concluded that the main drivers for soil sealing are population density (possibly expressed in the number of households) and economic activity. This is also confirmed by other studies (e.g. EEA, 2005b; Verburg and Westbroek, 2006; EU Ruralis, WUR/MNP, 2008). This may not be solely the result of an increase in population, but it can be the result of a change in behaviour (Scalenghe and Ajmone Marsan, 2009).

4.2.6 Impacts of soil sealing on soil resources in Europe between 1990 and 2000

The uptake of land for artificial surfaces draws from many different Reference Soil Groups, and shows a scattered geographical distribution (Annex 2.3a-d). However, most land take due to soil sealing appears to draw from Cambisols, and to a lesser extent from Fluvisols and Luvisols. These soil groups are likely to include soils with a high importance for the land use services food production, biodiversity and water retention (Figure 4.3). For the Cambisols, this is partly explained by their widespread occurrence in Europe.

4.2.7 Trends in soil sealing from 2000-2030 following the Global Co-operation scenario (B1)

Trends in soil sealing at the European level from 2000 to 2030 and assessment of drivers
Trends in soil sealing for the period 2000-2030 were derived from the simulations with the GTAP, IMAGE and CLUE model chain for global change scenario B1 (source: Tasks 1 results in Chapter 3). The scenario reflects strong spatial planning through restrictive policy aiming at compact cities, with urban growth mainly in large cities and provincial towns, and restrictions to build in green areas. This pattern can be recognized in the Task 1 map of simulated dominant land use or cover changes for 2030 (Figure 3.9). It shows that urbanization will extend around existing urban networks and industrial and commercial areas. Outstanding concentrations include the networks of Liverpool-Birmingham, London, Birmingham, Dublin, the Dutch 'Randstad', the Ruhr area, Warsaw, Paris, Lyon and Barcelona.

Following the B1 scenario, an area of 10264 km^2 is expected to be converted into built-up land at the expense of other land cover/use types (Annex 1). The main land cover types from which newly built-up land is taken are pasture (45.2%) and arable land (44.1%) (Figure 4.12a). The large take up of agricultural land for newly built-up land may be explained by the socio-economic and policy assumptions for the simulated scenario, in which current CAP export subsidies are abolished, border support is phased out, and income support for farmers is reduced.

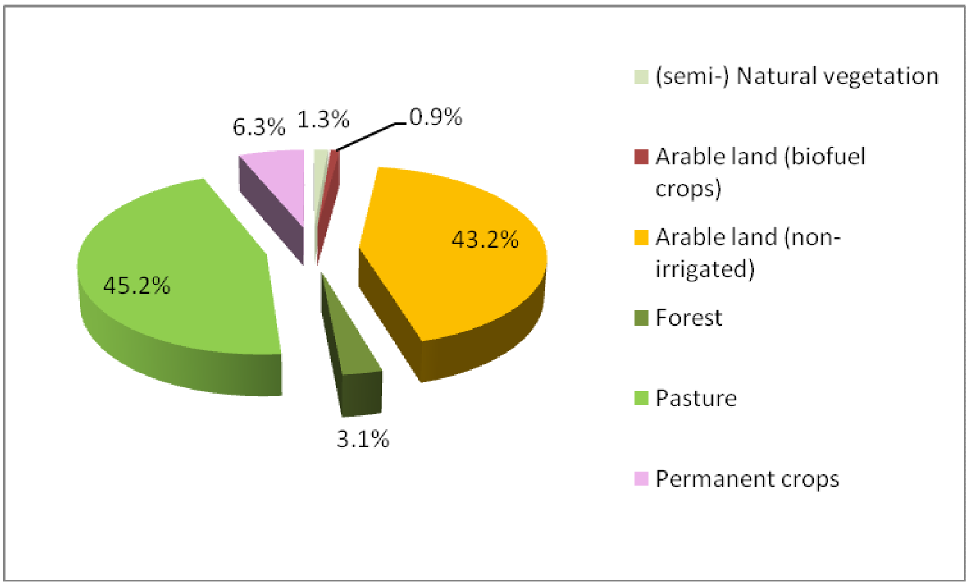


Figure 4.12a. Areal contributions of land cover types converted into built-up area between 2000 and 2030 according to simulations with the GTAP, IMAGE and CLUE model chain for global change scenario (B1). Source data: Task 1 of this study.

Trends in soil sealing at NUTS0 level between 2000 and 2030

The net development of built-up area in individual countries in Europe between 2000 and 2030 according to the modelled scenario is illustrated in Figure 4.12b. In all countries the net built-up area increases. The largest absolute increase is observed in France (2444 km^2) and the United Kingdom (1858 km^2). Relative increases in built-up area are largest in the smaller countries (Ireland, 33.8%; Malta, 26.4%; Cyprus, 21.0%; Netherlands, 13.2%) (Figure 4.13), but important extensions of built-up land are also projected for larger countries (Greece, UK, France, Spain: 8 to 11%).

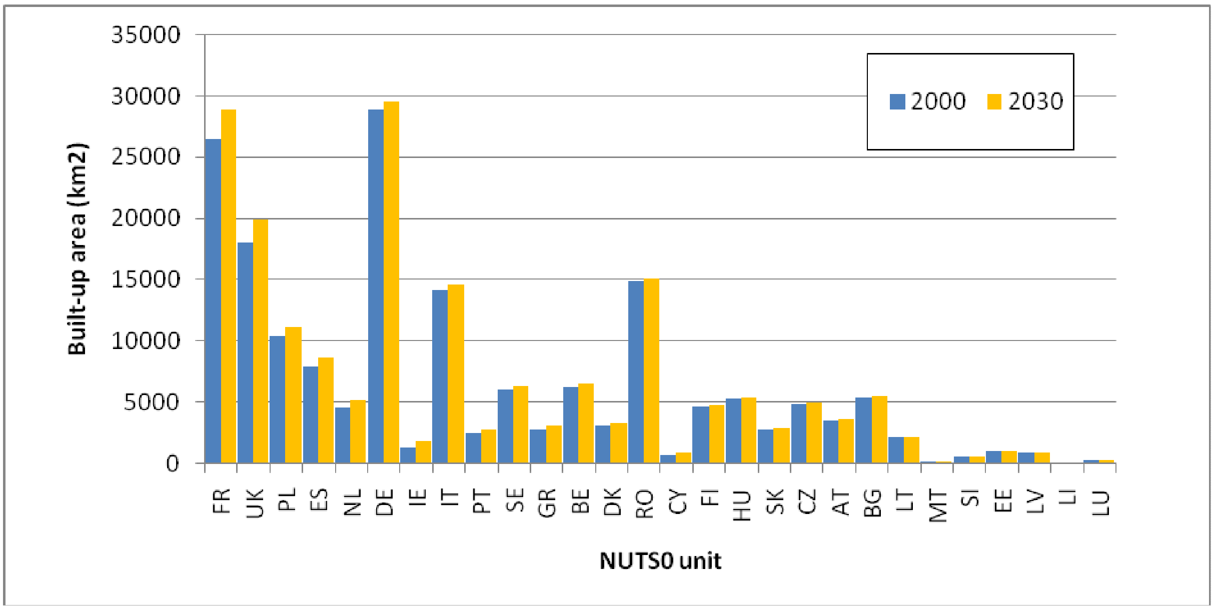


Figure 4.12b. Built-up area (km2) in European countries (NUTS0 units) in 2000 and 2030, sorted according to decreasing absolute increase. Source data: Task 1, of this study.

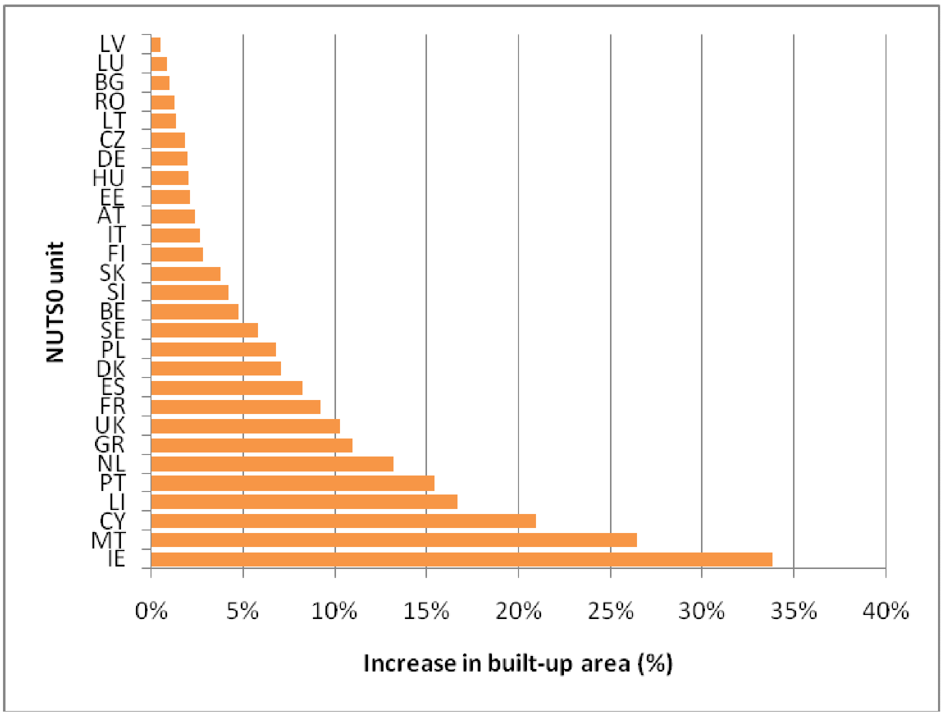


Figure 4.13. Increase in built-up area in countries of the EU in the period 2000-2030 compared to the built-up area in 2000.

4.2.8 Drivers of soil sealing from 2000 to 2030

The drivers of soil sealing from 2000 to 2030 are reflected in the socio-economic and policy assumptions for the Global Cooperation (B1) scenario. In this scenario, spatial urban planning is restricted, leading to compact urban growth compared to the other IPCC-SRES scenarios. Furthermore the scenario is characterized by a global orientation with a preference for social and environmental values in addition to economic profit. As indicated in the analysis of source land cover types for newly built-up land above, land for newly built-up area comes largely from the agricultural sector, and to a far less extent from nature areas (apart from a contribution by forests). This is in line with the focus of the scenario on environmental sustainability and biodiversity.

Population increase is expected to be stimulated by external and internal migration and high fertility rates. It is therefore assumed that the main driver for soil sealing between 2000 and 2030 according to the B1 scenario is population growth. This would be reflected in a large share of the newly built-up land to be destined for houses, services and recreation. We cannot verify this assumption, because the land cover dataset for 2030 does not show information on the type of built-up area.

4.2.9 Impacts of soil sealing on soil resources in Europe from 2000-2030

Annex 2.4 shows the uptake of Reference Soil Groups for built-up areas from other land cover in 2030. As observed between 1990-2000, the largest proportion of sealed soils are from Cambisols, Fluvisols and Luvisols (Annex 2.5). These soil groups are likely to include soils of high importance for the land use services food production, biodiversity and water retention (Figure 4.3). With regard to food production, this corresponds to the observation that agriculture is the main land use type giving over land to built-up area.

4.2.10 Discussion

Trends in soil sealing from 1960 to 2000 and drivers

The estimated trends of soil sealing in Europe show that over the past 50 years, built-up area has first grown at a high speed from 1960 to 1990, and steadily increased after 1990 all over Europe. These trends are confirmed by reports from the EEA (EEA, 2001, 2002; EEA, 2006) and JRC (2006), and by the study of Scalenghe and Marsan (2009), describing the geography of soil sealing in Europe.

Western European countries experienced the largest changes from 1990 to 2000, much larger than the recently acceded member states. This is also confirmed by the EEA studies, and the study by Verburg and Westhoek (2006) on soil sealing in Europe. An analysis of population growth in relation to trends of soil sealing by the EEA (2002, in: Van Camp *et al*., 2004) showed that the area of built-up land increased at a faster rate than the population. The decoupled growth rate of built-up area is explained by the steady increase of number of households and average residential space per capita since 1980, a.o. due to the increasing demand for second homes and increased living area as a result of increasing welfare (EEA, 2001, in: Van Camp *et al*., 2004; European Commission, 2005). This is in line with the finding from EEA (2006), described in this report, that land uptake by housing, services and recreation was responsible for the largest expansion of built-up area.

The growing urbanization in the coastal zones of the Mediterranean countries is a consequence of increasing pressure of tourism according to a study from EEA-UNEP (2000) and JRC (2006). In Central and Eastern Europe, soil sealing is a relatively small problem compared to other soil threats, like erosion, salinization and contamination. However, built-up area increased in the late 80's due to political and economic changes, leading to the development of new infrastructures, migration of rural population to the cities and development of new settlements (Baltic Environmental Forum, 2001, in: Van Camp *et al*., 2004). This development was located around industrial areas, cities, rural settlements and tourism in the coast of the Black Sea (UNECE, 1999). In line with these observations, our analysis revealed that of the newly acceded countries, large uptake for industrial and commercial sites took place in the Czech Republic, Slovakia and Hungary. Van Camp *et al*., (2004) pointed out that pressure is also increasing in some coastal zones, like in the Baltic coast of Latvia.

The new built-up areas have been at expenses of agricultural land for the largest part, and forests and (semi-)natural to a lesser extent. This is confirmed by reports from the EEA (1999), EEA-UNEP (2000) and JRC (2006). Currently, agricultural land receives more attention from the policy forming community, partly because of the spatial claims from urbanization (e.g. LNV/WUR, 2008). Europe's agricultural area is expected to decrease by 20 Mha up till 2030 due to claims from the formation of artificial surfaces, nature development and bioenergy cropping (EU Ruralis, 2008). Population and prosperity growth are the most important drivers for land take from agricultural areas (EEA, 2005a,c; Rijk, 2008; EU Ruralis, 2008). For historical reasons, urban metropolitan zones are often located in areas with prime agricultural land. This implies that more inputs and/or cultivated land are required for obtaining the same agricultural production elsewhere, on less suitable soils, resulting in higher pressures on water, soil and biodiversity. This is called suboptimal land use. Urban areas have been able to, and are still expanding at the expense of rural areas (Figure 3.4). One of the reasons is that it is often cheaper to develop previously undeveloped land, than to redevelop land previously in use for housing, industrial and commercial use, recreation or transport infrastructure. This phenomenon is also termed the 'rural-urban gap'.

Trends in soil sealing from 2000 to 2030 and drivers
The estimated trends in soil sealing from 2000 to 2030 show progressive soil sealing with compact patterns of urbanization. These trends correspond to the findings in the EU Ruralis study (Eickhout and Prins, 2008) and Verburg and Westhoek (2006). They imply that soil sealing will particularly affect the areas around large cities. For historical reasons, these are often the best soils for agriculture, which may set limitations on agricultural production capacity (see also Section 4.4 on impacts). Currently, there is a renewed interest for prime agricultural land from the policy forming community in Europe, farmers' organizations and interest groups (e.g. www.primeagriculturalland.eu). One of the reasons is the increasing spatial claims from urbanization.

The results of this study show that for the total of considered European countries, the rate of growth of the built-up area is significantly lower in the period 2000-2030 in the B1 scenario compared to the period from 1990-2000. This is due to the regulation of urban growth in the Global Cooperation (B1) scenario. For global change scenarios with a lower degree of regulation (A1 and A2), the simulated growth rate of built-up area is similar to the trend of the past decades (Verburg and Westhoek, 2006).

According to JRC (2006) the projected rate of soil loss due to surface sealing is relatively low in countries which already experienced significant urbanization, like The Netherlands and Germany, and relatively high for countries where urbanization levels have been generally low, like Portugal, Finland or Ireland. These projections are not confirmed by our study, where large relative increases were also observed for countries which experienced important soil sealing in the past decades, like the UK, France and The Netherlands. The high relative increases for Portugal and Ireland were also found in the present study, but not for Finland (only 2.9%).

For a few Central and Eastern European countries, we found larger growth rates of built-up area for the period 2000-2030 than for the period 1990-2000 (Poland, Lithuania, Slovakia, Slovenia), but for the other countries in these regions projected growth rates are similar to or lower than rates in the period 1990-2000. Increased growth rates compared to the period 1990-2000 can be explained by the enlargement of the EU and the integration of the new countries in the common market, which are expected to cause an increased migration to urban areas and transport of goods, leading to the laying out of infrastructure and residential sprawl. However, this effect is hardly noticeable for countries with relatively strong economies, like the Czech Republic and Hungary, with growth rates of 0.2 to 0.3% in both periods.

Impacts of soil sealing on soil resources in Europe
Soil sealing in Europe affected predominantly the Reference Soil Groups (WRB2006) Cambisols, Fluvisols, and Luvisols in the period 1990-2000. The same soil groups are estimated to be affected in the period from 2000-2030. These soil groups are likely to include soils with a high importance for the land use services food production, biodiversity and water retention due to their good structure, water holding capacity and nutrient status. It should be noted that these qualifications are rough, since the soil classification at the level of soil reference groups does not give information on specific capacities and limitations of soils, as is

expressed in the map qualifiers and diagnostic criteria at lower taxonomic levels of the WRB2006 soil classification system. Also, the land use and climate will determine to what extent the soils will be able to perform land services and soil functions. DG JRC is currently developing a system to evaluate the functional ability of soils. Soil quality evaluation based on soil characteristics from soil classification schemes require a detailed evaluation process of soil characteristics represented by the soil classification system, both with regard to the relative importance of evaluation properties for specific soil functions, and the dynamics of the soil properties (Tóth *et al.*, 2008a). In combination with expressions of the soil sustainability (soil quality across a gradient of stress and disturbance), such a system could be used to assess impacts of soil sealing on soil resources. The analysis presented in this report provides a first indication of which reference soil groups have been and are likely to be affected by soil sealing in the European Union, and what the impact of this could be on the land use services addressed.

Land consumption and soil sealing essentially convert soils into urban soils (e.g. Brown *et al.*, 2005 and Scheyer and Hipple, 2005; in: Lorenz and Lal, 2009). In the WRB 2006 soil classification system, these soils are classified as in the Technosol reference soil group (IUSS Working Group WRB, 2006). Technolsols may be sealed by technic hard rock or other materials and may contain artifacts, or be entirely constructed from human-made materials. Until recently, urban soils and technosols have only been studied to a limited extent with respect to their land service performance for the urban (and per-urban) population. One of the reasons is that information on the soils below developed areas is often lacking. National soil maps often show built-up areas as areas without information on soil types, and soil databases often contain few profiles in urban areas.

The impacts of soil sealing on land use services through impacts on soil resources and soil functions requires the assessment of changes in soil functions as a result of soil sealing. For this assessment, information on soils in urban areas is required. Soils in urban areas have different characteristics and suitability for the different soil functions. This study gave an estimate of the existing reference soil groups that have been and are likely to be affected by soil sealing. The assessment of impacts on land services requires a trade-off analysis based on the performance of urban soils on the land services considered. Research on urban ecosystems is required for a proper assessment. A recent example is the study by Lorenz and Lal (2009), focussing on the preservation of C and N sinks in urban soils.

4.2.11 Conclusions

Over the past 50 years, built-up area has first grown at a high speed from 1960 to 1990, and steadily increased after 1990 all over Europe. The growth in built-up area cannot be quantified with reasonable reliability, but is at most some 60.000 km^2. Over the period 1990-2000, the built-up area increased with roughly 10.600 km^2 for the EU27. The largest increase of built-up area occurred in Western Europe for housing, services and recreation, at a faster rate than the growth of the population. This is explained by the steady increase of number of households and average residential space per capita since 1980, a.o. due to the increasing demand for second homes and increased living area as a result of increasing welfare. Most of the built-up area was laid out on land previously in use for agriculture (84%, EU24).

Urban sprawl in Central and Eastern European countries has been generally lower than in the other EU countries. However, uptake of land for industrial and commercial sites was important in some of these countries.

Following the Global Cooperation (B1) scenario for global change, some 10.300 km^2 is expected to be converted to built-up area between 2000 and 2030 in the EU27, corresponding to a significantly lower annual growth rate of the built-up area (343 km^2/y) than in the period 1990-2000 (1060 km^2/y). This is explained by the regulation of urban growth in the global change scenario. The growth is expected to result in compact patterns of urbanization.

The main drivers for soil sealing in the period 1990-2000 were population density, due to population growth and change in residential behaviour, and economic activity. For the period 2000-2030, population growth is assumed to be the main driver.

Land take for artificial surfaces in both periods occurred at the cost of soil groups likely to include soils with a high importance for the land use services food production, biodiversity and water retention.

The assessment of impacts of soil sealing on land services requires a trade-off analysis based on the performance of urban soils on the land services considered. Research on urban ecosystems and specifically urban soils is required for a proper assessment.

4.3 EU POLICY MEASURES AND SOIL SEALING

4.3.1 Soil Sealing and EU Policy

Soil sealing can impact upon a range of ecosystem services. It ameliorates the land surface and inhibits the ability of soil to perform its core functions; impacting upon hydrological flows, soil biodiversity, soil's ability to sequester carbon, fragments habitats and river catchments. Importantly, sealing represents an opportunity cost, removing the potential for that soil/land area to be used particularly for the production of biomass (whether this be natural or for human cultivation). It can also represents a threat particularly in relation to its impacts on water availability reducing infiltration rates, increasing rates of flow into surface water bodies, as a consequence this potentially increases both flooding and water scarcity as a consequence of reduced groundwater recharge, soil water storage capacity and river baseflows.

Sealing can be full or partial, ie totally disrupting or simply interrupting/altering specific functions. It is generally associated with urban development and, within this, specific types of development that can partly or completely interrupt function. This includes elements such as roads, any form of hard standing and buildings, but also less obvious activities such as capping of landfills, use of greenhouses etc. Partial sealing can also occur from other subsurface activities, for example pan production associated with certain agricultural practices.

Government policy or funding is often one of the drivers determining the scale and nature of urban, road and infrastructure development; therefore, it both contributes to and, if well conceived, can help limit long term sealing impacts by promoting considered development and concepts such as sustainable urban drainage. In addition policies, specifically those aiming to protect natural resources such as water, biodiversity or the availability of productive land can limit or shape sealing. The following sections investigate the nature of policy and legislative instruments used in Europe that impact upon soil sealing.

4.3.2 Overview of most relevant policies

EU requirements and policies impact upon the use of land, hence soil use, via three different mechanisms. These are: requirements set out in legislation; through flexible mechanisms such as the requirements to establish certain plans or programmes; and through the funding of development or protection activities. As a consequence there are an array of EU policies that potentially impact upon soil management and sealing. Given the limited development of dedicated soil protection policies at the European level to date, EU requirements predominantly act indirectly to protect soils ie the primary objective of a given piece of legislation is to protect water bodies or biodiversity *per se* but given the inter linkages between environmental media this can result in some protection of soils dependent upon the approach to implementation adopted.

EU policy has a more limited role in dealing with soil sealing, than for other soil degradation problems; soil problems associated with agriculture (such as erosion) and pollution (such as contamination via air and water deposition) have received greater attention to date. This imbalance is a consequence of three factors. Firstly, contamination and erosion in particular have been dealt with as part of holistic measures to limit in particular water and air pollution. Secondly, the more limited nature of EU competency over key issues determining sealing such as land use planning, building standards etc has limited the ability to act collectively at the EU level. Finally, EU funding of relevance is has often focused on delivering development and construction of infrastructure. Soil requirements linked to the receipt of funding have only been extensively applied in the agricultural sector, were limited provisions have been imposed by Member States under Cross Compliance.

Soil sealing is a problem primarily associated with construction and largely urban development. here is no legal basis for urban policy in the EU Treaty. Despite this, however, the EU has a long tradition of being active in the field of urban development and regeneration, taking a role in supporting cities and regions in their quest for competitiveness and cohesion. It is widely recognised that there is a strong need to take into account the urban dimension of EU policies and especially of Cohesion Policy. This is intended to promote the objectives of the Lisbon Strategy and the Sustainable Development Strategy. The primary mechanisms for delivering this is via funding either for direct action to improve urban condition or to promote the sharing of good practice in terms of urban development and renewal. Moreover, the EU has a considerable funding programme to deliver transport infrastructure. Via these programmes the EU can potentially impact soil sealing issues within these spheres.

Table 4.3, below presents the policies and legislation already in place within the EU that potentially impact upon land management and soil sealing. Within the table it is highlighted which EU level policies and actions are considered to have the greatest positive and negative impacts upon sealing in Europe. It should be noted that table 4.3 merely recognises the potential for these measures to have a positive or negative impact, the actual impact seen will depend upon the approach to implementation adopted. In particular the implementation of EU Directives at the national and the rigour of guidance applied to EU funding regimes.

The mechanisms deemed to have a potentially positive impact are environmental measures that indirectly could limit sealing in order to deliver their primary policy objective. These are:

- the water framework Directive, which through the use of river basin management planning requires account to be taken of the quantity of water available in the catchment and as such sealing is of relevance;

- the flood risk management Directive, which is of relevance given the emphasis on the development of plans to limit flood risk and this might include consideration of runoff and the impacts of sealing;
- the environmental impact assessment Directive, this requires development projects to take account of the impacts on the environment associated with action, as soil functionality is vital to other environmental services this should be assessed to avoid inappropriate sealing;
- the strategic environmental assessment Directive, this requires plans and programmes to be assessed for their environmental impacts importantly at this level it is possible to divert eg urban development away from high value soils avoiding sealing of particularly problematic locations; and
- the habitats and birds Directives, these require the establishment of protected areas, while the aim is to protect certain species and the habitats they require in so doing the soils are also protected limiting sealing in the landscape.

The EU policies and mechanisms predicted to have the greatest negative impacts upon sealing are all tools for funding and the support of construction. This is because, while development does not have to lead to inappropriate or problematic sealing such programmes are not sufficiently environmentally proofed to ensure that soil conditions are adequately taken into account. By promoting development in all likelihood these mechanisms promote sealing. It should be noted that it is not considered that the EU should cease to fund development but that mechanisms identified to ensure that soil condition/function is adequately into account. The funding mechanisms identified are:

- the Trans European Transport Network or TEN-T which promotes the construction of transport infrastructure in Europe;
- the Structure and Cohesion Funds, which support improved urban environments which could have negative impacts if this leads to urban expansion or more intense development; and
- the European Investment Bank, the bank offers grants for urban renewal and development of infrastructure which could lead to increased sealing.

Table 4.3 Evaluating existing EU Policy, programmes and informal initiatives that have the potential to impact upon soil sealing

Key

Green shading and underlined policy title indicates polices with the most significant potential positive impact on sealing
Yellow shading and italic policy title indicates polices with the most significant potential negative impact on sealing

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
Soil Protection			
Thematic Strategy for Soil Protection (COM(2006)231	Strategy sets out the model for a European approach to soil protection, including identifying key threats to soil quality in Europe. The strategy explains why further action is needed to ensure a high level of soil protection, sets overall objectives and explains what kind of measures must be taken. It establishes a ten-year work program for the European Commission. This is complemented by a proposal for a new framework Directive on soil protection, which is currently being debated under the codecision process.	In the strategy sealing is identified as one of the key threats/degradation processes impacting Europe's soils and that unlike for other soil threats a national or regional approach to deal with this problem is most appropriate. On sealing the TS sets out limited actions – to limit sealing by rehabilitating brownfield sites and to mitigate its effects by using construction techniques that allow maintenance of as many soil functions as possible. The only direct action highlighted in relation to soil sealing was the dissemination of best practices for avoiding sealing and inappropriate urban expansion.	Positive initiative but limited impact - Actions non binding and v. limited in scope. Impact will depend on the ultimate outcome of negotiations over the soil framework Directive, aimed at implementing key actions under the TS, see section 1.5 Soil sealing issues were initially intended to be much higher in profile under both the soil and urban Thematic Strategies. However, this was subject to political pressure upon the Commission both internally and via MS. It was considered too sensitive and an issue of MS competence.
Sustainable Urban Development			
Thematic Strategy on the Urban Environment (COM(2005)718)	The Strategy aimed to bring together EU action on urban environment issues, focusing upon synergies between other EU policies and training/dissemination of best practice. It makes limited reference to ensure sustainable urban design via appropriate land use planning, helping to reduce urban sprawl, loss of natural habitats and biodiversity. It is commented that integrated management of the urban environment should foster sustainable land-use policies which avoid urban sprawl and reduce soil-sealing. The Urban Environment	Focused on promoting good practice in terms of action on the urban environment, including sealing of soils.	Positive initiative but limited impact - Actions non binding and v. limited in scope.

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
	Thematic Strategy, however, has no legislative weight in its own right and devolved dealing with soil sealing primarily to the soil protection Thematic Strategy.		
European Spatial Development Perspective (ESDP) - http://ec.europa.eu/regional_policy/sources/docoffic/official/reports/pdf/sum_en.pdf	The ESDP is an informal EU policy. Under Germany's 1999 Presidency of the Council of the European Union an Informal Council of Ministers was held focusing upon spatial planning in Potsdam. In response to the discussions the ESDP was published, setting out a strategic approach to spatial development policies aimed at moving towards a balanced and sustainable development of the territory of the European Union. This does not represent a formal policy measure under EU law and more coordinated action by EU Member States to address challenges faced in Europe in the context of regional development with the intention of promoting: – economic and social cohesion; – conservation and management of natural resources – cultural heritage.	The dossier does highlight the need to protect Europe's soils, but focussed primarily on contamination/pollution and erosion issues. Need to protect Europe's soil functions are highlighted, including as a policy option for the future.	Raised the profile of spatial issues at EU level and the need to protect EU soils, leading up to the adoption of the 6EAP and soil TS. Little impact on action or policy at EU level.
Territorial Agenda of the European Union (TAEU) - http://www.bmvbs.de/Anlage/original_1005295/Territorial-Agenda-of-the-European-Union-Agreed-on-25-May-2007-accessible.pdf	The TAEU is also an informal EU policy measure. Following on from the ESDP initiative under their earlier Presidency, in 2007 Germany again instigated an informal ministerial conference on spatial issues. At the meeting, held in Leipzig on 24 and 25 May 2007, Ministers agreed the TAEU. The TAEUs's focus is primarily upon territorial cohesion issues, making the best use of territorial diversity and identifying development opportunities. The TAEU complements the Leipzig Charter on Sustainable European Cities, also launched by the German Presidency, on May 24th 2007 (http://www.eu2007.de/en/News/download_docs/Mai/0524-AN/075DokumentLeipzigCharta.pdf)	Although environmental issues are mentioned in the TAEU, soil and its sealing is not specifically highlighted. The TAEU's main role in this context is highlighting the importance of spatial issues in the EU and the role of the urban environment	No impact excluding highlighting spatial issues at the EU level
Promoting Development in Europe			
Lisbon Strategy	During the meeting of the European Council in Lisbon (March 2000), the Heads of State or Government launched a "Lisbon Strategy" aimed at making the European Union (EU) the most competitive economy in the world and achieving full employment by 2010.	This promotes European growth and employment, complemented by the EU SDS - see below. Limited relationship to sealing aside from the fact that growth is often associated with urbanisation and road building	Limited but potential impact on perception of what type of development is acceptable.

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
		programmes.	
Trans European Transport Network	TEN-T is the programme via which European investment on transport infrastructure is coordinated with the objective of improved mobility across Europe. Investment in transport infrastructure in Europe has been estimated for the EU 25 as €5,526 million for 2006 with an estimated total spend by the EU 25 of approximately €775,632 million between 2000 and 2006 inclusive27. Funding for transport is split between the Trans-European transport budget, grants under the Cohesion fund, ERDF and loans/guarantees from the European Investment Bank[28]. Between 2007 and 2013 expenditure on transport infrastructure under TEN-T is anticipated to be €389.821 million with 21% dedicated to support for road building. The Guidelines define the TEN-T roads as composed of motorways and high-quality roads – existing, new or to be adapted. The total length of the current TEN-T roads, including ordinary roads yet to be upgraded, was approximately 98.500 km in EU27 in 2005.	Road building in particular, in addition to urban expansion, represents a major source of soil sealing especially in more rural localities. Development of roads that do not accommodate technology to limit sealing can significantly contribute to this issue.	Potentially large amounts of EU money, especially targeting road development, could have a negative impact on soil sealing especially if funding is not tied to environmental requirements relating to this.
Structure and Cohesion Funding[29]	There are three objectives set out for EU funding – convergence, regional competitiveness and employment and European Territorial Cooperation – aimed at promoting sustainable development and cohesion across the EU. Under these priorities the ERDF, ESF and Cohesion Fund variably fund initiatives[30] . Within these supporting Europe's cities is seen as a priority. Under the convergence objective primarily there is funding set aside. Under cohesion funding some €21.1 billion has been earmarked for urban development between 2007 and 2013, representing 6.1% of the total EU cohesion policy budget. Of this, €3.4 billion is targeted at the rehabilitation of industrial sites and contaminated land areas, €9.8 billion for urban and rural regeneration projects, €7 billion for clean urban transport, and €917 million for housing. In addition historic programmes for urban support are integrated under the convergence and regional competitiveness streams.	Support for improved urban environments and sustainable development of cities is a priority and can lead to improved social and environmental conditions. However, is this support leads to expansion or supports inappropriate development, installation of hard surfaces in areas of previously open areas.	Potentially negative impact on sealing if this encourages either urban expansion or alternatively more intensity of development.

27 http://ec.europa.eu/transport/infrastructure/doc/transport_invesment_across_europe.pdf

28 http://ec.europa.eu/transport/infrastructure/funding/funding_en.htm

29 For full details of EU efforts related to urban renewal and funding see http://ec.europa.eu/regional_policy/sources/docgener/presenta/urban2009/urban2009_en.pdf . There is no direct reference made to sealing of soils within this; although the need to protect soils and their relationship to climate issues is identified.

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
European Investment Bank	The EIB offers grants to support issues such as urban renewable and development of transport infrastructure.	As per above	As per above
Water Management			
Water Framework Directive (2000/60/EC)	The implementation of the WFD is a priority in order to address mismanagement of water resources with the objectives of preventing and reducing pollution, promoting sustainable water use, protecting the aquatic environment, improving the status of aquatic ecosystems and mitigating the effects of floods and droughts. The WFD will ultimately require the management of river catchments to ensure the protection of water resources.	Soil sealing impacts on the ability of water to infiltrate and travel through a rivers catchment both as overland and sub-surface flows. As a consequence this can impact upon both flooding and droughts.	Potentially v. influential measure that if fully and robustly implemented will require a new way of planning within river catchments. Still under development, and implementation will vary depending upon MS ambition.
Flood risk management Directive (2007/60/EC)	This measure requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. Member States are required to develop flood management plans taking account of land use, water and soil management.	Soil sealing is repeatedly linked to flood events, mitigation of flood risks also results in the dedication of large areas where sealing is prevented, hence aiding infiltration.	Potentially could require MS to address soil sealing concerns if these are a factor in flood events. Reducing sealing could potentially be an action within flood management plans.
Addressing the challenge of water scarcity and droughts in the European Union (COM(2007)414)	This Communication represents an initial set of policy options to increase water efficiency and water savings. It highlights the importance of land use planning and the better management of river catchments.	Represent initial EU action to address concerns over water scarcity – limited link to sealing. Potentially could be of interest into the future	Limited impact at present, could increase over time
Development Control			
EIA Directive (97/11/EC)	Directive on the assessment of the effects of certain public and private projects on the environment, amending Directive 85/337/EEC. The EIA procedure ensures that environmental	In theory EIA assessments should cover all relevant environmental impacts associated with development,	Potentially very influential but it depends upon the quality of the EIA procedure completed

30 Structuring for EU Funds under the three overarching objectives between 2007 and 2013, from http://ec.europa.eu/regional_policy/policy/object/index_en.htm -

Objectives, Structural Funds and instruments
2007-2013

Objectives	Structural Funds and instruments		
Convergence	ERDF	ESF	Cohesion Fund
Regional Competitiveness and Employment	ERDF	ESF	
European Territorial Cooperation	ERDF		

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
	consequences of public and private projects are identified and assessed before authorisation is given. The public can give its opinion and all results are taken into account in the authorisation procedure of the project. Direct and indirect effects of a project on the following factors are considered: human beings, fauna and flora; soil, water, air, climate and the landscape; material assets and the cultural heritage.	including soil and soil sealing. As the central mechanism for determining and mitigating the impact of developments EIA is potentially a key tool for limiting sealing impact, however, in reality soil and particularly sealing impacts are often not comprehensively assessed.	and the prioritisation given to soil and sealing at the scoping stage of the assessment.
SEA Directive (2001/42/EC)	The Directive requires authorities to undertake an environmental assessment of certain plans and programmes which are likely to give rise to significant effects on the environment. The Directive does require an assessment to consider the potential impacts upon soils; however, SEA as an instrument is highly flexible.	The SEA Directive is closely linked to land use planning and as such has a potentially significant role in limiting the impact of development in terms of soils sealing. However, given the flexibility afforded under the SEA Directive soil issues can be overlooked. Moreover, soil is often not considered in terms of its functionality in such assessments and there is little data often to support decisions regarding soil impacts. SEA will have the greatest impact on soil sealing in MS where the SEA process is used to scope areas for development, as part of developing a spatially planned approach; often, however, it is simply used as a cross checking process.	Potentially very influential but it depends upon the approach to consideration of soils and the broader role of SEA within spatial decision making.
Indirect control of development activity			
Habitats Directive (92/43/EEC); Birds Directive (79/409/EEC); Natura 2000.	Avoiding pollution and the deterioration of agricultural soils are implicit preconditions for the protection or recovery of habitats and species under both of these Directives. Natura 2000 is an ecological network of nature protection areas comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive, and Special Protection Areas (SPAs) under the Birds Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats, and therefore protects these areas at risk of land degradation and desertification.	Protecting designated areas from intensive development and sealing.	By protecting areas of land from development and applying strict requirements on any activities conducted within a protected area this can prevent sealing in specific areas.
Council Regulation	Member States are required to ensure that land which was under	Protecting specific areas from	Limited impact given the

Policy / Programme/ Initiative	Description	Link to Soil Sealing	Impact on Sealing Issues
1782/2003/EEC – Article 5 – Cross-compliance requirement to maintain permanent pasture	permanent pasture at the date provided for the area aid applications for 2003 is maintained under permanent pasture. (1 May 2004 for New Member States and 1 January 2007 for Bulgaria and Romania). See Chapter 7 for details.	intensification of development	nature of protection, but potentially offers the opportunity to safe guard areas.
Strategic Requirements			
EU Sustainable Development Strategy (SDS) European Council DOC 10917/06	The EU SDS sets out a single, coherent strategy on how the EU will more effectively live up to its long-standing commitment to meet the challenges of sustainable development. The strategy sets overall objectives and concrete actions for seven key priority challenges for the coming period until 2010: Climate change and clean energy; Sustainable transport; Sustainable consumption & production; Conservation and management of natural resources; Public Health; Social inclusion, demography and migration; Global poverty and sustainable development challenges.	Soil and water contamination; Soil erosion; Soil compaction; Declining soil biodiversity, fertility and organic matter content; Soil sealing.	EU-27. The strategy proposes mechanisms for improving the coordination with other levels of governments and calls upon business, NGOs and citizens to become more involved in working for sustainable development[31].

[31] http://ec.europa.eu/environment/eussd/

4.3.3 Future policy developments

Into the future there are several key legislative measures under development at EU that may offer an alternative policy basis for addressing the protection of land and the limitation of soil sealing. The most important of these is the new proposed framework Directive on soil protection – the potential impacts of which are outlined below. Within this section future policy priorities and potential future actions to address soil sealing are set out. It should be noted that in response to the Soil Thematic Strategy the Commission is also developing a best practice guidance document to help Member States address questions of soil sealing.

Proposal for a Framework Directive on Soil Protection

Currently this proposal for a framework Directive remains under debate within the co-decision process. The European Parliament adopted its first reading opinion on the proposal, however, progress has stalled due to objections from specific Member States regarding the implementation costs. If adopted in its current form the measure would require Member States to better map areas at risk of soil degradation or priority areas for action. In addition, specific requirements are set out in particular related to contamination and sealing. This would be the first legally binding EU measure specifically devoted to soil and land degradation.

Within the Directive sealing is defined and specific requirements relating to this are set out. The latter were amended and expanded by the European Parliament within their first reading opinion – see Table 4.4 below. While the Parliament's requirements are more detailed both texts in essence require Member States to develop guidelines and best practices to ensure the quality of development and the consideration of the sealing impacts to maintain soil function.

It should be noted that while a significant minority of Member States do not support a Directive on soil issues, others are keen to see this legislative measure be approved. Importantly, in surveys it has been noted by many experts in this field that soil issues fail to be prioritised by busy national and regional governments without a clear EU regulatory mandate requiring them to address this. It was noted that for example, while EU policies exist requiring the protection of water and air but not soils, soils will always receive more limited attention.

Table 4.4. Summarising the treatment of soil sealing within the proposal for a Framework Directive on Soil Protection and within the European Parliament's First Reading Opinion

Definition and Sealing Requirements as set out in COM(2006)232 – proposal for a framework Directive on soil protection.	First Reading Opinion of the European Parliament – amendment to sealing requirements
Definition - 'sealing' means the permanent covering of the soil surface with an impermeable material. ***Sealing requirements*** - For the purposes of preserving the soil functions referred to in Article 1(1), Member States shall take appropriate measures to limit sealing or, where sealing is to be carried out, to mitigate its effects in particular by the use of construction techniques and products which will allow as many of those functions as possible to be maintained.	***Sealing Requirements*** - For the purposes of preserving the soil functions referred to in Article 1(1), Member States shall take suitable measures to limit sealing, and to minimise its effects, to the extent which is necessary, in particular where a proposed development project involves soil sealing, and where: ▪ the project is of a type listed in either Annex I or Annex II of Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment and requires an assessment under that Directive; ▪ the assessment indicates that there are likely to be impacts arising from sealing that significantly impede one or more of the soil functions listed in Article 1(1). This will allow as many of those functions as possible to be maintained. 2. Member States shall decide on the measures which are appropriate, in particular those mentioned in paragraph 3, taking into account the costs and benefits of such measures. 3. As sealing is an irreversible process, Member States shall develop codes of good practice on sealing that: – preserve river basins and the natural flow of water; – prevent increased flood risks, resulting from sealing; – promote proper access to green areas in expanding cities; – preserve valuable geomorphological soil structures, characteristic landscapes and coastal areas; – preserve archaeological sites, prehistoric caves and historical sites; – avoid the visual impacts of extractive industries; – facilitate industrial and urban spatial planning on areas already affected by industrial and urban planning; and – promote brownfield investments.

Anticipated evolutions in policy priorities

Over the coming years policy attention devoted to water quantity, availability (both scarcity and flooding) and climate adaptation is anticipated to increase. As a consequence of soil sealing's important interaction with water flow patterns; this reprioritisation is anticipated to also affect the focus devoted to soil sealing issues. Details of the anticipated changes in policy priorities and their importance from a soil sealing perspective are set out below.

- *Increasing prioritisation of water quantity issues* – The debate on the quantity of water available to meet our needs looks set to increase in profile. Hydrological flows over the land, infiltration rates and retention capacities of the soils are integrally linked to the debate on the availability of water. Degradation of land linked to sealing by urban uses or inappropriate management practices in rural areas will increasingly come under pressure as we attempt to ensure that water remains available for our needs, and that extreme rainfall events (predicted to become more frequent and unpredictable linked to climate change) do not result in increases in flooding and destruction.

- *Increasing importance of land management in mitigating and adapting to climate change* – The need for rapid and decisive action to combat climate change and adapt to the associated consequences we are already seeing, is paramount. Adaptation to climate change will become a debate of increasing importance and priority, linked to that on water scarcity and availability. The importance of high quality and land conditions is likely to increase as we begin to live in a more unpredictable world.

- *Rising Pressure upon land use and conflicting land pressures* – There is increasing debate in Europe about appropriate land use and potential future conflicts, between urbanisation, food production, burgeoning biomass production etc. The issue of spatial resource availability looks set to rise up the wider European agenda, despite the historic in ability to address this subject at the EU level due to competency issues.

Targeting soil sealing into the future – Actions proposed by the working group for soil sealing under the Thematic Strategy for soil protection.

During the development of the soil Thematic Strategy and associated framework Directive the stakeholder working group charged with considering soil sealing issues identified a series of responses to the challenges posed by sealing – these are set out and reviewed in Table 4.5 below. Some of the actions recommended might be possible to promote at the EU level. The majority, however, would require cultural shifts within the different European nations, especially in terms of perceptions regarding urbanisation, its causes and trends such as increasing household number.

Table 4.5. Review of responses proposed by Task Group 5 on soil sealing, soils in urban areas, land use and land use planning[32]

Key – Bold highlighting – identifies actions perceived by the researchers to be the most realistic/pragmatic in terms of delivering change in sealing patterns.

Proposed Response	WG Recommendations	Evaluation
Convention on soil consumption restriction	City growth is accompanied by sealing. This means that control and decrease of city growth will also reduce the growth of sealed areas. To express the political will for this urgent target an international convention on soil consumption restriction of cities should be achieved.	Given the perceived relationship between urban and economic growth such an international convention is unlikely to be politically acceptable. Moreover, it is unclear what direct restrictions it could place upon action.
Controlled city growth	**Often cities are expanding onto the most fertile soils, this means they are consuming not only soils but the best soils. City growth should be controlled that way that only soils of lowest fertility of the region are used for expansion of the city. For that purpose soils must be surveyed and their quality assessed.**	**There is a potential to use existing tools, if properly linked to spatial planning decisions, to help address this ie role of SEA. However, there are often reasons expansion is occurring in fertile areas ie historical location of cities in river valleys or in areas offering good food production capacity. However, in light of likely increases in pressure on land there is a real need to address this within broader efforts to promote more considered land use decisions.**
Technical Measures to restrict sealing	– limiting construction of large single story buildings eg for storage/warehousing. Move to taller buildings with a smaller base – relieving some impacts by establishment of green roofs – advancing e-commerce to reduce road construction – construction of temporary buildings that can be easily removed with soils returned to their original capacity	While efforts at the EU level can identify and promote good practice in this field action would need to be taken at the national, regional and local level across MS. The concept of payment or compensation for loss of natural resource is controversial and would have to be considered as part of a more holistic approach to this eg as part of the broader land services debate. It would need to be part of a clear policy process to avoid misuse.
Fiscal measures for restricting sealing	– payment for the loss of natural resources associated with construction – payment to enable the re-establishment of the original soil state/compensation elsewhere	
Soil measures to restrict sealing	– trend towards increased living space per person needs to be addressed – More efficient use and organisation of buildings	
Diminishing the impacts	**Adoption of techniques to reduce the loss of function associated with surface sealing** – **Use of permeable hard standing** – **Use of subsurface rain water redistribution**	**There is quite a high potential that by using best practice techniques a certain amount of soil function can be retained. This could potentially have a significant impact upon issues such as hydrology but there needs to be a prioritisation of sealing issues.**

32 Working Group on Research, Sealing and Cross-cutting issues, Task Group 5 on Soil Sealing, Soils in Urban Areas, Land Use and Land Use Planning, Final Report, May 2004 - http://circa.europa.eu/Public/irc/env/soil/library?l=/reports_working/final_reports/volume_ii_sealing/sealing_planningdoc_1/_EN_1.0_&a=d#_Toc72646332

	systems – **Planting of trees etc whose roots penetrate below the sealed surface** – **Green roofs**	
Soil compensation and substitution	**Establishment of a system of pedotopes ie soil areas with clearly identifiable and defined functions to use as a basis for compensation and substitution as a consequence of sealing.**	**Establishment of a system for valuing soils is key to the broader role out of action to address and limit the impacts of sealing. It should be noted that some functions are not easy to compensate for eg hydrological function. Once there is a clearer information base this could become a more established part of EIA/SEA evaluation.**
Planning response	**Low sealing and low sealing effect development should be part of any planned development and broader spatial designed expansion should take account of the functions of the land that it is replacing. Plans should be assessed for their sealing impact.**	**The needs to address sealing needs to become a more established part of considerations when planning developments etc. However, as illustrated by problems associated with eg loss of gardens to hard standing, this also needs to be considered throughout the life of a building.**
De-sealing	There could be an active approach to either promoting desealing or allowing natural processes of desealing to occur in some abandoned sites to help return soil function to the land.	This potentially has a role in urban renewable, but there would be a need to ensure that prior to land abandonment funding was in place to enable this/policy in place to require desealing.

4.3.4 Conclusions – Role of EU policy in combating soil sealing

Soil sealing is very much linked to urban development, road building and other construction, hence building standards and land use planning. Its environmental impacts of most significance relate to changes in water flow patterns impacting water availability and flooding. There is also an important opportunity cost linked to sealing due to the limitations in places upon future land use including the production of biomass for nature conservation or agricultural purposes. Given the EU's limited competence over land use planning issues and the impasse over the soil framework Directive, there are no binding measures requiring Member States to address this issue.

Actions at the European level anticipated to have the greatest positive impact are associated either with the protection of water resources or protection of land for alternative, predominantly nature conservation, purposes. Under the water framework Directive there is the potential to control activities within river catchments that impact on the quantity, as well as quality, of waters. The floods Directive, despite is focus on the development of plans, may also impact on sealing; at least raising consciousness surrounding the impact soil amelioration has upon natural hydrological flows.

The EIA and SEA Directives potentially represent relatively strong tools promoting the consideration of environmental impacts in land use and development decisions. However, impact on soil sealing is often not seen as a priority within such assessments. Moreover, a lack of data makes effective assessment of impact on soil function problematic. The SEA Directive, in particular, could offer substantive protection to areas deemed as offering valuable soil functions; but only if appropriately applied. Such an approach would rely on two important factors: a clear understanding of the role of different soils, beyond simply their value as an agricultural resource; and the application of SEA as a tool to help determine spatial decisions rather than simply review the impact of spatial decisions. At present such an approach is not the norm within Member States.

Conversely, EU policies also promote urban renewal, urban development, investment in transport infrastructure and road building. Whilst these are important socio-economic objectives for Europe, their inappropriate promotion could lead to increased sealing. For example, if road building were promoted without specifying the use of appropriate technologies to limit sealing impacts or more indirectly stimulating car ownership leading to an increase in the sealing of green spaces such as gardens and the desire top expand road networks. This effect would be felt most acutely if the intensity and scale of urban development were to increase. The more effective consideration of soil function issues and risks of soil sealing prior to approval of funding requests could, however, be an effective way of limiting the negative impacts of EU urban investment on soils. However, as for SEAs and EIAs this would require an improved understanding of the value of soils and how their functions can be valued.

In terms of policy tools, to date the most effective EU instruments for limiting soil sealing are either those requiring the protection of land areas ie for nature conservation, or mechanisms that require plans to be made at a more local level such as the water framework Directive. This highlights the importance of decisions relating to soil condition being effectively considered at the local level and demonstrates the limitation of binding requirements at the EU level. Going forward approaches that require and facilitate better integration of soil sealing issues into water, land use and development decision making are likely to prove most effective. This might include both supporting more effective mechanisms for assessing soil value to developing best practice in the consideration of soil sealing risks.

4.3.5 Soil Sealing at the national level – impact and action

The level and expansion in soil sealing are often strongly correlated to Gross National Product (Burghardt *et al*., 2004), given sealing is associated with construction and the development of land. In several Member States sealing has been raised as an issue of concern either due to expanded extent urban areas, leading to loss of fertile soils for agriculture and forestry, or increased intensity of development, leading to increased flood risk, pressure on sewage systems and loss of local character (Lexer *et al*., 2005; Banko *et al*., 2004, in: Huber *et al*., 2008). For this reason, policy and public responses to limit sealing and land consumption can be seen in a number of EU Member States. This section examines the nature of national and regional efforts that can help to limit sealing and the policy mechanisms available for use.

National efforts and soil sealing

Efforts (and the level of perceived need) to address soil sealing at the national and regional level vary significantly across and within the EU Member States. The desire to address soil sealing depends on national and local priorities and experiences. This can lead to three types of policy response:

- the development or adaption of the national or local policy framework to better address soil sealing and its impacts;
- tailoring the implementation of EU measures to encompass sealing issues and impacts[33]; and
- by funding out reach and support activities to educate local people and construction companies to take account of sealing issues when making development decisions.

[33] While the policy framework is generated at the EU level, the decisions regarding implementation and consideration of soil sealing as a concern vary significantly, hence this is a national/regional decision

Case examples – soil sealing challenges across Europe

Below are set out examples from across Europe of the concerns associated with and actions being adopted to combat soil sealing. This examines the different causes and solutions being put forward.

Loss of land in Austria to development – cultural shifts and regional impacts

According to figures from the Austrian Environment Agency (the Umweltbundesamt) settlement and transport activities in Austria require the consumption of around 12 hectares per day. This figure is occurring despite relatively low rates of population growth, with sealing occurring both in rural and urban areas. Expansion is associated with extensive road development and also cultural shifts leading to higher levels of single family dwellings.

Around 4,300 km² of Austria's surface area is utilised for either building land or transport purposes, with approximately 40% of this total area considered sealed. There has also been a clear and consistent upward trend in the use of land for both roads and buildings. However, the scale of the problem varies significantly across Austria's counties or Bundeslands. According to figures from the Umweltbundesamt sealing poses the greatest challenge in Lower Austria, closely followed by Upper Austria and then Burgenland (Umweltbudnesamt, 2009[34]) .

Increasing intensity of sealing and local action – Ealing Borough,London, UK

Many Member States are experiencing problems associated with the expansion of urban areas and the consumption of land. There is, however, an additional aspect to sealing that is sometimes overlooked that of increasing intensity of urban development. This is a potentially significant problem in the UK due to restrictive greenbelt policies and the promotion of brownfield site redevelopment. While this addresses the challenge of urban sprawl this leads to the infilling of space within existing urban areas, and if constructed without considering sealing impacts, this can generate problems particularly associated with run off of rain water. Moreover, in densely populated cities and with increasing car ownership, plus pressures on individuals time people are increasingly paving over their front gardens to provide parking for cars but also for easy management of land.

In the UK there have been a number of initiatives, particularly following on from the flooding events in 2008 to address the unrestricted change of use of front gardens. The UK Town and Country Planning Act was altered in 2008 to require that hard surfacing of front gardens of more that 5m2 be porous or be accompanied by a soakaway/provision for rainwater storage or subject to planning permission. However, enforcement of this requirement has been patchy by local authorities and provisions only apply to front not back gardens, Moreover, in intensely urban areas such as London the 5m2 limit can prove problematic. This has lead to more community based action, as seen in the Borough of Ealing, in West London.

The Ealing Front Garden Project[35] was established under Ealing Borough Council's Agenda 21 programme and funded by the local Council. A survey of front gardens in Ealing showed that:

- a quarter of the borough's 74,300 front gardens are completely hard surfaced - no vegetation at all;

[34] http://www.umweltbundesamt.at/en/umweltschutz/raumordnung/flaechenverbrauch/

[35] http://www.ealingfrontgardens.org.uk/index.htm

- a further fifth of front gardens in this borough have nearly all (90-99% of their area) hard surfaced;
- well over half of the borough's front gardens have 70% or more of their area under hard surfacing; and
- the average front garden in the borough has 68% of its area covered in hard surfacing.

The Ealing Frong Garden Project brings together information on the UK legal situation, problems associated with wide scale hard surfacing of front gardens and guidance on alternatives. For example details are provided on types of porous products and approaches to dealing with gardens to maximise parking and minimise maintenance without introducing hard standing. It also sets out policy solutions at the local level to address the issue of increased hard standing. This includes removing creation of hard standing from the list of permitted developments or removing the introduction of a cross over on the pavement (needed to access a front garden by car) from the list of permitted developments. An emphasis is also placed on awareness raising to ensure people understand the alternatives.

Sealing patterns and protection - Saxony, Germany
Lower Saxony is the second largest German Lander, whose authorities have been particularly concerned with the need to preserve soil functionality. The Saxon State Agency of Environment and Geology is concerned with the countrywide protection of the soil and its functions independent from its actual use. The analysis from Saxony identified that soil protection is still a subordinate issue in regional and urban planning. Construction measures are generating the most extensive losses of soil by sealing, excavation, filling and dissection of land.

In Germany there is a Federal legal base for the protection of soils, with the Federal Soil Protection Law enacted in 1998 and implemented in Saxony in 1999. However, the focus of this is considered to be contamination issues with limited consideration of the prevention of degradation – which is key to prevent sealing.

A study by the SSAEG (Gunreben, 2003) identified that the degree of sealing for soils within the state is around 4.5 percent. The amount is increasing at a rate in excess of 4 hectares per day. The average rate of sealing between 1989 and 2001 was 5.3 hectares per day, which is the equivalent of the area of 7 football fields per day. The study showed that the proportion of sealed surfaces in cities ranged between 15 percent and 25 percent, with Hanover occupying the first place. The major types of land usage with high surface sealing are settlements with detached and semidetached houses and industrial estates. The greatest increment in land usage types leading to surface sealing occurs not in the inner cities but rather on their peripheries and along the main trunk roads.

Within analysis of planning applications it was noted that buildings, while requiring extensive horizontal extent, often do not fulfil their permitted vertical extent. It was commented that changing the nature of building design could potentially reduce by one third the building land needed for industrial development. In addition to identifying this type of practical opportunity the Saxon State Agency of Environment and Geology has generated various tools and guidance documents to help better understand and address the issue of soil sealing in the region these include:
- Information on the environmental monitoring by satellite data (2003).
- Information on the mapping and assessment of soil sealing (2005).
- Saxon soil assessment instrument (2005).

- Guideline soil protection for planning and licensing procedures in the Free State of Saxony (2001).
- Materials and modules for the design of area management systems (2007).

Potential policy tools

This section sets out details of the types of policy tools Member States or their regions are currently using to address soil sealing. It should be noted that use of these tools is often sub optimal and is inconsistent, however, the information below is intended as a basis upon which future solutions might be developed.

River basin management

Under the water framework Directive Member States must produce river basin management plans. Of the plans submitted to the Commission 13 Member States mentioned to the soil sealing (Hudec *et al*., 2007), when asked to report on the implementation of the Directive. River basin management plans offer an opportunity to identify, plan for and mitigate the water flow impacts associated with soil sealing if effectively implemented. At present, however, the primary focus of river basin management plans tends to be on quality rather that quantity issue; moreover, the majority of plans are only able to use indirect indicators of the surfaces sealed. According to Member State reporting soil sealing has only been identified as a pressure related to flooding and water quality in two international River Basin Districts, the Rhine and Scheldt.

At present river basin management plans are not being fully utilised to consider and mitigate sealing issues. However, into the future they offer a policy route that could be further exploited especially given the opportunities afforded in terms of taking account of local conditions and characteristics.

Best practice and capacity building

There are several initiatives particularly focused on capacity building around building and design techniques in order to limit the extent and impact of drainage. This includes initiatives and innovations supported by the industry such as capacity building on Sustainable Urban Drainage, run for example by CIRIA who host a forum on SUDs[36], support research projects and generate codes of good practice. These are aimed at limiting the impacts of development through for example using porous materials. There is also technical support of this nature for example to remediate land and de-seal.

More limited and less coordinated efforts are aimed at avoiding sealing in the first place and addressing the causes of sealing. The example of the Ealing Front Gardens Project is one illustration of offering support to address the causes of development or provide alternative designs. The EFGP also points to a number of other sources, for example Royal Horticultural Society guidance on garden design.

The work in the Lower Saxony identified that there is an opportunity to reduce sealing through better building design, as well as simply by changing the materials used. One commonly cites approach is the use of 'Green roofs' ie vegetated roofs, which can replace some of the functions (although not all) of the original soils. Others include: use of underground connections, floating city quarters or smart soils or biogrout (an in situ

[36] http://www.ciria.org.uk/suds/

biological treatment to ensure soils underneath eg transport infrastructure are more stable and permeable using micro organisms and nutrients. However, there are more extensive opportunities to consider the footprint of developments and the permanence of sealing, seeing soils rather than as a waste product of construction as something whose function should be conserved during a build. Finally, coordination of uses is also key ie reducing the overall need for built space by ensure its multifunctional use for example the use of mega dikes in the Netherlands for transport infrastructure (Van Ravesteyn, 2008).

To deliver adoption of these technologies will take a mix of solutions including capacity building, funding, support for industry, implicit support through planning systems and legal requirements promoting adoption.

Land use and development planning

As stated above prevention of sealing of soils with valued functions is the key to addressing the problem. This requires an effective land use planning system that can deal with the difference scales and causes of soil sealing, which sufficiently prioritise soil functions in need of retention and that has access to data that can support decision making as to where and how development can take place with the least impact. Box 4.4 presents a summary of particular spatial planning policies enacted at the Member State level. This section then goes on to examine key policy types used in Member States, their implications and limitations.

Box 4.4. Examples of spatial planning policy mechanisms being used to limit land consumption and soil sealing in European Member States

In many European countries there is some form of protection offered to land to prevent certain types of development in certain localities. Examples include:

- The target in the UK to build 60% of new houses in already built up areas (brownfield redevelopment) by 2007 (now to be extended) (Hamell, 2008).
- In Germany, the national target to reduce soil sealing from 120 ha/day to 30 ha/day in 2020 (Hamell, 2008).
- Compensation mechanisms for land lost to sealing, set out in German law but still to be implemented effectively (Hamell, 2008).
- In the Czech Republic the price for the conversion of fertile land to urban land has been multiplied by 20 in a recent amendment to the Soil Law (Hamell, 2008).
- In The Netherlands the Spatial Planning Agencies promotes the restructuring rather than expansion of industrial estates (PBL, 2009).

Prioritising soil function

According to research by the Scottish Government[37] 'soil functions, though given some recognition (e.g., as an EIA requirement) are generally poorly protected through the planning system. It could be said that every aspect of a building site is carefully scrutinised at the planning stage except the soil the site is based on. It is considered as a waste product but seldom as a resource'. There are two challenges a lack of understanding of the importance of soil function and the translation of this into policy measures.

In particular the EIA and SEA Directives offer significant opportunity to introduce consideration of soil issues into the planning system. However, this relies on effective

[37] Working Group in operation in 2008 in support of the review of Scottish Soils and the Scottish Soils Strategy published in 2009. http://www.scotland.gov.uk/Publications/2008/06/27092800/8

guidance highlighting the importance of soils and the data available to make an assessment. Moreover, the implementation of the SEA Directive is known to be inconsistent across Member States and even within Member States – for example in the UK the SEA Directive is considered to be more effectively implemented in Scotland, where dedicated arrangements were made to prioritise environmental considerations in the assessment of plans and programmes, where as in England this was simply absorbed into a sustainability assessment process that in practice can mean environmental issues can be superseded.

Many Member States recognise the need to protect high quality agricultural land from development, documented in papers inter alia from Slovenia (Magyar, 2005), Portugal[38] and the UK[39]. However, it is unclear how effectively prime land is being protected. It is know that valuable agricultural land is being converted. In some countries, for example Slovenia, the topography of the land is such that all the prime land uses ie road, urban and agricultural development are all seeking to make use of valley floors and relatively flat river valleys. These lead to conflict and sealing of fertile soils.

The Scottish Government noted that a policy on the protection of agricultural land is set out in their SDD Circular 18/87 (as amended by SOEnD Circular 25/1994). This states that when considering the allocation of land for development and in deciding applications for planning permission affecting agricultural land, the agricultural implications must be considered together with the environmental, cultural and socioeconomic aspects. In particular, prime quality land should normally be protected against permanent development or irreversible damage. However, in practice, very few planning applications are refused with agricultural land quality cited as a reason for refusal. Moreover, as the vast majority of land in Scotland is not defined as of prime agricultural quality, there is no protection for functionality of soils over most of Scotland.

Policies for constraining urban growth

Urban sprawl is a concern due to sealing and land consumption, but also for wider socio-economic and environmental reasons. As a consequence several Member States have policies intended to limit the extent of urban or semi urban developments. Among these the UK's approach to Greenbelt, limits to housing settlement boundaries in towns and villages and promotion of brownfield development is one of the strongest. The UK has successfully limited urban sprawl in some of its biggest cities by the rigid imposition of a Greenbelt around urban centres within which new development is severely restricted. Moreover, local government must set and enforce strict restrictions on the size and extent of rural towns and villages – to preserve the character of the landscape. While this has limited the expansion of cities and towns, it has lead to more intense, dense development, which is inappropriately developed could also lead to sealing problems.

Policies constraining urban sprawl and development often interact with other policies aimed at protecting areas from development including on the basis on biodiversity or landscape value.

---

38 Portugal noted in their reporting under the UNCCD the protection of territory of agricultural value against urbanisation as a measure to mitigate soil sealing.

39 Examined in local plans which limit development within a given region particularly in areas where agriculture is of particularly high value eg in East Anglia, also mention in the context of the Scottish review of soil sealing issues http://www.scotland.gov.uk/Publications/2008/06/27092800/8

Improving the information base

There is no clear mechanism for the valuing of soil functions or quantifying the benefits offered by a given piece of land or soil system. This represents a challenge, as beyond value to agriculture it is currently difficult to distinguish between soils. In the absence of the ability to distinguish the key functions of a given parcel of land it is difficult to ensure impacts of development are minimised.

There are some models and support tools used for spatial planning support. These include the JRC's MOLAND model which can for example compare impacts (e.g. on soil sealing) of alternative spatial planning & policy scenarios and determine critical factors affecting land use development (e.g. soil sealing). The model predicts land use development under alternative spatial planning and policy scenarios, based on environmental, social and economic data (JRC, 2003).

Other instruments include the EU-funded TUSEC-IP project to evaluate soil quality in urban areas (Vrščaj *et al.*, 2008). This can provide urban planners with an indication of areas suitable for constructing new developments without sealing good quality soil. The evaluation method can also predict the impact of land use changes on soil resources, by inputting predefined soil quality class values for different urban land uses, such as residential areas, playgrounds and shopping centres.

4.3.6 Conclusions – policy measures addressing soil sealing in Europe

It is clear from this review that the array of policy that potentially impacts upon soil sealing is vast. However, as is the case for the consideration of land degradation more generally, this is often not the primary priority. Measures predominately are directed at water protection, maintenance of broader environmental conditions or the promotion of development. Soil sealing is often not seen as a priority, except perhaps where it impacts on local flooding.

A key challenge for the consideration of soil sealing issues is ensuring recognition of its broader interaction with function. The functions provided by a high quality soil in a given locality are often poorly understood. With the exclusion of categorisations based on the value of land in terms of agricultural production, the spatial distribution of different important functions are often not mapped. It is necessary to understand the functions and broader services a portion of soil is performing, in order to make informed decisions regarding the impact of land use changes. This is problematic, however, given the limited data available for mapping such issues and the complexity of the interactions between soil functions and those offered by other media.

The combating of soil sealing is primarily dealt with by policies for which this is not the primary focus, as is the case for soil protection more generally. This lack of prioritisation can lead to suboptimal and potentially disjointed localised solutions. In the future land degradation issues are anticipated to shift up the policy agenda given the linkage to food production, water quantity and the importance of resilience in light of climate change. New policy approaches for protecting our land will therefore be needed.

4.4 ESTIMATION OF IMPACTS OF SOIL SEALING ON LAND SERVICES

4.4.1 Introduction

Soil sealing causes many pressures on soil ecosystems and soil functions, and through these, on land services. Natural, semi-natural and rural land is turned into urban and other artificial land covers, which influences soil functions. The effects may be adverse and in some cases beneficial to societies.

By interrupting the contact between the soil system and other ecological compartments, including the biosphere, hydrosphere and atmosphere, sealing affects basic processes in the water cycle, biogeochemical cycles and energy transfers. Examples of processes influenced are the filtering of infiltrating water, groundwater renewal, gaseous emissions, and runoff. The climate at mico- and meso-scales is altered due to changes in albedo, evaporation and local air temperatures (EEA, 2001; Burghardt *et al*., 2004; Van Camp *et al*., 2004; Huber at al., 2008; Lorenz and Lal, 2009). In addition to the direct effects on the soil system and other ecological compartments, soil sealing exposes adjacent unsealed areas to changes in water flow patterns, the fragmentation of habitats and pollution sources such as vehicular traffic (e.g. Burghardt *et al*., 2004; Scalenghe and Fasciani, 2008; Wolf *et al*., 2007, in: Scalenghe and Ajmone Marsan, 2009). Finally, urbanization may also affect the regional and global atmospheric climate by the urban heat island and pollution island effect (Lorenz and Lal, 2009).

As a result of the alterations to environmental cycles and components mentioned above, sealing causes a potentially irreversible loss of soil resources (e.g. fertility, humus, rootable soil volume) and soil functions (e.g. water storage capacity, ground water renewal, soil as sink and diluter for pollutants, transformation of organic wastes) (adapted from Burghardt *et al*., 2004). Scalenghe and Ajmone Marsan (2009) summarize the main impacts of soil sealing on environmental cycles and components (Table 4.6). The effects of soil sealing on the water cycle are probably the most widely studied in the scientific, engineering, and policy-forming communities. Studies date from the 1960s, with urban hydrologic analysis and design for planning of urban storm water systems for flood control (e.g. Leopold, 1968; Chow, 1985).. In recent years, attention for other effects on the water cycle has grown: decreased baseflow, increased loads of nutrients, sediment, volatile organic compounds (VOCs) and heavy metals, and large thermal shock loadings of streams (e.g. Beyer *et al*., 2009; Moglen, 2009; Squillace and Moran, 2007). Effects of soil sealing on biochemical C and N cycles have only recently been studied (e.g. Lorenz and Lal, 2009). A review of the impacts of soil sealing on energy transfer, water movement, gas diffusion and biota is given by Scalenghe and Ajmone Marsan (2009).

Despite sealing, soils can still perform functions. An example is the use of the subsoil for heat and cold storage near greenhouses in The Netherlands. Positive effects of soil sealing on the soil system and related ecological compartments are less obvious, but certainly exist. Examples are the sealing of land fills, the mitigation of contamination by radionuclides, and the preservation of cultural heritage (Van Camp *et al*., 2004; Scalenghe and Marsan, 2009). Also, urban soils have the potential to store large amounts of soil organic carbon (SOC) in the non-sealed areas, e.g. in gardens and parks, and thus, to contribute to mitigating increases in atmospheric CO2 concentrations (Lorenz and Lal, 2009).

Component	Effect	Temporal extent	Consequence
Heat	Decreased radiation absorption	short term	More reflective surfaces
		medium term	Heat island
Water	Less infiltration	medium term	Reduced chemical reactivity
		long term	Less filtering action
		medium term	Cracking
		short term	Loss of biomass
		short term	Loss of soil water storage
		long term	Dimishes the natural recharge of aquifers
	More runoff	short term	Increased runoff to adjacent areas
		medium term	Increased ponding time
		medium term	Probability of anaerobiosis
		short term	Transfer of contaminants
		long term	Increased risk of flash floods
	Barrier for perched water table	short term	increased risk of anaerobiosis
		medium term	release of contaminants
Gas	Reduced/interrupted exchanges	long term	risk of anaerobiosis
		short term	partial trapping
Biota	loss of plant cover/biomass	medium term	Reduced biodiversity
		long term	Reduced carbon sink
	Heat Urban Island	medium term	Thermal specialization
Landscape	Increased wind erosion	medium term	Increased air-borne particulate
	Increased water erosion	medium term	Increased erosion of adjacent areas
	Uniformity	short term	Reduced aesthetic appeal
		short term	Reduced visual appearance
		medium term	Reduced attractiveness

Temporal extent

short term
medium term
long term

Table 4.6. Effects, timing and consequences of soil sealing for environmental components. Source: adapted from: Scalenghe and Marsan, 2009.

This study aims to quantify the impacts of soil sealing on the land use services food production, biodiversity, water retention and soil carbon sequestration in the European Union. The approach to assessments of land and ecosystem services through the framework of soil functions, as defined in the Soil Thematic Strategy, is novel, and increasingly considered effective in interdisciplinary contexts studying sustainable development (Bouma, 2009; Scalenghe and Ajmone Marsan, 2009). Relations between the land use services in this project and soil functions as defined in the Soil Thematic Strategy were given in Figure 4.1. Below, likely impacts of soil sealing on the land services are discussed, with reference to the soil functions.

4.4.2 Methods

For the assessment of the impacts of soil sealing on land services, the performance of the land services is expressed by indicators. The impact assessment is based on an analysis of the change of the indicators from 1990 to 2000 and from 2000 to 2030. The land services, likely impacts of soil sealing, and indicators selected to describe the change in performance of the land services are outlined in Table 4.7.

Table 4.7. Land services, main soil functions add0ressed, likely impacts of soil sealing discussed in this study, and indicators of land service performance with their properties.

Land service	Main soil functions addressed	(Likely) impacts of soil sealing	Indicators	Dimension	Range	Measure of change	Data sources and methods used
Food production	F1: food and other biomass production	- Primary net production is reduced or shifted to new types of soils	Soil suitability for arable cropping and grassland	% area suitable for arable cropping/ grassland	0-100	Δ % area suitable	ESDB v2.0[40] SINFO[41]
Biodiversity	F3: habitat and gene pool of living organisms	- Limited or impeded habitat for biota	Mean Species Abundance (MSA)	MSA (% point)	0-100	Δ MSA (% point)	EURuralis 2
Water retention	F2: storing, filtering and buffering of materials	- Reduction of water infiltration - Diversion, canalization, concentration of runoff, accelerated discharge	Effective soil water storage capacity	mm for 0-100 cm of soil	0-400	Δ SWSC_eff (%) and (mm) (for 0-100 cm of soil)	PESERA[42] Wessolek *et al*. (2008)
Soil organic matter	F6: acting as a carbon pool	Limited or impeded storage of carbon	Soil organic carbon content	ton C/ha	30-90+	ΔSOC (%) and (kton C/y)	Miterra Europe[43]

[40] The European Soil Database distribution version 2.0, European Commission and the European Soil Bureau Network, CD-ROM, EUR 19945 EN, 2004

[41] "SINFO, New soil information for CGMS (Crop Growth Monitoring System), new and extended version of the soil data from the Soil Geographical Data Base of Europe (SGDBE) version 3.1, developed for use in the MARS Crop Yield Forecast Sing System",European Community- DG Joint Research Centre, July 2007.

[42] S.P.I.04.73. (2004). The PESERA Map: Pan-European Soil Erosion Risk Assessment. Special Publication Ispra 2004 No.73, map in ISO B1 format. Office for Official Publications of the European Communities.

[43] Velthof *et al*., (2008).

Food production

Land-based food production requires a large terrestrial surface, both in Europe and in the world. Soil functions addressed in this land use service include the production function (F1), the filter, storage and buffer function (F2), the habitat function for biota and genes (F3), and the cultural heritage function of rural land (F7). Under soil sealing, the growing environment for plant roots and working environment for agricultural activities is reduced or entirely replaced by land developed for other uses. As a result, the net primary productivity is reduced or shifted to new types of soils (e.g. Imhoff *et al*., 2004; Nizeyimana *et al*., 2001), and the performance of all related soil functions is reduced.

Urban development, at present together with bioenergy cropping and nature development, sets claims on the available land resources. In the case of urban development, this often occurs on high-quality agricultural land. This is because many towns that started as agricultural trading centres have become successful and growing cities. Part of their original comparative advantage was their proximity to productive and fertile agricultural land (e.g. Hofmann, 2001; Hack ten Broeke *et al*., 2008; WUR/LNV, 2008; Imhoff *et al*., 2004; Nizeyimana *et al*., 2001).

The suitability of soils for arable cropping and permanent grassland was used as an indicator of the performance of the land service food production. The soil suitability for arable cropping and permanent grassland was calculated from the revised soil suitability criteria used in the Crop Growth Monitoring System (CGMS)[44] of the MARS Crop Yield Forecasting System (Lazar and Genovese, 2004). These suitability criteria distinguish suitable soils per crop group on the basis of crop growth limiting properties: slope, texture, agriculture limiting phase, rooting depth, drainage, salinity and alkalinity.

The assessment of soil suitability for crop growth in CGMS was based on the definition of unsuitable class values for each of the 7 mentioned soil parameters. The slope, texture and phase data were obtained from the Soil Geographical Database of Europe (version 4), which is part of the European Soil DataBase (ESDB version 2.0). Rooting depth, drainage conditions, salinity and alkalinity were derived from basic soil properties using pedotransfer rules in the Pedotransfer Rule DataBase, which is also part of the ESDB v2.0.

Baruth *et al*., (2006) validated the suitability rules for the calculation of uniform soil suitability maps for crop growth. They showed that it is not justified to calculate soil suitability maps at the level of crop groups for Europe. The application of uniform soil unsuitability criteria at the level of Europe is possible only for the broad selection of soils which are more or less suitable for arable farming as separated from low potential soils. Therefore, in Task 2, we used soil suitability maps at the aggregated levels of arable crops (calculated with the A6 suitability rule) and permanent grassland (calculated with the grass 2 rule) to quantify impacts of soil sealing on food production (Table 4.8).

---

44 http://mars.jrc.it/mars/About-us/AGRI4CAST/Crop-yield-forecast/The-Crop-Growth-Monitoring-System-CGMS

Table 4.8. Successive soil suitability classes defined with increasingly severe criteria. Blue and orange indicate respectively suitable and unsuitable classes for a soil property. Arrows indicate the rules used for expressing soil suitability in this study. Adapted from Baruth *et al.* (2006) with kind permission from the authors'.

	Rooting depth	Rooting depth	Rooting depth	Texture	Texture	Texture	Texture	Texture	Drainage	Drainage	Drainage	Drainage	Stone content	Stone content	Stone content	Slope	Slope	Slope	Slope	Slope	Salinity	Alkalinity
	<10	10-20	20-40	fine	very fine	rocks	peat	no text.	imper-fect	tmp poor	poor	very poor	>10 %	>15 %	>20 %	8 – 15	15-25	>25	8-30	>30		
Class	1	2	3	4	5	7	8	9	I	TP	P	VP	10	15	20	2	3	4	5	6	H	H
Arable 1	orange	orange	orange	green	orange	orange	orange	orange	orange	orange	orange	orange	green	green	green	orange	orange	orange	orange	orange	orange	orange
Arable 2	orange	orange	orange	green	orange	orange	orange	orange	green	orange	orange	orange	green	green	green	orange	orange	orange	orange	orange	orange	orange
Arable 3	orange	orange	orange	green	orange	orange	orange	orange	green	orange	orange	orange	green	green	green	green	orange	orange	orange	orange	orange	orange
Arable 4	orange	orange	orange	green	orange	orange	orange	orange	green	orange	orange	orange	green	green	green	green	green	orange	green	orange	orange	orange
Arable 5	orange	orange	orange	green	green	orange	orange	orange	green	green	orange	orange	green	green	green	green	green	orange	green	orange	orange	orange
⇨ Arable 6	orange	orange	orange	green	green	orange	orange	orange	green	green	green	orange	green	green	green	green	green	orange	green	orange	orange	orange
Arable 7	orange	orange	green	green	green	orange	orange	orange	green	green	green	orange	green	green	green	green	green	orange	green	orange	orange	orange
Grass 1	orange	orange	green	green	green	orange	green	green	green	green	green	orange	green	green	green	green	green	orange	green	orange	orange	orange
⇨ Grass 2	orange	orange	green	green	green	orange	green	green	green	green	green	orange	green	green	green	green	green	green	green	green	orange	orange

For the quantification of impacts, it is assumed that the conversion of land into artificial area or built-up land will cause the land to be no longer available to use for arable crops or grassland. There are recent developments of agricultural activities becoming interwoven in urban areas, like roof top cropping in The Netherlands, and the agrocities in Asia. However, the land cover flow analysis at the level performed in this study does not allow us to distinguish these areas from built-up area not used for agriculture. The analysis was carried out by overlaying the soil suitability maps with maps of the land cover flows 1 (urban land management), 2 (urban residential sprawl) and 3 (sprawl of economic sites and infrastructures) for the period 1990-2000, and with maps of the land cover flows from non built-up to built-up area for the period 2000-2030. The land becoming unavailable for arable cropping or permanent grassland due to these conversions is depicted as a % of total area for NUTS3 units in the European Union.

Biodiversity

Impacts on relevant soil functions for biodiversity are mainly due to the reduction in the functional ability of soils to provide a habitat for biota and genes (F3). Soil sealing replaces habitats for ecosystems by pavement and buildings or non-native ecosystems in green areas, and causes fragmentation of areas. Fragments of previously existing ecosystems may be to be too small or too isolated to support species. Therefore the sealing of soils almost always results in a loss of biodiversity (e.g. Braat and Ten Brink, 2008; Scalenghe and Marsan, 2009). Urbanization has impacts on the areal coverage of ecoregions, rare species and protected areas due to the shrinking distance between cities and protected areas (McDonald *et al.*, 2008). Little is known about biodiversity in soils and the effects of soil sealing on soil biodiversity. However, the diversity of soil organisms is known to be very extensive compared to other environments, and therefore large impacts from soil sealing may be presumed.

The Mean Species Abundance (MSA), indicator is used in this study to assess the impacts of the projected changes in land use and soil sealing impacts on biodiversity – there being no other biodiversity indicator that can be readily linked to land use change models (IEEP, Alterra, Ecologic, PBL and UNEP-WCMC, 2009). The MSA metric was specifically developed as part of the GLOBIO3 model (by the Netherlands Environment Assessment Agency) to estimate future changes in terrestrial biodiversity (Alkemade *et al.*, 2006, 2009). MSA has the advantage that it is based on an assessment of the impacts of key pressures on biodiversity and can be modelled with relative ease. MSA is also applicable at different scales from national to global. Biodiversity loss is calculated in terms of the mean species abundance of the original species compared to the natural or low-impacted state. If the indicator is 100%, the biodiversity is similar to the natural or low-impacted state. If the indicator is 50%, the average abundance of the original species is 50% of the natural or low-impacted state and so on. A strength of the MSA indicator is that it is possible to link scenarios on economic developments, climate and land-use change (indirect and direct drivers) to dose-response relationships between environmental pressures and mean species abundance.

However, there are significant limitations of the MSA with respect to its appropriate use and what can be deduced from changes in its value (IEEP, Alterra, Ecologic, PBL and UNEP-WCMC, 2009). For example, MSA represents the average response of a selection of species belonging to an ecosystem and does not look at individual species responses. Therefore, an MSA of 50% could mean that half the original species have gone extinct, or that all species are at half the original abundance, a major difference requiring different policy responses; therefore MSA does not capture extinctions. Nor is the MSA able to give weightings in terms of the importance of species (for example, giving higher importance to species of Community Conservation Interest[45]). Further, the MSA does not take into account the different levels of diversity in the intact habitats. The aggregation of average responses across species and ecosystems may also mask differences among regions or biomes. Projections of MSA changes therefore need to be carefully interpreted in terms of their biodiversity impacts. A detailed account of the methods used to calculate the MSA indicator are provided in Annex 2.6.

The MSA index was calculated following the procedure in EU Ruralis 2.0. It is derived from land-use, land use intensity (agriculture and forestry), N-deposition, fragmentation, infrastructure developments and policy assumptions on high nature value (HNV) farmland protection and organic agriculture. In the calculations for Eururalis 2.0 the impacts of climate change on biodiversity are not taken into account. According to Arets *et al.*, (in prep.) the rationale for this that climate change will not have significant effects on biodiversity up till 2030. However, this conflicts with mounting evidence that habitat conditions and species distributions are already changing as a result of the direct impacts of climate change (e.g. EEA, 2005d; Reid, 2006; Ferrer *et al*., 2008; Olofsson *et al*., 2008; Settele *et al*., 2008). This therefore reduces the relevance of the MSA results to this study, which attempts to take project climate change impacts into account. But, in practice, although direct climate change impacts on biodiversity are likely to be profound in the long-term, impacts by 2030 are likely to be relatively moderate compared to other land use changes (and possibly indirect effects of climate change, such as biofuel and biomass production).

The MSA index is influenced by soil sealing through a direct reduction of biodiversity on and below sealed surfaces, and through fragmentation by infrastructure (roads, railways). Maps of the MSA for the EU27 in 2000 and 2030 were received from Task 1. No data were available for the period 1990-2000. Both the direct reduction of MSA under sealed surfaces and the fragmentation through infrastructure are incorporated in the calculation. A value of 5% is assumed for built-up areas. Values for other land cover types are given in Table 4.9.

[45] Ie. species listed in Annex 1 of the Birds Directive and Annex 2 of the Habitats Directive.

Table 4.9. Mean species abundance value per land-use type.

Source: Eickhout and Prins (2008).

Land use class	Mean Species Abundance
Built-up area	5
Arable land (non-rrigated) Intensive and extensive	10
Pasture intensive (>50 LSU/km^2)	10
(semi-) Natural vegetation (including natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes)	70
Inland wetlands	100
Glaciers and snow	100
Irrigated arable land	5
Recently abandoned arable land (i.e. 'long fallow'; includes very extensive farmland not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30 cm)	30
Permanent crops	20
Biofuel crops (intensive)	10
Forest (natural/plantation – average forest age in region between 50 and 80 years)	70
Sparsely vegetated areas	100
Beaches, dunes and sands	100
Salines	100
Water and coastal flats	100
Heather and moorlands	100
Recently abandoned pasture land (includes very extensive pasture land not reported in agricultural statistics, grasses and shrubs below 30 cm)	30
Woody biofuel crops	30
Pasture extensive (<50 LSU/km^2)	40
Forest (plantation when average forest age in region is under 50 years)	60
Forest (plantation when average forest age in region is under 40 years)	45
Forest (plantation when average forest age in region is under 30 years)	35
Forest (plantation when average forest age in region is under 20 years)	25
Forest (plantation when average forest age in region is under 10 years)	15
Forest (natural – average forest age in region older than 80 years)	100

The analysis was carried out by calculating the change in the MSA index from 2000 to 2030 in the areas which experienced a land cover flow from non-developed land cover to artificial land cover. The change in the MSA index was expressed as the average change in this area in each NUTS3 unit in % points of the index.

Water retention

Water retention in soils is crucial for the capturing and filtering of rainfall or runoff, plant growth, evapotranspiration and groundwater recharge. The water retention land use service is mainly facilitated by the storage function of soils (F2). Soil sealing typically results in increased impervious surfaces that reduce the infiltration rate, new drainage ditches and channels that increase the runoff velocity, deep infiltration systems, and reservoirs (Singh 1992, in: Hejazi and Markus, 2009; TCB, 2009b). In fact, sewerage systems and surface runoff to open surface waters take over the water retention function from the unsealed soil. This may also apply to unsealed areas within built-up areas, as these often have artificial or compacted layers at depth, like plastic layers in road borders, or the soils on top of underground constructions.

Many studies have evaluated the effects of urbanization on infiltration and runoff production, and found reduced infiltration, reduced recharge of groundwater, and increased discharge of surface runoff to adjacent areas (e.g. Reynard *et al*., 2001; in: Hejazi and Markus, 2009; Assouline and Mualem, 2002; Schmidt and Michael, 2004; Choi and Deal, 2007; Perry and Nawaz, 2008; in: Scalenghe and Marsan, 2009; TCB, 2009a). The flow rate of water from development sites with high proportions of sealed surfaces can be two to three times that from predominantly vegetated surfaces (Dunnett and Clayden, 2007). This may exert a greater pressure on the sewerage system and increase the risk of flooding within and around urban areas (e.g. Natale and Savi, 2007; in: Scalenghe and Marsan, 2009).

Apart from consequences for flood water management, decreasing infiltration in urban areas has effects on the temperature of urban sealed and constructed land surfaces and air temperature due to decreased evapotranspiration. A fall in evapotranspiration increases the vulnerability of the cities' residents to increasing summer temperatures that are assumed to occur due to climate change, as the evaporative process supports cool urban areas (Gill *et al*., 2007).

The main routes taken by rainfall in built-up areas are by evapotranspiration, infiltration, which can be split up in shallow infiltration and deep infiltration (i.e. percolation from the saturated zone to the groundwater), and surface runoff (Figure 4.14). Experimental studies show that the infiltration capacity of soils is dramatically decreased under sealed covers compared to vegetation covers on the same soils (e.g. Schmidt and Michael, 2004; Dunnett and Clayden, 2007). The extent to which infiltration is reduced due to soil sealing depends on the proportion of sealed surfaces within built-up areas and on the age of the sealed cover. Generally, with increasing cover age the permeability of the surface cover material decreases due to the clogging of drainage openings by fine dust, tire abrasion and other substances.

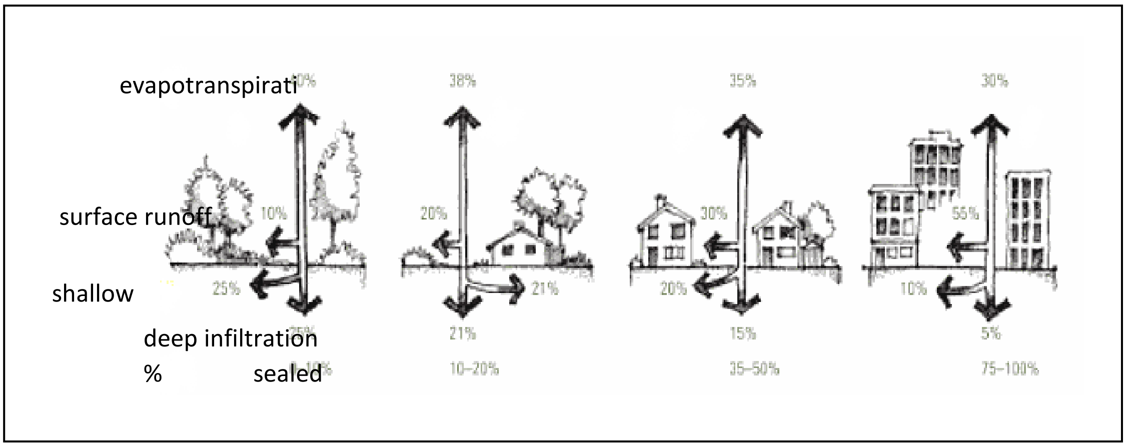


Figure 4.14. Water balance components in built-up areas with increasing proportions of sealed surfaces. Adapted from Dunnett and Clayden (2007). Original source: FISRWG (10/1998). With kind permission from the Federal Interagency Stream Restoration Working Group (FISRWG).

Impacts of soil sealing on water retention include the reduction of water infiltration and increased runoff volumes and peak flows. However, sealed, impervious areas with direct hydraulic connection to the drainage network and receiving waters have a much larger effect on storm-water hydrographs than impervious surfaces that drain to pervious areas, like lawns or road borders (Walsh *et al.*, 2009). This implies that the degree of connectivity of sealed, impervious areas to channel networks and streams should be included for a proper analysis of the impacts of soil sealing on infiltration and runoff production, and thus water retention, at the level of urban catchments. However, the land cover information and the working scale available in the project does not enable a spatial representation of connectivity. Therefore only the direct effect of sealed, impervious area on water retention will be considered.

To indicate the change of performance of the land use service water retention as a result of soil sealing, we used the change in the effective soil water storage capacity in the first 100 cm of the soil (SWSC_eff). This property is the maximum infiltration depth that can be absorbed by the soil before the shallow water table rises to land surface, initiating ponding or saturation excess overland flow (Nachabe *et al.*, 2004).

SWSC_eff was mapped for several countries the European Union in the framework of the PESERA project[46], based on the European Soil Database (v2.0). The calculation was based on the availability of storage capacity in the soil pore system in the unsaturated topsoil, accounting for the capacity of the soil for infiltration and for water uptake by plants. This capacity depends on the soil hydraulic functions[47]. A part of the pore space is easily drainable under small values of the soil suction (PO, Figure 4.15). This part consists of the larger pores, and will capture a part of the infiltrating rain water on an unsealed soil surface during rainfall events. Parts of the soil system with smaller pore sizes are only accessible for infiltrating rain water or for uptake by plants at higher values of the soil suction (EAW and RAW, Figure 4.15). Full details of the calculation of SWSC_eff are given in Gobin *et al*. (2003).

[46] S.P.I.04.73. (2004). The PESERA Map: Pan-European Soil Erosion Risk Assessment. Special Publication Ispra 2004 No.73, map in ISO B1 format. Office for Official Publications of the European Communities.

[47] (water retention function and unsaturated hydraulic conductivity function)

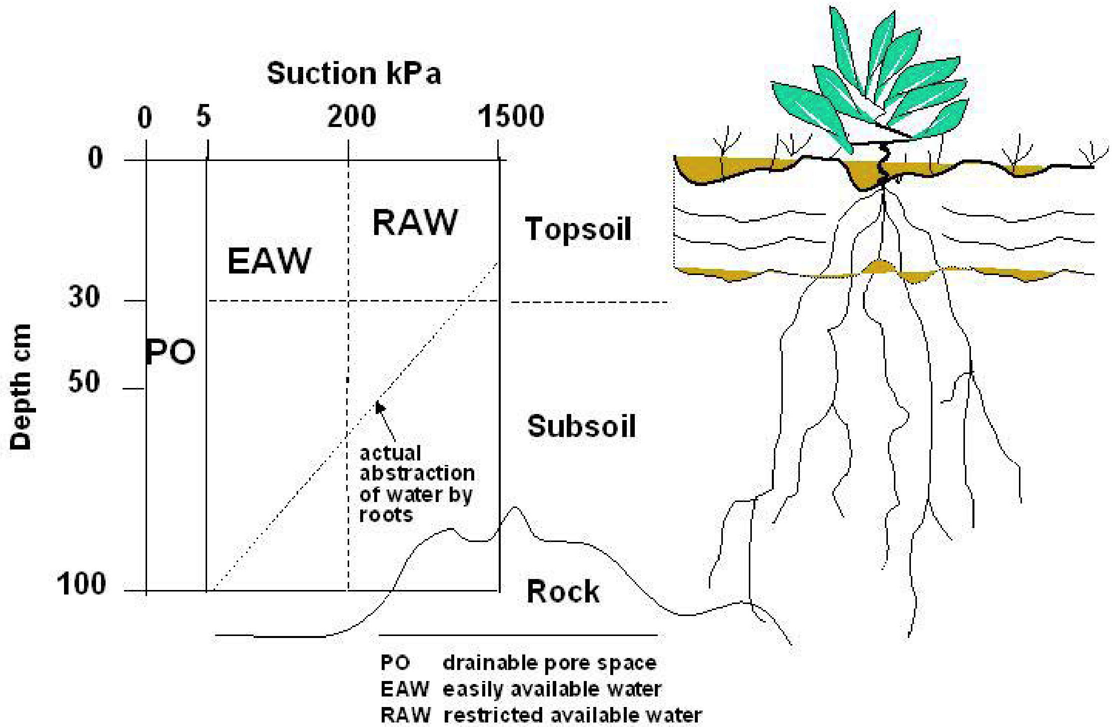


Figure 4.15. Water retention in the soil-plant system. Source: Gobin *et al.*, 2003.

In this present study, impacts of soil sealing on water retention were quantified by calculating the change in SWSC_eff in areas subject to soil sealing between 1990 and 2000 and between 2000 and 2030. The change was expressed in % of the total soil water storage capacity in NUTS3 and NUTS0 units, and in mm per km^2 of NUTS0 units.

The map of SWSC_eff provided by the PESERA project covered 23 countries in the EU. For this reason, results are given for these countries only. The map was based on the European Soil Map (ESDB v2.0), which does not display soil mapping units in parts of some urban areas (e.g. Paris, London). For this reason, the SWSC_eff map has missing values in these parts of urban areas, and consequently also the mapped changes in SWSC_eff have missing values there (Figure 4.16).

Figure 4.16. Schematic view of coverage of SWSC_eff map.

Soil organic matter

The presence of soil organic matter in soils is particularly important to several environmental and ecological functions of soil such as fertility, biological activity and gas exchanges with the atmosphere and leaching losses to water. Soil organic matter includes a wide variety of materials that differ greatly in their residence time in soil. Some of this material is composed of labile compounds that are easily decomposed by microbial organisms, returning carbon to the atmosphere. Some of the soil organic carbon (SOC), however, is converted into recalcitrant compounds (e.g. organic-mineral complexes) that are very slowly decomposed and thus can be retained in the soil for decades to centuries or more.

The current loss rate of SOC due to land use change is estimated at 1.6 ± 0.8 Pg C per year (Smith, 2008). The size of the pool of soil organic carbon is large compared to gross and net annual fluxes of C to and from the terrestrial biosphere (Smith, 2004). Small changes in the SOC pool can therefore have significant impacts on the concentration of CO2 in the atmosphere. To mitigate the increase in concentration of greenhouse gases in atmosphere and its effects on global warming terrestrial ecosystems can be used as carbon sinks. And more important, the conservation of carbon in soils to prevent emissions of CO2 is highly relevant to both the climate change debate and to the thematic strategy on the protection of soil of the European Commission.

The level of SOC in a particular soil is determined by many factors including climatic factors (e.g. temperature and moisture regime) and soil-related factors, e.g. soil parent material, clay content, cation exchange capacity (Dawson and Smith, 2007). Organic carbon inputs to the soil are largely determined by the land use, with forest systems tending to have the largest input of carbon to the soil. Grasslands also tend to have large inputs, though the material is often less recalcitrant than forest litter. Depending on interactions with previous land use, climate and soil properties, changes in management practices may induce increases or decreases in SOC stocks. Generally, management-induced SOC stock changes are manifested over a period of several years to a few decades, until SOC stocks approach a new equilibrium.

Soils in urban areas may be sources or sinks of CO2 depending on previous land use, soil burial or collection during development, and current management, particularly with respect to nutrient and water applications (Pouyat *et al*., 2002; Qian and Follett, 2002). Only a few studies have been conducted that evaluate the effect of settlement management on soil C, and most of the focus has been on North America (e.g. Pouyat *et al*., 2002), making it difficult to generalize (Lorenz and Lal, 2009). Nevertheless, it is clear that biogeochemical cycles in urban ecosystems are altered by human activities. Direct effects include changes in the biological, chemical and physical soil properties and processes in urban soils. On the other hand, urban soils have the potential to store large amounts of soil organic carbon in the non-sealed areas, e.g. in gardens and parks, and thus, contribute to mitigating increases in atmospheric CO2 concentrations. However, the amount of SOC stored in urban soils is highly variable in space and time, and depends among others on soil parent material and land use. According to Lorenz and Lal (2009) the SOC pool in the topsoil (0-30 cm) may range between 16 and 232 Mg ha-1.

Impacts of soil sealing on soil organic carbon stocks were assessed using the MITERRA-Europe model. MITERRA-Europe was developed to assess the effects and interactions of policies and measures in agriculture on N losses on a regional level in the EU-27 countries (Velthof *et al*., 2009). MITERRA-Europe is partly based on the existing models CAPRI and RAINS, supplemented with a N leaching module and a measures module. The model was extended with a soil organic carbon module, which is based on the IPCC tier 1 approach (Lesschen *et al*., 2008).

Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html) provides the guidance on the estimation of the emissions and removals of CO2 and non-CO2 greenhouse gasses. In MITERRA-Europe the Tier 1 approach was implemented to assess changes in soil organic carbon stocks due to land use changes or changes in land management. The IPCC protocol distinguishes six types of land use: forest land, cropland, grassland, wetlands, settlements and other land. For this study we extended these land use types with perennials and abandoned land. The protocol distinguishes between two categories: (i) no land use change and (ii) land use change. The amount of soil organic carbon in mineral soils is calculated by multiplying a default reference value, which is a function of soil type and climate, with a coefficient for land use, a coefficient for management and a coefficient for input crop production.

The amount of soil organic carbon (SOC) is calculated as:

SOC = SOCREF * FLU * FMG * FI

with

SOCREF	= reference carbon content of the soil (ton C per ha)
FLU	= coefficient for land use
FMG	= coefficient for management
FI	= coefficient for input crop production

The default reference SOCREF is the carbon stock to a depth of 30 cm, which is a function of soil type and region (Table 4.10). This data is combined with the data at the HSMU-level (soil type and climate region) to calculate an average SOCREF per NUTS2 region. The resulting SOCREF ranges from 36 to 113 t C ha-1 in the topsoil (0-30 cm). Table 4.11 shows the assignment of FLU, FMG and FI to the land use and management types in MITERRA-Europe.

Table 4.10. SOC_{REF} per climate and soil type (ton C/ha)

Region	HAC soils	LAC soils	Sandy soils	Spodic soils	Volcanic soils	Wetland soils
Boreal	68	NA	10	117	20	146
Cold temperate, dry	50	33	34	115*	20	87
Cold temperate, moist	95	85	71	115	130	87
Warm temperate, dry	38	24	19	80*	70	88
Warm temperate, moist	88	63	34	80*	80	88

* Estimated

Table 4.11. Relative stock change factors for cropland, grassland and forest land in MITERRA-Europe

Land use and management types	Land use (F_{LU})	Management (F_{MG})	Input (F_I)
Forest	1.00	1.00	1.00
Intensively managed grassland	1.00	1.14	1.11
Extensively managed grassland	1.00	1.14	1.00
Rough grazing grassland	1.00	1.00	1.00
Long term cultivated	0.80 (dry) 0.69 (wet)		
Long term perennials	1.00		
Paddy Rice	1.10	1.00	1.00
Abandoned land	0.93 (dry) 0.82 (wet)		
Full tillage		1.00	
Reduced tillage		1.02 (dry) 1.08 (wet)	
No tillage		1.10 (dry) 1.15 (wet)	
Low input			0.95 (dry) 0.92 (wet)
Medium Input			1.00
High input/ no manure			1.04 (dry) 1.11 (wet)
High input / With manure			1.37 (dry) 1.44 (wet)

Change in SOC stocks can be estimated for mineral soils with land-use conversion to Settlements using the initial (pre-conversion) SOC stock and SOC stock after conversion. Annual rates of emissions (source) or removals (sink) are calculated as the difference in stocks (over time) divided by the time dependence of the stock change factors, which is by default set at 20 years.

Default stock change factors are not needed for the Tier 1 method for 'Settlements Remaining Settlements' because the default assumption is that inputs equal outputs and therefore no net change in soil carbon stocks occur once the settlement is established. For conversions of land to settlements the IPCC guidelines suggest to use the following assumptions:

- for the proportion of the settlement area that is paved over, assume product of F_{LU}, F_{MG} and F_I is 0.8 times the corresponding product for the previous land use (i.e., 20% of the soil carbon relative to the previous land use will be lost as a result of disturbance, removal or relocation)
- for the proportion of the settlement area that is grass, use the appropriate values for improved grassland
- for the proportion of the settlement area that is cultivated soil (e.g. horticulture) use the no-till F_{MG} values with F_I equal to 1
- for the proportion of the settlement area that is wooded assume all stock change factors equal 1.

However, the land use data sets that are used in this project do not give the detailed information regarding land uses within the land use category 'urban area'. Therefore we assumed that soil organic carbon stocks are 0.9 times the corresponding product of the previous land use (i.e. 10% of the soil carbon relative to the previous land use will be lost).

In the definition of the IPCC the category settlements includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. For this study we defined all built-up area (class 1 from the CORINE legend) as settlements. The analysis was carried out by calculating SOC stocks as a result of land cover flows resulting in the formation of artificial surfaces for the periods 1990-2000 and 2000-2030. For the period 1990-2000 we did not use the LEAC land cover flows, since these do not give sufficient detail about the previous land use for the conversions to artificial surfaces. Instead we made an overlay with the CORINE map of 1990 and the CORINE map of 2000 to derive the land cover flows.

4.4.3 Impacts of soil sealing on food production

The soil suitability for arable cropping and permanent grassland in the European Union is depicted in Figure 4.17. What stands out is that large areas are mapped with a high percentage of suitable area for arable cropping and permanent grassland. This is due to the fact that the A6 and Grass 2 sets of suitability rules only enable to distinguish low potential soils from soils which are more or less suitable for arable cropping. This means that the areas mapped as having large percentages of suitable land include all areas which could be used for arable land use or permanent grassland to some extent. Overall, the majority of suitable areas is indicated in the north-western Europe, central Europe, and less in the Mediterranean countries, except for Italy.

The change in the availability of suitable land for arable cropping and permanent grassland due to soil sealing is shown in Figures 4.18 – 4.24. The availability of suitable land for arable cropping decreases in the period 1990-2000 with up to 2.9% of the area in NUTS3 units due to internal transformations of urban areas, up to 4.0% due to urban residential sprawl, and up to 5.1% due to the sprawl of economic sites and infrastructure (Figures 4.18 – 4.20). Decreases in the area of suitable land for permanent grassland amount to resp. 2.9%, 4.2% and 5.1%. This implies that the sprawl of economic sites and infrastructure has the largest impact on the availability of suitable land for food production. Average values of the percentage loss of land suitable for arable cropping over NUTS0 units are largest in The Netherlands (1.2%), followed by Belgium, Ireland, Portugal and Denmark (Figure 4.22). Similar values were found for the loss of land suitable for permanent grassland (Figure 4.23).

The largest impact of internal transformations of urban areas are observed in NUTS3 units with large urban centra in the Dutch ‘Randstad’, Belgium, the industrial Ruhr area, Madrid, Rome, Paris, Athens, Birmingham. But relatively large impacts are also found in Northern France (Picardie), the border region of Germany and the Czech Republic, the border region between Austria and Slovenia, and the region around Murcia (Figure 4.19). Losses of suitable land for food production due to internal transformations of urban areas are smaller in the Po plain in Northern Italy, in the new member states (Estland, Lithuania and Latvia, Hungary, Romania), and the interior parts of Spain, France and Greece.

Soil sealing due to urban residential sprawl leads to relatively high losses of suitable land for arable cropping and permanent grassland in The Netherlands, the urban regions around Madrid and Murcia, along the Mediterranean coasts (especially Portugal), and in Germany, Northern Italy and Sardinia. Relatively low losses due to urban residential sprawl are found in Poland, the Baltic States, Hungary, Romania, Bulgaria, Greece, Eastern France, North-western England and Slovenia (Figure 4.20).

The sprawl of economic sites and infrastructure leads to the largest losses in suitable land for arable cropping and permanent grassland, especially in NUTS regions with active economic centres like in The Netherlands and Belgium, the Ruhr area, Middle and Eastern Germany, Warsaw, Madrid, Porto and Lissabon, Dublin, London and Murcia (Figure 4.21). Analogous to the other land cover flows, smaller impacts of soil sealing on the availability of suitable land for agriculture are found in the Baltic States, Poland and Romania.

Overall, impacts of soil sealing from 1990 till 2000 on the available suitable land for food production are larger in Western Europe compared to Central and Eastern Europe. Relatively high losses of suitable land for arable cropping and permanent grassland occurred in The Netherlands, Ireland, Belgium, Germany and Portugal (Figure 4.22 and Figure 4.23). The smallest losses were observed in Bulgaria, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia and Slowakia.

The patterns of change are not very different for the availability of land suitable arable cropping and permanent grassland, because the suitability maps are not very different (Figure 4.17). Generally, the suitability for arable cropping is more critical, with areas with lower suitability in Spain, Northern Greece, Austria and Hungary.

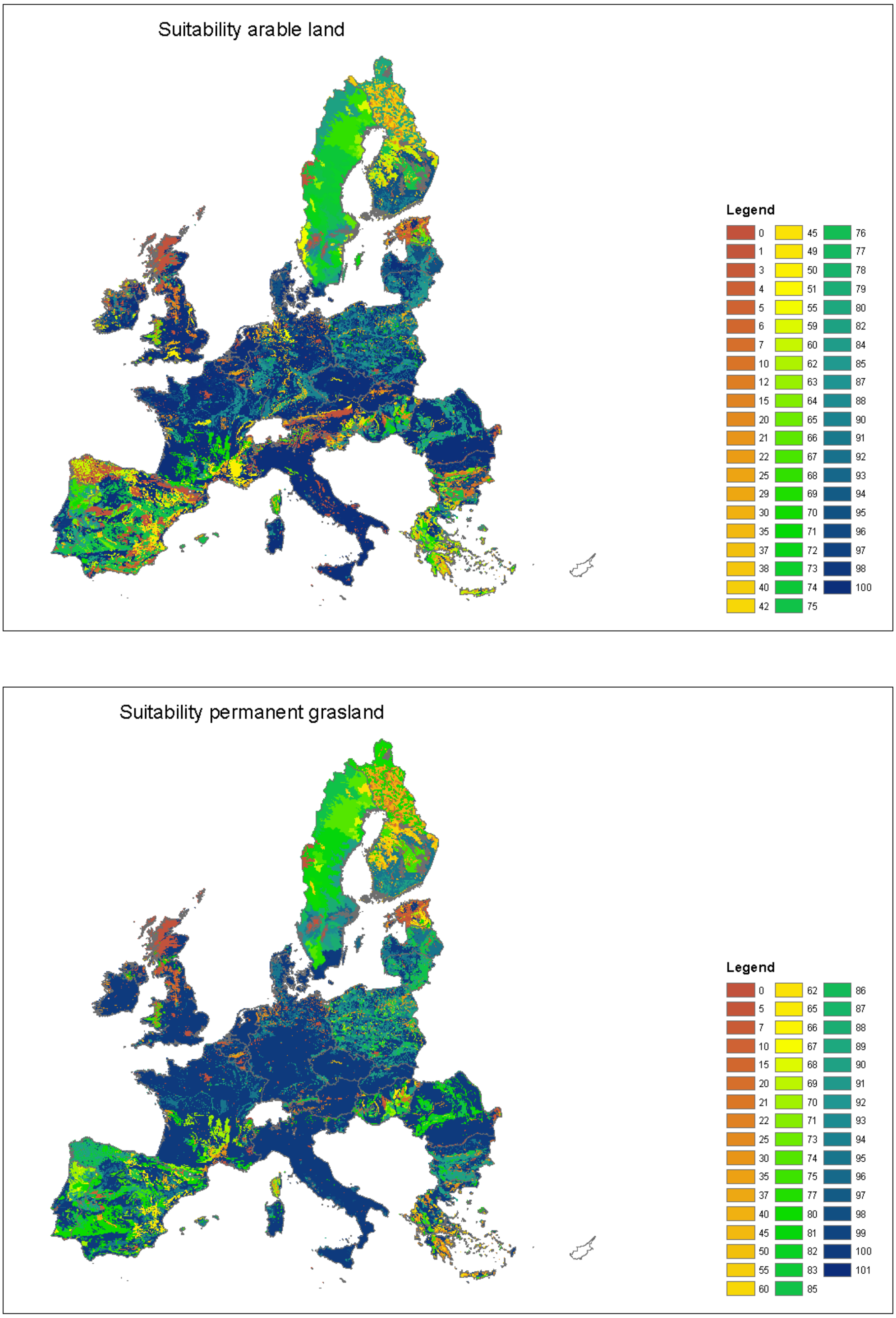
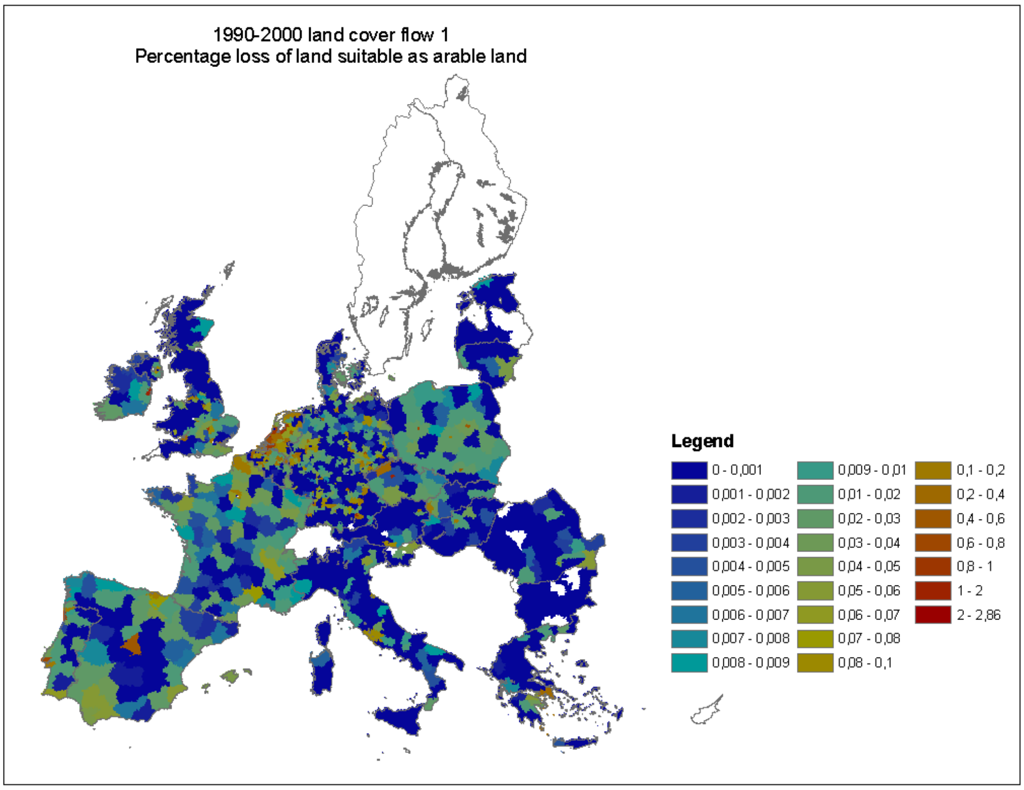


Figure 4.17. Soil suitability for arable cropping (top) and permanent grassland (bottom) according to the suitability rules A6 and the Grass 2 rule from the revised soil suitability criteria for the Crop Growth Monitoring System. Source data: SINFO-second version.



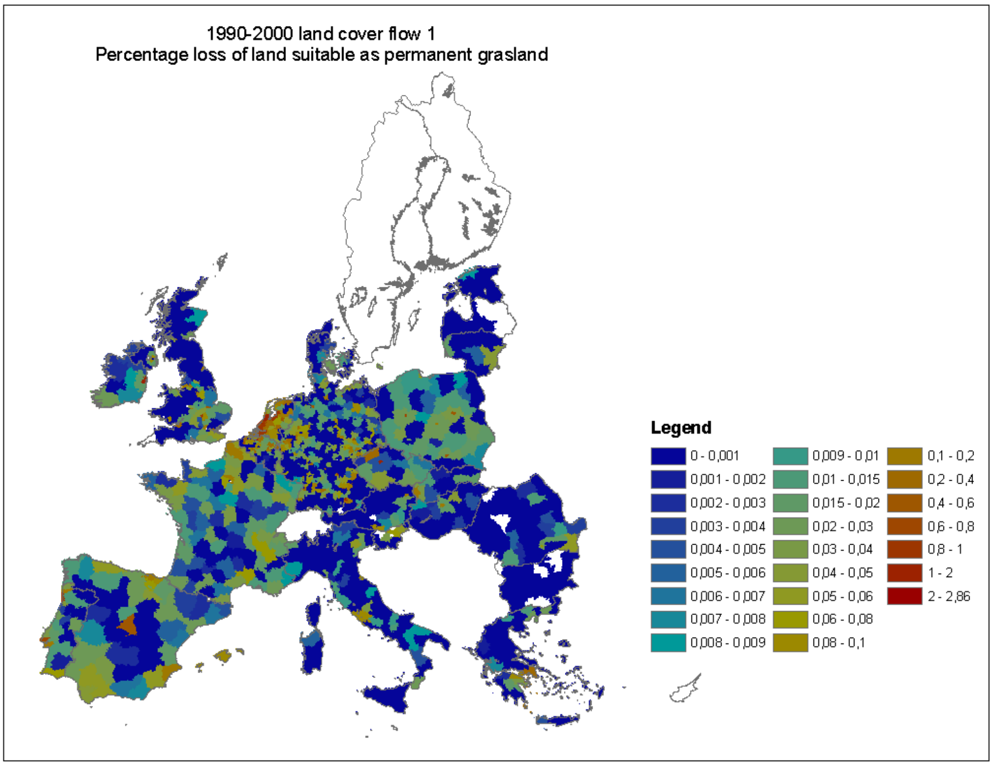
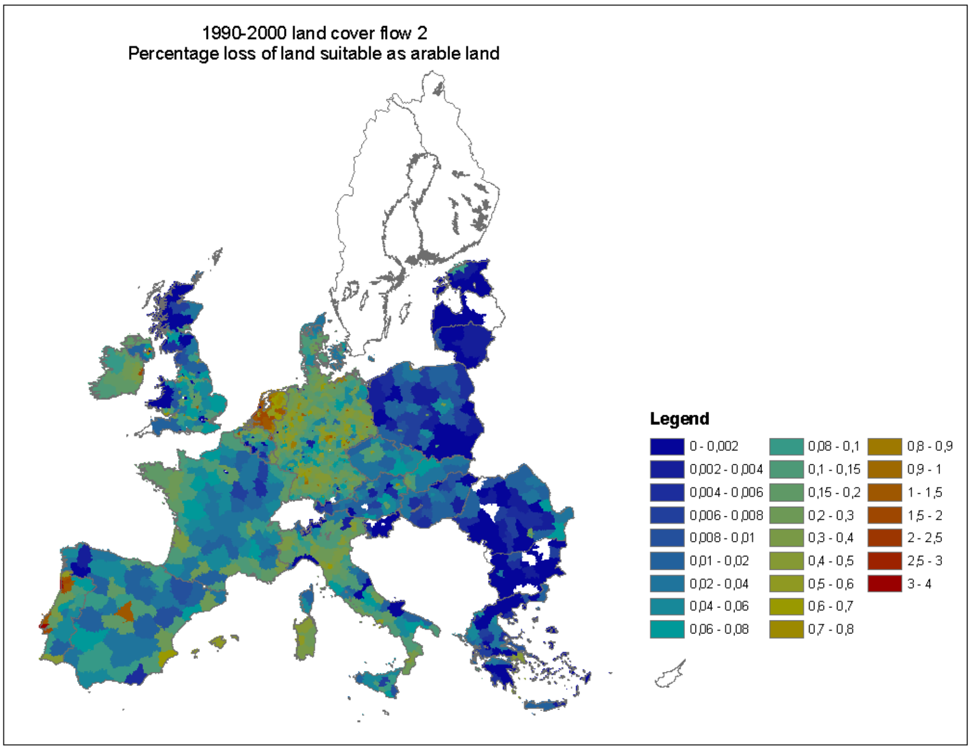


Figure 4.19. Conversion of land potentially suitable for arable land (top) and permanent grassland (bottom) due to internal transformation of urban areas (urban land management, LCF1) from 1990 till 2000 (in % of the area per NUTS3 unit).



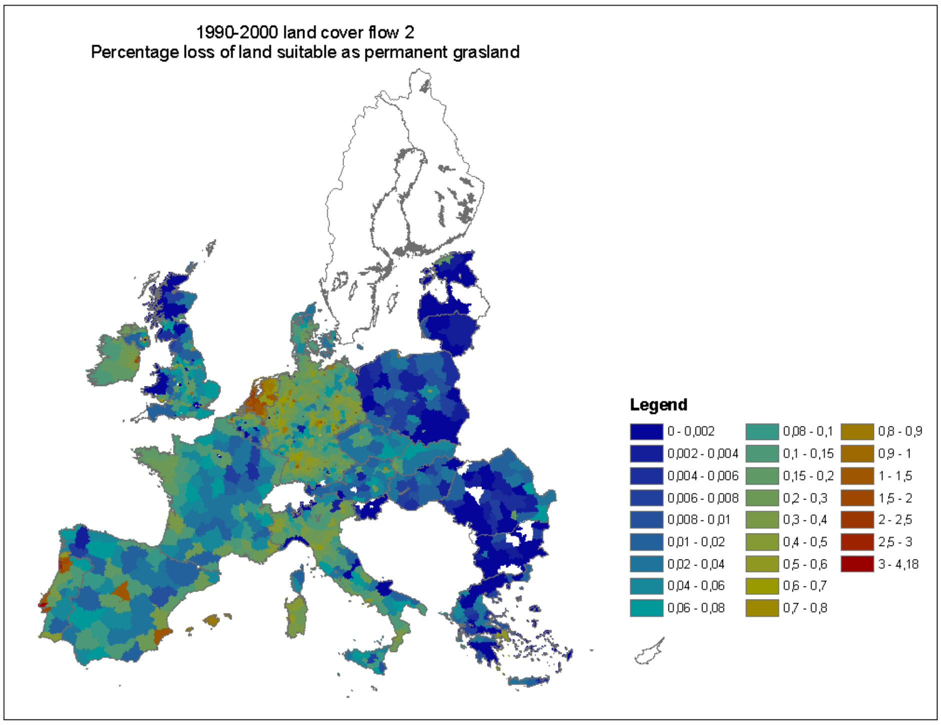
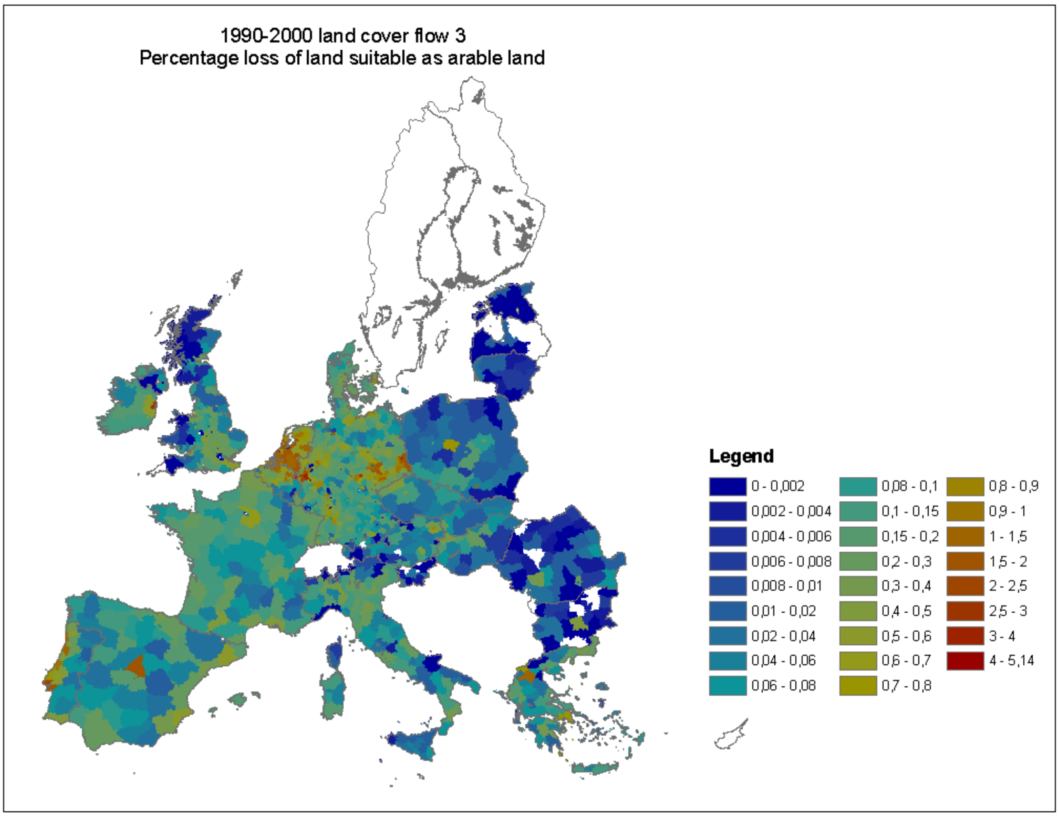


Figure 4.20. Conversion of land potentially suitable for arable land (top) and permanent grassland (bottom) due to urban residential sprawl (LCF2) from 1990 till 2000 (in % of the area per NUTS3 unit).



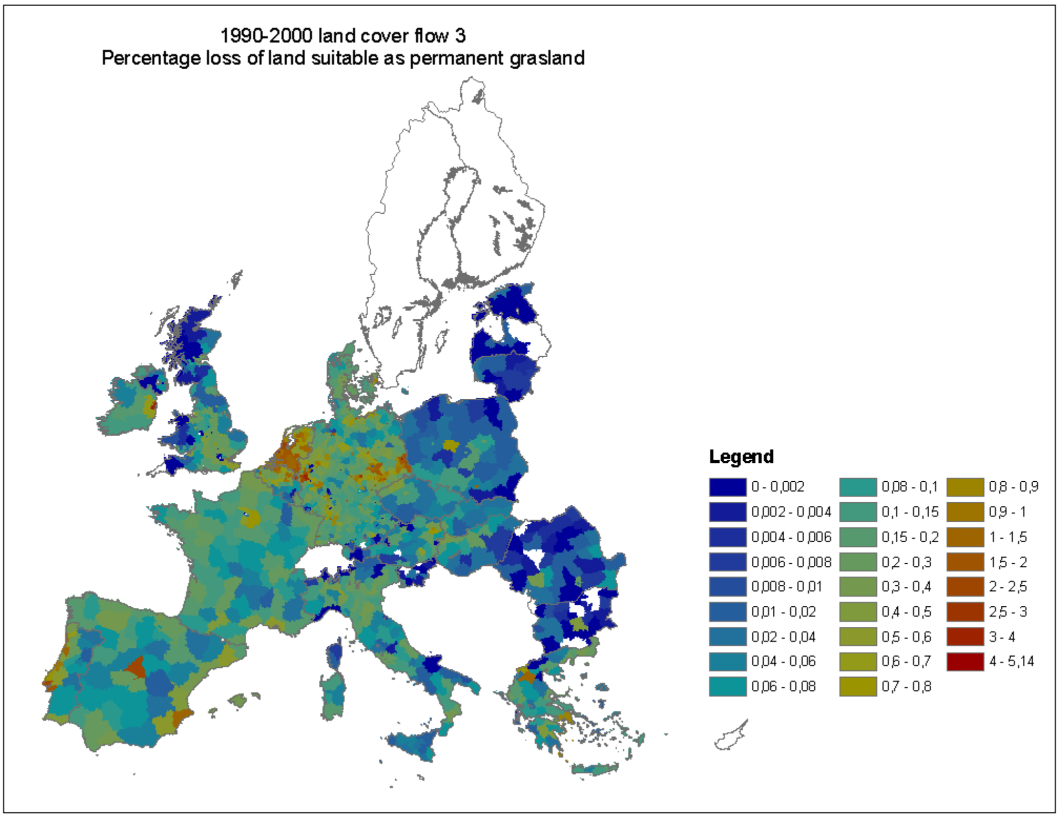


Figure 4.21. Conversion of land potentially suitable for arable land (top) and permanent grassland (bottom) due to sprawl of economic sites and infrastructures (LCF3) from 1990 till 2000 (in % of the area per NUTS3 unit).

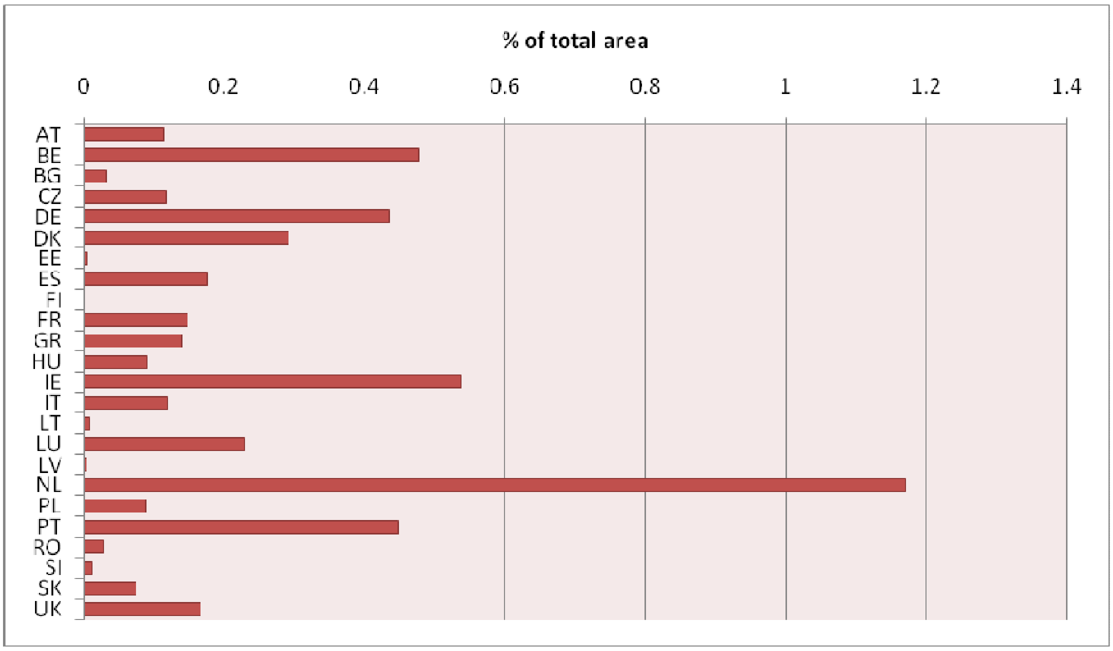


Figure 4.22. Average percentage of area suitable for arable cropping lost in NUTS0 units due to the sprawl of economic sites and infrastructure from 1990 till 2000 (averaged % of NUTS3 units within NUTS0 units).

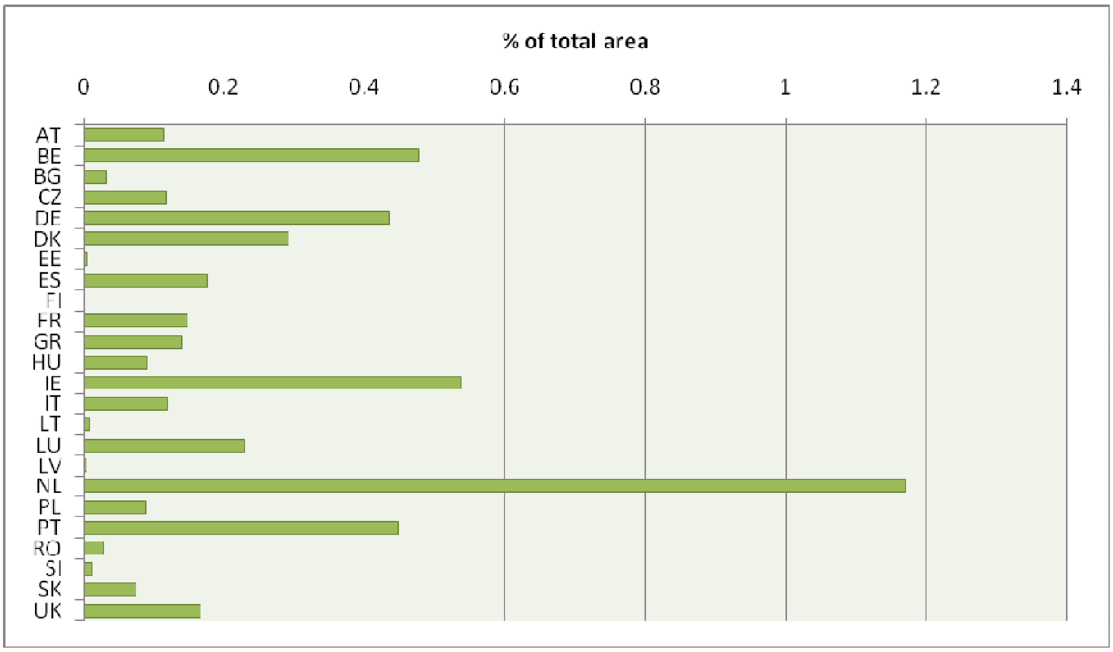
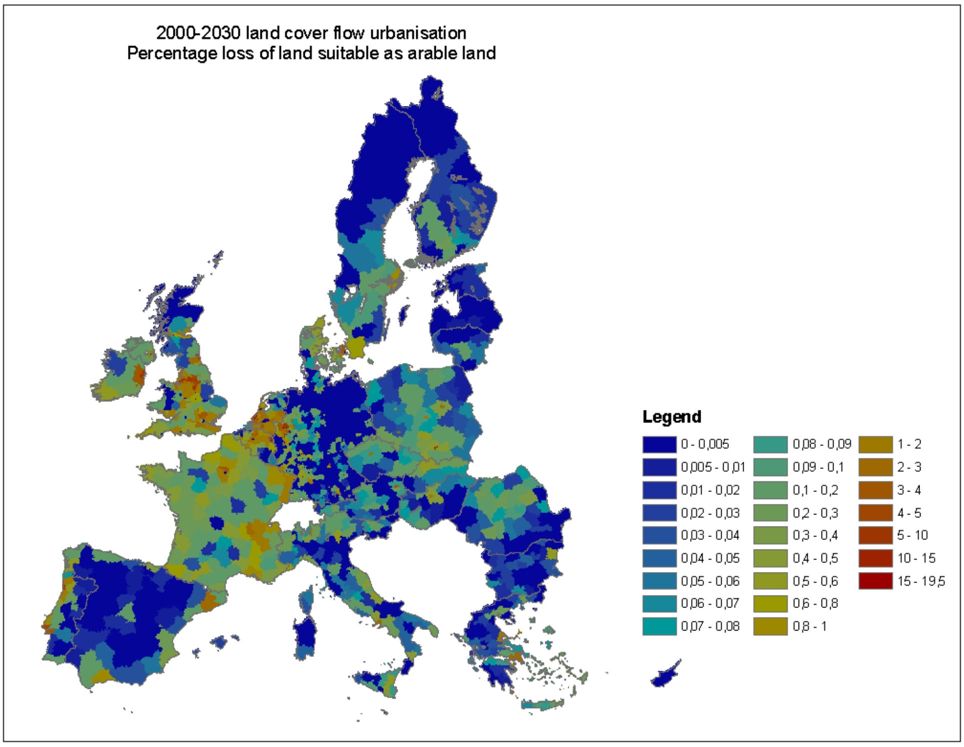


Figure 4.23. Average percentage of area suitable for permanent grassland lost in NUTS0 units due to the sprawl of economic sites and infrastructure from 1990 till 2000 (averaged % of NUTS3 units within NUTS0 units).



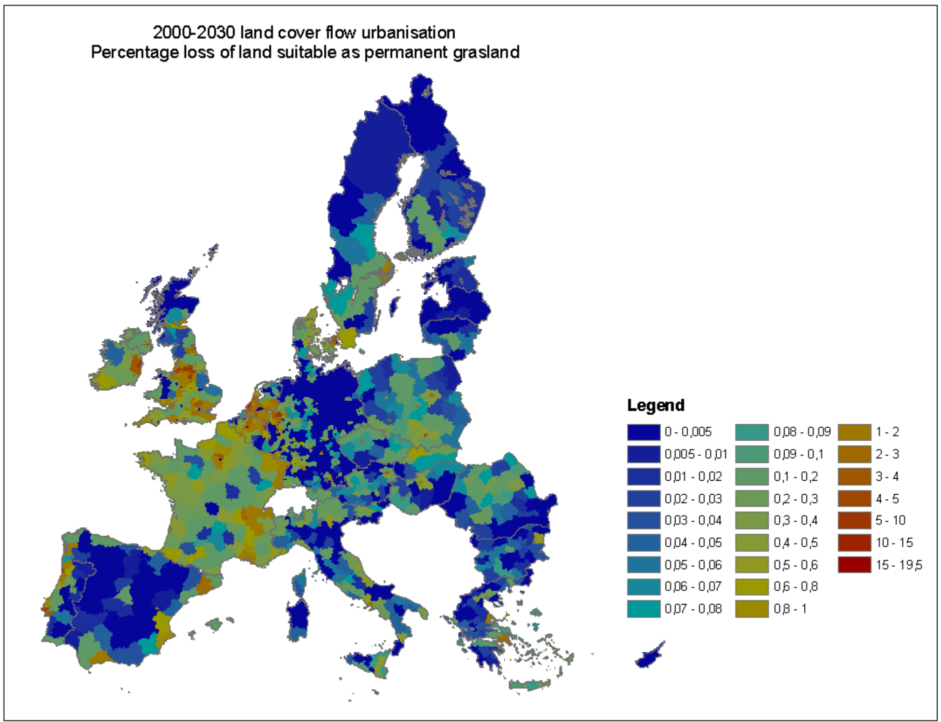


Figure 4.24. Conversion of land potentially suitable for arable land (top) and permanent grassland (bottom) due to the conversion from non built-up land to built-up land from 2000 till 2030 (in % of the area per NUTS3 unit).

Impacts of soil sealing from 2000 till 2030 on the availability of suitable land for arable cropping and permanent grassland show different patterns from the impacts in the period 1990-2000 (Figure 4.24). First, it should be noted that the land cover flow used to calculate the loss of suitable land per NUTS unit in the period 2000-2030 includes all conversions from not developed land to built-up area. It is analogous to the sum of the three land cover flows used to describe trends in soil sealing for the period 1990-2000 (internal transformation of urban land, urban residential sprawl, sprawl of economic sites and infrastructure).

Overall, losses of suitable land are comparable to the period 1990-2000, up till a few percent of the areas in NUTS3 units (Figure 4.25), but the patterns are different. This implies that for the period 2000-2030 the rate of loss of suitable land is lower per decade than in the period 1990-2000. The loss of suitable land in Central and Eastern European member states (a.o. Poland, Romania, Hungary) is relatively higher in the period 2000-2030 compared to 1990-2000. This may be due to the economic development of these countries after accession to the European Union. Areas affected take up to several percents of the total area per NUTS3 unit.

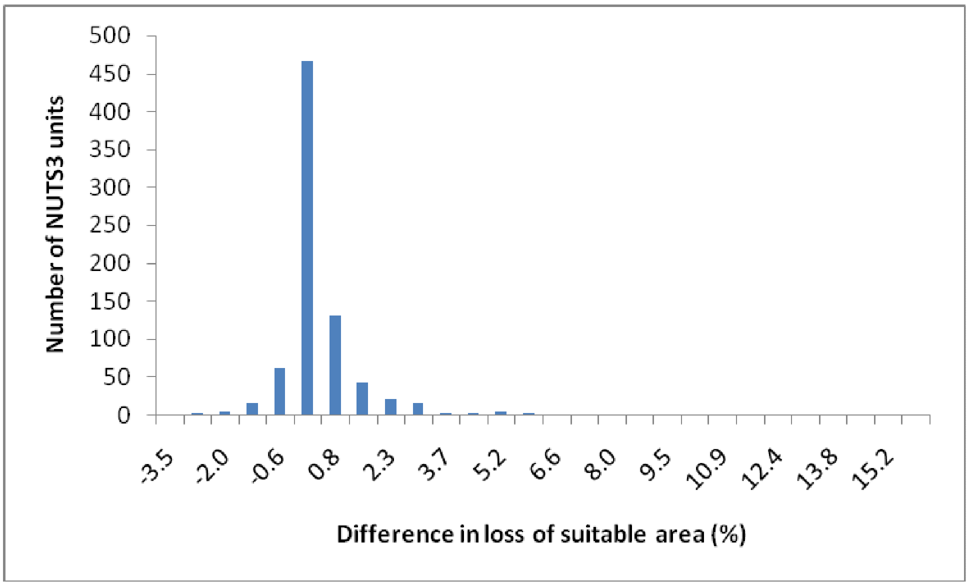


Figure 4.25. Difference between loss of suitable area for arable cropping (in areal % per NUTS3 unit) between 2000-2030 and 1990-2000.

In Western Europe, relatively high losses of suitable land occur due to soil sealing in The Netherlands, France, Ireland and the UK (Figure 4.24). This in contrast with Germany and Spain, where losses are extremely low. This is because in these countries, many NUTS3 units do not have land cover flows from non built-up to built up area. For Germany, this may be explained by the focus of the land use planning system on balancing human and environmental needs, enhancing the rural-urban balance (Science for Environment Policy, 2009).

When the loss of area of suitable land for food production was averaged over NUTS0 units, the largest loss was found in The Netherlands (3.0 and 3.2 % for arable cropping and permanent grassland resp.), followed by the UK and Ireland (Figure 4.26).

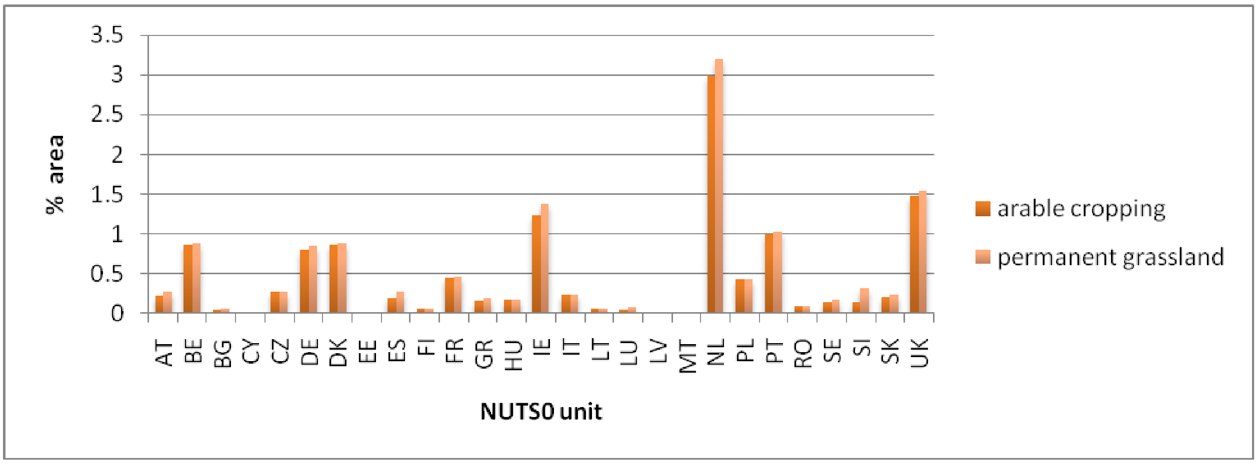


Figure 4.26. Average percentage of area suitable for food production lost in NUTS0 units due to soil sealing between 2000 and 2030 (averaged % of NUTS3 units within NUTS0 units).

The high losses of suitable land found for The Netherlands, France, Ireland and the UK correspond to the results from a modeling study on the spatial impacts of climate and market changes on agriculture in Europe (Hermans and Verhagen, 2008). This study showed that north-western Europe, especially Ireland, the UK, northern Germany, Denmark, The Netherlands and Belgium, will have an increased productivity for wheat, potatoes and grass in the global change scenarios A1[48] and B2[49], as a result of changes in climate, CO2 and technology. If the B1 scenario considered in the present study has similar effects on productivity, a loss of agricultural land in these parts of the EU will therefore have relatively large impacts on food production, compared to losses in regions with lower productivity, like southern Spain, southern Italy and southern France.

Studies reporting on the loss of agricultural land due to urbanization come from the US, Canada and Asian countries with rising economies (e.g. China, India), where the quality of agricultural land ('prime agricultural land') is given more attention in spatial planning than in the EU, or at least is mapped. For the US, Imhoff *et al.* (2004) reported a loss of agricultural land due to urbanization up till 3% of the total land area in the period 1995-2004, which is high compared to the rates of loss we found in EU countries. This urbanization was found to take place on the most fertile lands and hence had a disproportionately large overall negative impact on the net primary productivity (NPP). Though the relative loss of agricultural land appears small compared to the stocks (29% of the total land area in the US in 2004; 46% in the EU in 2000), the loss of NPP due to urbanization of agricultural lands is important in terms of biologically available energy. Imhoff *et al.* (2004) reported a loss due to urbanization of agricultural lands of NPP equivalent to the caloric requirement of 16.5 million people, or about 6% of the US population in 2004. The city of Nanjing, China, expanded at an annual rate of seven percent between 1984 and 2003. Over the total occupied area the soils of the

[48] In general terms: very rapid economic growth and rapid introduction of new and more efficient technology, gradually declining population after 2050, reduction in regional differences in income, energy system based on fossil technology. Liberalized market without government intervention.

[49] Local solutions for economic, social and environmental sustainability, sustainable development within regions, less rapid and more diverse technological development and lower economic growth and population growth. Continuation of current policy.

first and second quality class exceeded 60% (Zhang *et al*., 2007, in: Scalenghe and Ajmone Marsan, 2009).

Most of the soil sealing in the EU in the periods 1990-2000 and 2000-2030 took place on farmland, as was shown in Section 4.1. Recent concerns with the land use service food production in relation to soil sealing derive from the awareness in the policy forming community that agricultural land in Europe is faced with various pressures, one of which is urbanization. Other pressures include demands for increased food and biomass production from a growing world population and the need to adapt to climate change (e.g. PBL and Stockholm Resilience Centre, 2009; IAASTD, 2008; OECD, 2008). The production of primary biomass for food and stock feed must double to feed the world population by 2050 (Bolck *et al*., 2008). Changing consumption patterns towards more meat and dairy products raises demand on the global cereal markets in the long term. In combination with concerns for sustainable agricultural land use, in the EU a general debate is starting on the question if protection of prime agricultural land, amongst others against spatial claims from soil sealing, is necessary (e.g. LNV/WUR, 2008, Hamell, 2008). Partly in response to this development, the European Commission is preparing a new classification of agricultural areas with natural handicaps, as a follow-up to the less favoured areas scheme. Member states are currently asked to judge criteria (Europa Press Releases Rapid, accessed June 2009). According to a study on spatial impacts of climate and market changes on agriculture in Europe (Hermans and Verhagen, 2008), at a European level food production (wheat, potatoes and milk) is secure, even in the most extreme climate scenario and in a free market. However, consequences could be serious for individual regions.

When the demand for food increases there will be an increase of agricultural land, because agricultural productivity cannot keep pace with the increase in global demand for agricultural products (PBL and Stockholm Resilience Centre, 2009). This might involve 100 to 250 million ha for production of food and feed worldwide, depending on the scenario of global change (Fischer, 2008). PBL and Stockholm Resilience Centre (2009) mentions an increase of the global agricultural land area of 4% in 2030, compared to 2010, assuming significant growth in agricultural productivity, based on the FAO Agriculture Towards 2030 study, which used the Worldbank Baseline scenario (FAO, 2006a). Also, for the EU, an increase of ca 80,000 km^2 in the agricultural land area (crop land and grassland) was projected from 2010 till 2030. For the period 2010-2050 however, a decrease of ca 100,000 km^2 was projected.

The expected growth in food production will be realized first and foremost by increase of crop yield (75%), then by increase of land (12%) and more products per hectare (13%) (Fischer, 2008). Recent scientific studies indicate that the availability of additional suitable land for agriculture in the world is restricted (Fischer, Shah and Van Velthuizen, 2001; Rabbinge, 2007; Killer *et al*., 2007; Banse, Nowicky and Meijl, 2008; Koning *et al*., 2008; Lal, 2008; Nillson and Fischer, 2008).

According to the trends in land use change projected in this study for the period 2000-2030 (Section 3.3), the demand for increased food and biomass production referred to above does not show in an increase in agricultural land in the EU up till 2030 at least. In contrast, the agricultural area in the EU is declining already many decades, and is projected to do so up till 2030. This corresponds to results from the EURuralis study (Eickhout and Prins, 2008), where agricultural land (arable and pasture) was projected to decline from 46% in 2000 to 40% in 2030. This is mainly driven by a rather stable demand for agricultural products combined with ongoing improvements in yield per hectare (www.eururalis.nl). The EURuralis study observed a smaller growth of crop production and the production of animals from 2000 till 2030 will in the EU (up till 50 millions of tonnes of crop and 50 Mhead of farm animals in the B1 scenario) due to lower demographic and economic growth. The lower meat production also results in fewer crops needed for feed. In the B1 scenario, production of crops in EU15 is especially influenced by trade policies, and the production of heavily protected products like cattle is decreasing.

Apart from demand for food and biomass production, the likeliness of land take for urbanization from agricultural land depends on the way property rights are arranged. In many member states, farmland is privately owned. Owners must seek permission from the relevant authorities to change the use of the land for building purposes, which is granted if the scheme fits in with local land use and construction plans. In some member states, like The Netherlands and Germany, there is a system of transparent land assessment by public or private bodies, as well as free market competition. Governments cooperate with the private sector in land development. Full compensation, including increased value of the land after development, is paid to owners in the Netherlands and Germany for compulsory purchase of farmland (Tan *et al*., 2009, in: Science for Environment Policy, 2009). In recent years, the focus of the land use planning system has shifted to environmental and landscape values. In correspondence to the economic and demographic development in the B1 scenario, this may partly explain why the conversion rate of farmland – as a proxy for suitable land for agriculture - will be slower in the period 2000-2030 compared to 1990-2000.

4.4.4 Impacts of soil sealing on biodiversity

The spatial distribution of biodiversity in the EU27, expressed as the MSA indicator, is shown for the situation in the year 2000 and 2030 in respectively Figure 4.27 and Figure 4.28. The projected change in biodiversity from 2000 to 2030 is shown in Figure 4.29. The highest MSA values for biodiversity in Europe are found in Scandinavia and mountainous areas. Areas with high amounts of agricultural land or urbanization show the lowest MSA values. Over the EU27, from 2000 to 2030 the MSA biodiversity increases significantly in the Alps and Italy due to afforestation. Increases also occur in former West Germany, Austria, Southwestern France, Northern Spain, Portugal and Romania. In these areas, the increase is probably due to land abandonment. According to Eickhout and Prins (2008), the overall increase in the projected MSA biodiversity values in the EU27 in the Global Cooperation (B1) scenario are due to expected increases in nature friendly management of forests, more organic farming in agriculture in place of intensive agriculture, and the decline in agricultural land due to land abandonment.

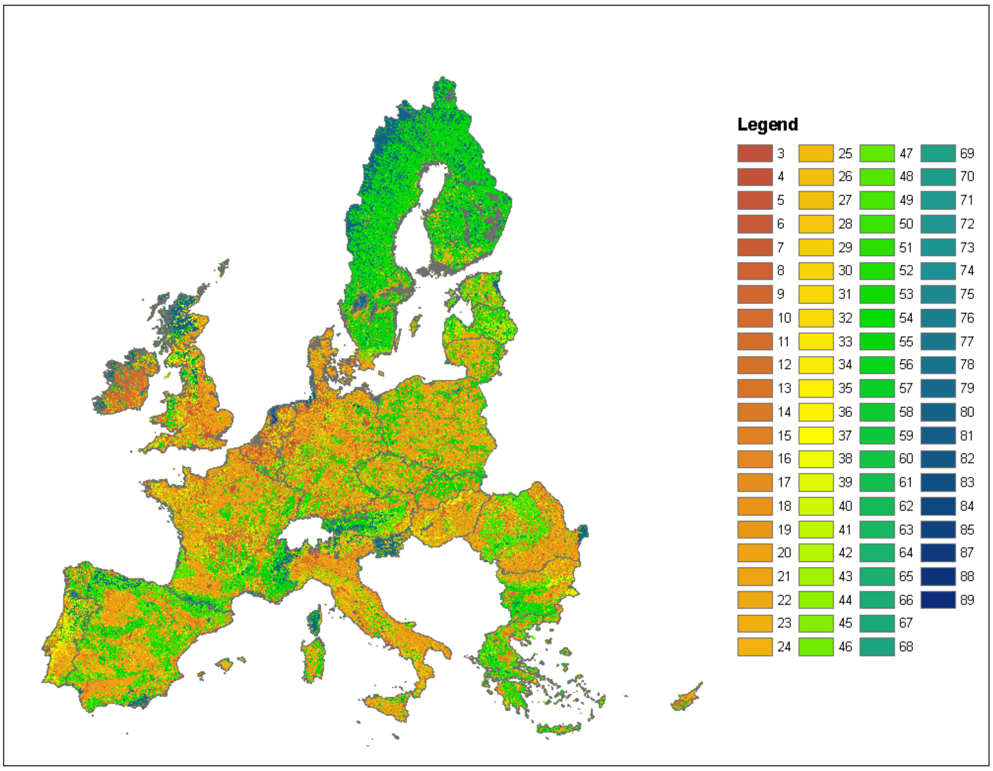


Figure 4.27. Biodiversity in the EU-27 in the year 2000, expressed as the Mean Species Abundance (%).

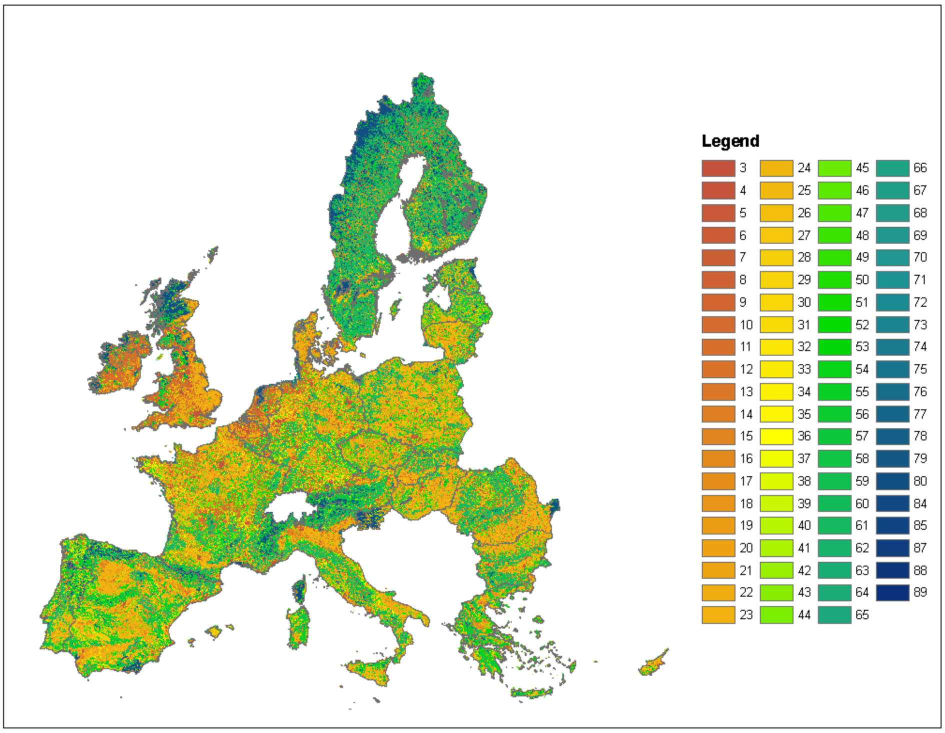


Figure 4.28. Biodiversity in the EU-27 in the year 2030 following the Global Cooperation scenario (B1), expressed as the Mean Species Abundance Index (%).

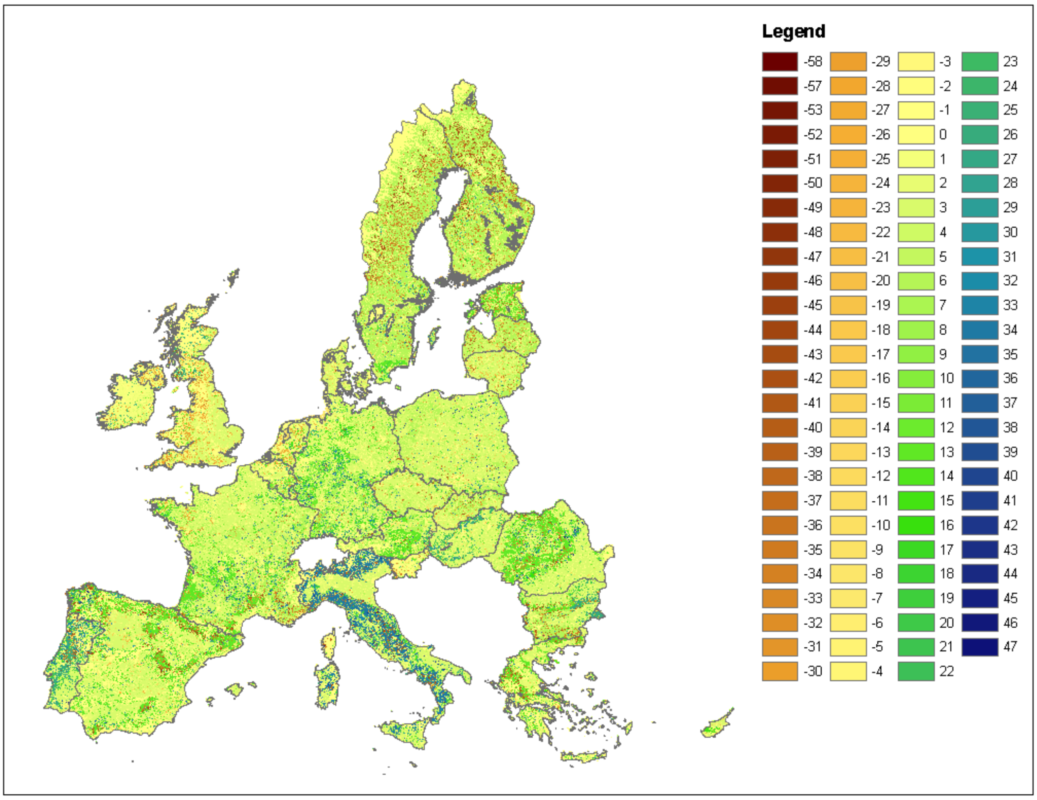


Figure 4.29. Projected change in biodiversity in the EU-27 from 2000 to 2030, expressed as change in the Mean Species Abundance Index (% point).

However, these projections need to be considered with care as there is uncertainty over the reliability of the modelled projections of the extent of abandonment (see Section 3.4.2), and the assumptions in the MSA indicator on the biodiversity value of farmland and the benefits of abandonment are almost certainly overly simplistic in an EU context (see Section 8.2 for detailed discussion).

Figures 4.30 to 4.33 show changes in biodiversity, expressed in changes of the MSA index in areas subject to land cover change due to the impacts of soil sealing (including direct land loss and fragmentation). These areas differ between NUTS3 units. Therefore, the changes in biodiversity should be interpreted against the areas affected by soil sealing in the NUTS3 units.

Figure 4.30 and Figure 4.31 show the average change in biodiversity with respect to NUTS3 and NUTS0 units in areas which were built-up in 2000 as well as in 2030. In these areas, either the sealed area remained unchanged, or the area has undergone internal transformation due to urban development (infilling), recycling of developed urban land, or development of green urban areas (Box 4.2). Changes in biodiversity in these areas appear small, in the order of magnitude of a few percentage points. This is explained by the fact that biodiversity in built-up areas is already low compared to other land cover types, and if changes occur, small areas are affected compared to other land cover changes. Clusters of NUTS3 units with negative changes occur in the Baltic States, Poland, Slowakia, Romania, the UK and Northern Spain (Figure 4.30).

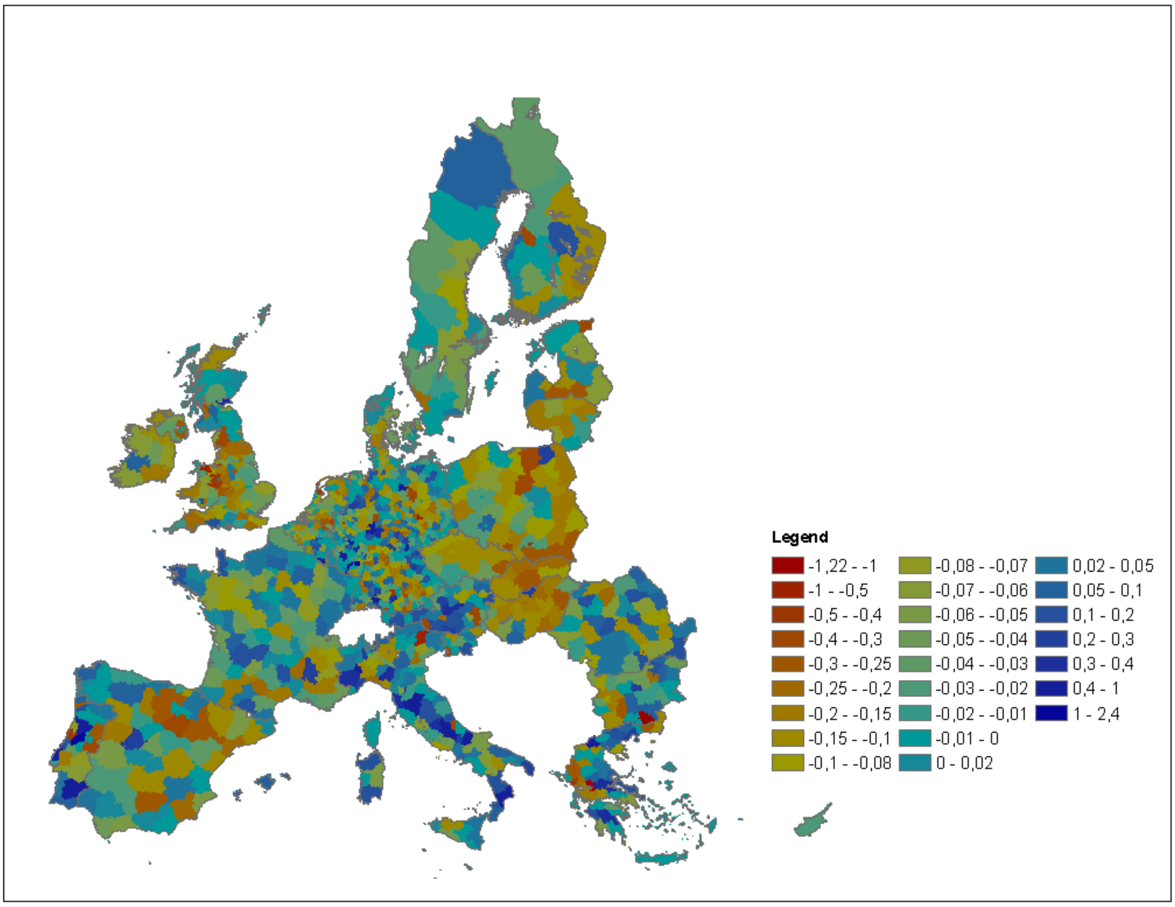


Figure 4.30. Average change in biodiversity expressed as change in the MSA index in % point) in NUTS3 units in built-up areas in 2000 and in 2030.

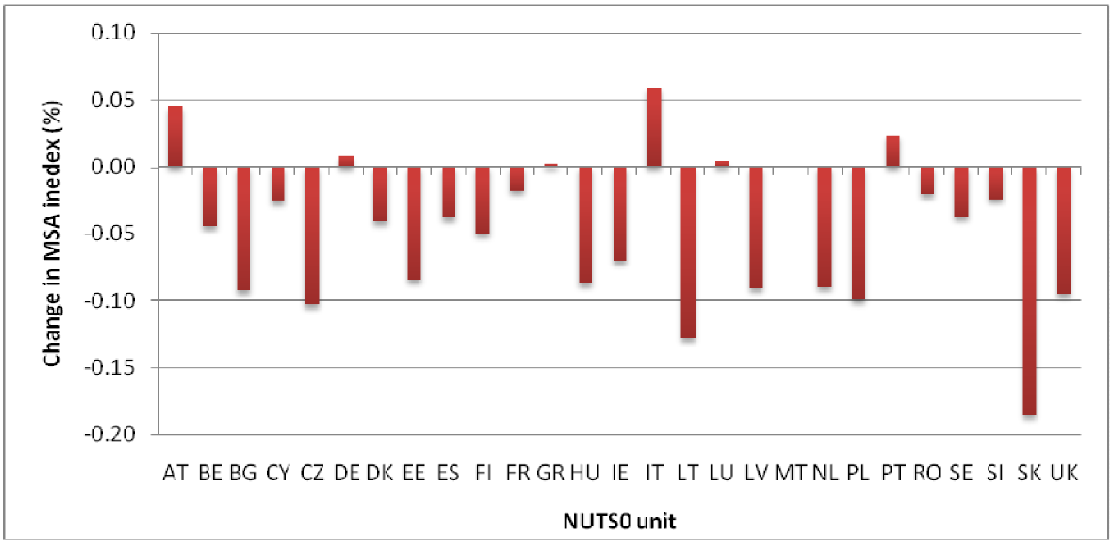


Figure 4.31. Average change in biodiversity expressed as change in the MSA index in % point) in NUTS3 units in built-up areas in 2000 and in 2030, averaged over NUTS0 units.

In areas projected to be converted from non-built up area to built-up area from 2000 to 2030 a decrease in biodiversity is expected in all Member States of the EU27 (Figure 4.32 and Figure 4.33). At the level of NUTS3 units, large decreases (-40 to -50% point) were observed in NUTS3 units in Finland, Estonia, Latvia, Poland, the Czech Republic, Slowakia, Hungary, Greece and Spain (Figure 4.32). Positive changes in biodiversity in areas converted into built-up land were observed in three NUTS3 units. However, these changes only cover several km^2, and are therefore not further discussed. In the areas not mapped (white in Figure 4.33), no changes in land cover from non built-up to built-up areas occurred.

It should be noted that the observed biodiversity changes do not refer to the absolute or relative area affected by soil sealing. Instead, they represent the change of biodiversity in areas affected by soil sealing, irrespective of their extent within the NUTS3 or NUTS0 unit. This explains why Member States with high absolute or relative increases in built-up area like France, the UK, Ireland or The Netherlands, do not necessarily show the largest decreases in biodiversity in areas converted into built-up land. As such, the change in biodiversity presented here can be interpreted as an expression of the detriment caused to biodiversity in areas affected by soil sealing. Considering the data in this perspective, the largest decrease in biodiversity due to soil sealing was observed at NUTS0 level in Estonia and Latvia (-34 resp - 35%), followed by Belgium (-29%), Greece (-28%), Hungary (28%), and Lithuania (-26%). This may be due to the high MSA biodiversity value of the habitat types that are converted to built-up land in these areas.

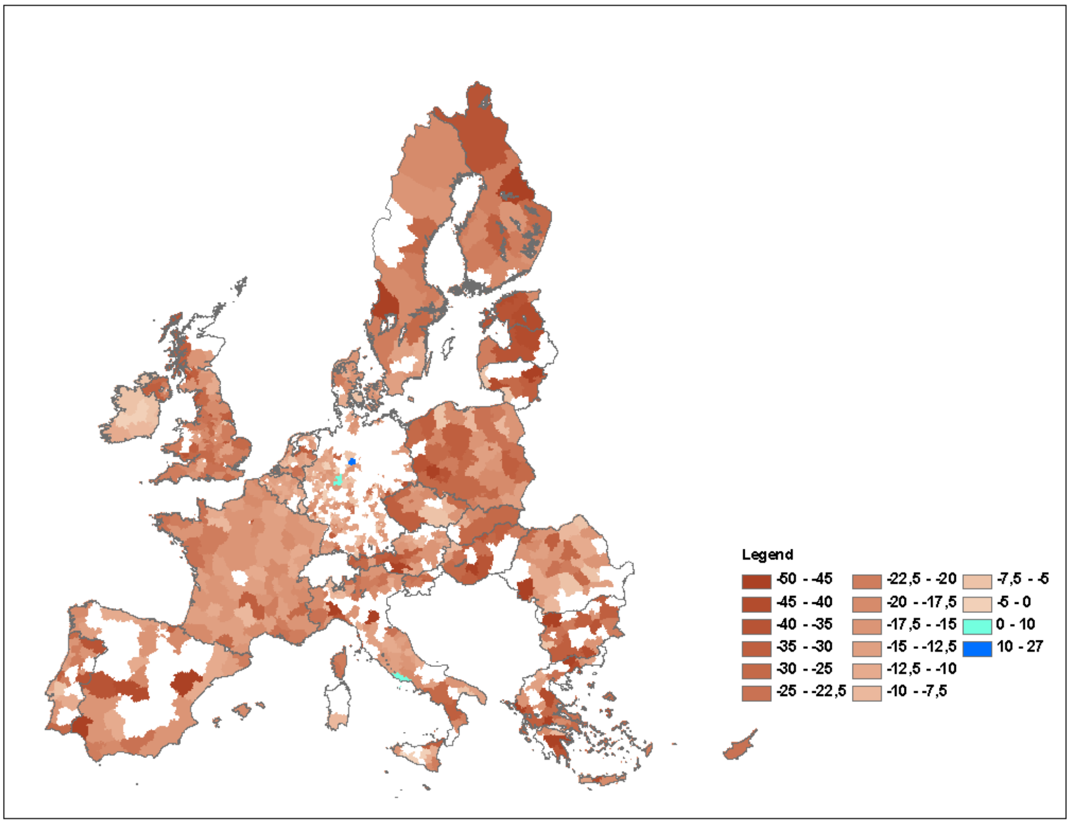


Figure 4.32. Average change in biodiversity (expressed as change in the MSA index in %) in NUTS3 units over areas changed from non-urban to urban land use from 2000 to 2030. In white NUTS3 units no change from non-urban to urban land use took place.

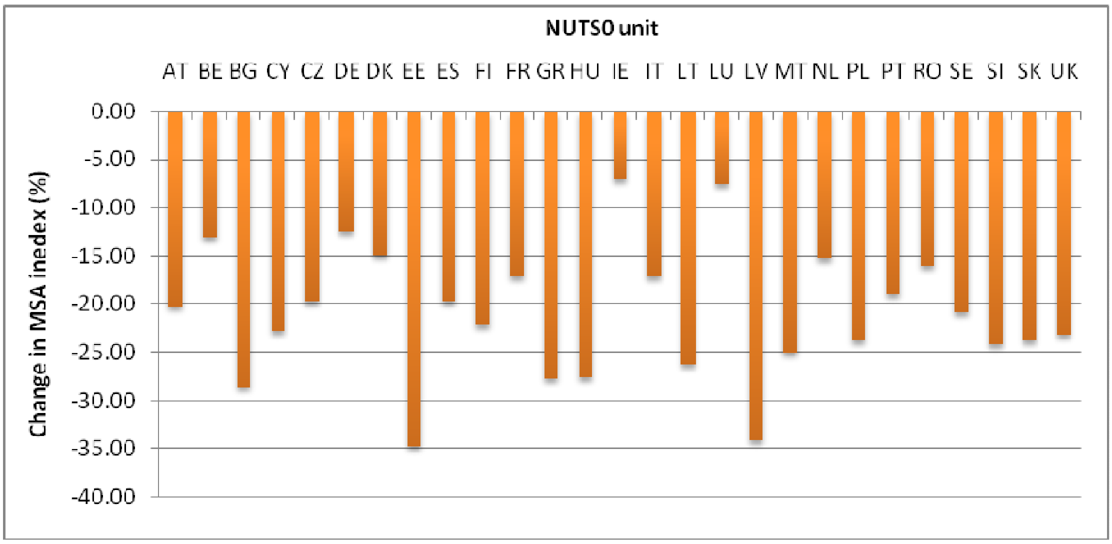


Figure 4.33. Average change in biodiversity expressed as change in the MSA index in %) in NUTS3 units in areas converted from non built-up to built-up areas in 2000 and in 2030, averaged over NUTS0 units.

Biodiversity change mainly results from climate change and land use change (Fischlin *et al.*, 2007; in De Chazal and Rousevell, 2009). Effects from climate change on the MSA index until 2030 are considered negligible, as explained in the methods section (Section 4.4.3). Instead, the biodiversity index is mainly driven by land-use change (over 50% biodiversity loss). This has a direct impact on biodiversity; for example an old forest has a higher biodiversity then intensively cultivated arable land. According to the EU Ruralis study (Eickhout & Prins, 2008), of the pressures considered in the calculation of the MSA the most important are the fragmentation of habitats by infrastructure, urbanization or agriculture (2% biodiversity loss), the disturbance by roads (2% biodiversity loss), climate change and pollution by for instance nitrogen emissions (10% biodiversity loss). The percentage loss allocated to the different pressures on biodiversity are based on extensive review of dose – response relationships in the literature, presented in Alkemade *et al.*, (2009).

The effects of soil sealing on biodiversity (direct reduction and fragmentation) are only part of the land use changes projected in the land cover change from 2000 till 2030. Therefore, the observed biodiversity changes cannot be solely attributed to soil sealing. We tried to overcome this limitation by considering only biodiversity changes in areas affected by soil sealing. It should be noticed however, that the MSA index does not account for new species occurring in built-up areas, like crows and gulls.

The decrease in biodiversity observed in the EU27 in this study contrasts with the overall increase projected in the Global Cooperation (B1) scenario (Figure 4.29 and Eickhout and Prins, 2008). The EU Ruralis study showed that in all scenarios of socio-economic change, the MSA index increases in comparison with the situation in 2000. The increase is estimated at 2 % point for the EU15 and the EU10 (from resp. 38 to 40 % point and 33 to 35 % point), and 4% point for the EU2 (from 32 to 36 % point). Averaged over the EU27 the increase is 2 % point. The main reason is the decline of the agricultural area in the EU. This area is thought to transform in a more natural environment, partly due to the expected enhancement of the Natura 2000 network (www.eururalis.eu).

In our study we found an average decrease of the MSA index of 21 % point. The decrease in biodiversity index observed in this study is because the change in biodiversity was considered in areas with land cover change from non built-up area to built-up area only. However, compared to the other scenarios, several characteristics of the Global Cooperation (B1) scenario mitigate the effects of soil sealing: the ban on residential development in NATURA2000 areas, incentives to limit fragmentation of habitats by infrastructure in natural areas, and a strong spatial planning aiming at compact cities. Despite these mitigating aspects, the difference with the change in the MSA index observed for areas turned into built-up land in this study is large. This indicates that the policies and incentives of the reference scenario may have positive effects for the conservation of biodiversity in areas not subject to urbanization, but do not affect areas converted into built-up land.

Partly this result may be due to the assumptions in the calculation of the MSA index. The index is not differentiated within built-up areas, where an average index of 5 % point was assumed, compared to for example 100 % point for sparsely vegetated areas (Eickhout and Prins, 2008). Therefore developments to regreen built-up areas are not expressed in the data for 2000 and 2030. However, this was neither the case in the EU Ruralis calculations, and therefore does not explain the difference between the changes projected for all land cover types (EU Ruralis) and land converted into built-up area (this study).

The change in biodiversity observed in this study was also compared to changes projected in the OECD Baseline scenario for Europe, as described by Braat and Ten Brink (2008). According to the OECD Baseline scenario, the rate of biodiversity loss in Europe for the period 2000 till 2050 is -0.23% points/yr (Braat and Ten Brink, 2008). The major contributors to the biodiversity loss are the conversion to agricultural land, the expansion of infrastructure and climate change (Braat and Ten Brink, 2008). In our study, the average rate of biodiversity loss for areas affected by soil sealing in the EU27 is -0.70 % points/yr. It refers to effects from soil sealing only, and does not refer to the conversion of agricultural land or to any other land cover change, like the OECD Baseline scenario.

The assumptions on policies and the time frame in the OECD Baseline scenario differ from those in the Global Cooperation (B1) scenario, for example concerning the change of area of agricultural land which is expected to increase in the former, and to decline in the latter. Despite the differences in the scenario assumptions, the comparisons of the change in MSA index found in this study for the period 2000-2030 with the EU Ruralis projections for the EU27 and the OECD Baseline scenario show that the MSA index decreases in areas converted into built-up land to a much larger extent than it will increase (EU Ruralis) or decrease (OECD Baseline scenario) in the projections for the ensemble of land covers in the EU27 or Europe. Consequently, the conclusion may be justified that the protection of biodiversity in built-up areas will require larger attention from governments and the EU. In case of a policital will to conserve biodiversity in urban areas, this is possible through urban planning. It would however require the making available of space in urban areas, and the application of nature management and development. The monitoring of biodiversity in urban areas would require a different index, because the MSA index does not account for new species in these areas.

4.4.5 Impacts of soil sealing on water retention

The spatial distribution of the effective soil water storage capacity (SWSC_eff) is shown in Figure 4.34. High values (up till 180 mm/100 cm) occur in relatively deep, well drained soils, mainly Luvisols and Podzols, in Northern Europe (see also Annex 2.1). Soils with small values of SWSC_eff are mainly found in shallow soils (Leptopsols, Regosols) or soils with hard pan layers of calcium carbonate (Calcisols).

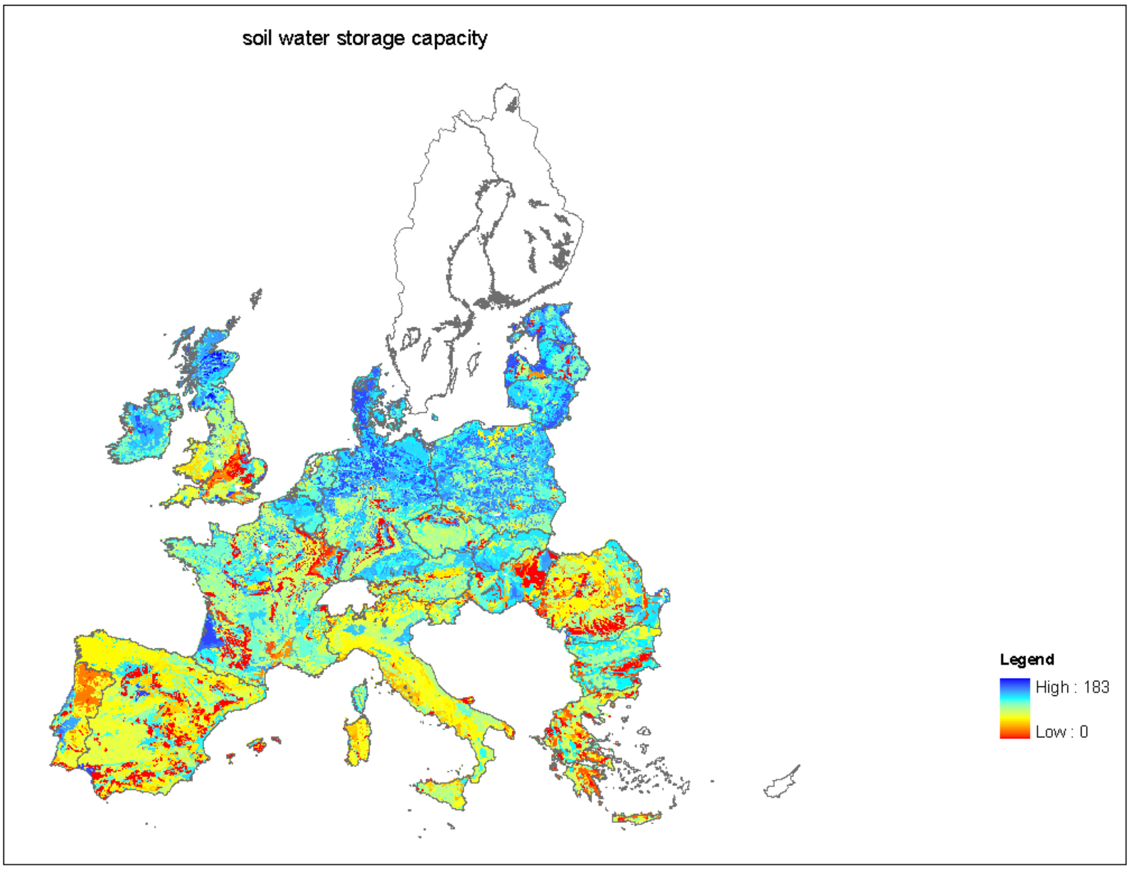


Figure 4.34. Effective soil water storage capacity (mm for the first 100 cm of soil). Adapted from the PESERA database. Source data from Brian Irvine, University of Leeds, UK.

The change in effective soil water storage capacity (SWSC_eff) in areas subject to soil sealing from 1990 till 2000 is depicted in Figure 4.35. It reflects the summed value of SWSC_eff in areas subject to urban land management (LCF1), urban residential sprawl (LCF2) and sprawl of economic sites and infrastructure (LCF3) (Box 4.2). As the proportion of sealed surfaces within the areas subject to these land cover flows is unknown, the reduction in available SWSC_eff for the storage of rainwater is a maximum estimate. The actual SWSC_eff becoming unavailable will be smaller, depending on the proportion of the areas actually sealed (see Figure 4.14 and Table 4.12), and on the reduction of infiltration in these areas based on the cover type and age, as explained in Section 4.4.2.

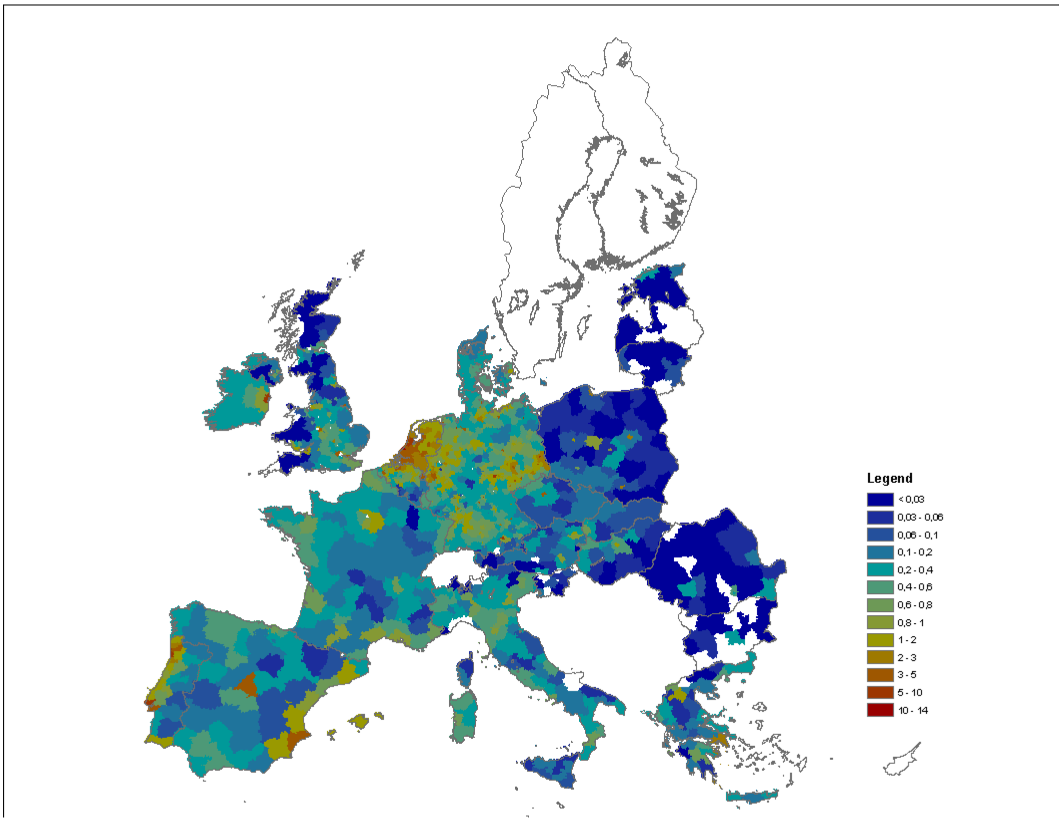


Figure 4.35. Maximum potential change in effective soil water storage capacity (SWSC_eff) (mm in the first 100 cm of soil) as a result of soil sealing in countries of the EU as a % of the total SWSC_eff in NUTS3 units, for the period 1990-2000.

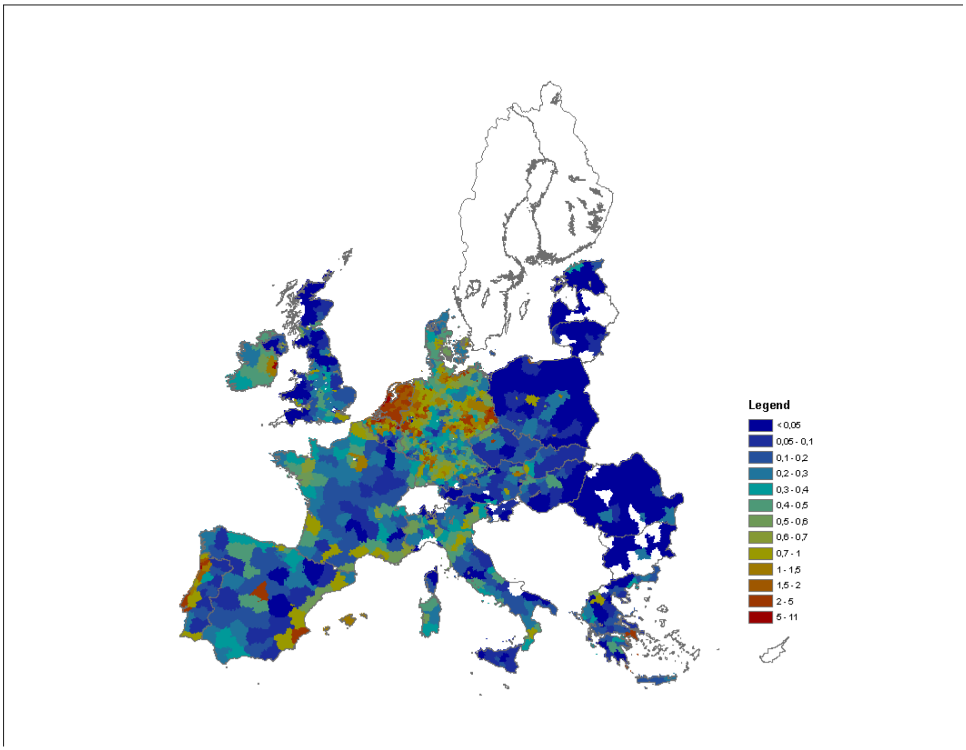


Figure 4.36. Maximum potential change in effective soil water storage capacity (SWSC_eff) (mm in the first 100 cm of soil) as a result of soil sealing in countries of the EU (mm per km^2 in NUTS3 units) for the period 1990-2000.

Changes in the effective soil water storage capacity due to soil sealing compared to the total available storage capacity in NUTS3 units were largest (>5%) in The Netherlands, Belgium and in the urban zones of Madrid, Murcia, Porto and Lisbon, Dublin, Birmingham and London, Athens, and in NUTS3 units in the eastern part of former East Germany. The same pattern was observed for the change in SWSC_eff, expressed in mm/km^2 of the NUTS3 units. The difference between the expressions is that the change in SWSC_eff expressed in % of the total storage in a NUTS unit takes account of the absolute values and spatial variability of SWSC_eff within the unit, whereas, when expressed per km^2 area of the NUTS unit, it takes account of the area of the unit only.

For the urban zones in The Netherlands, Belgium and Germany the observed changes in SWSC_eff are even more significant, considering that soils in these areas have relatively large values of SWSC_eff (Figure 4.34). Relatively small or negligible changes (<0.05% and <0.1 mm/km^2) were observed in the Central and Eastern European countries, in line with the observation that some of these countries have soils with small values of SWSC_eff (Figure 4.34).

For the period from 2000 to 2030 the situation is different. In many NUTS3 regions, notably in Germany and Spain, no land cover flows to built-up land are projected to occur. These areas appear as white units in the map of change of SWSC_eff (Figure 4.37 and Figure 4.38). Apart from these differences, and relatively larger changes in central and North-Eastern France, the pattern of changes is roughly comparable to the period 1990-2000. However, the changes are larger in the period 2000-2030 (up till 24% versus 14% in 1990-2000). This is also visible in the average change per NUTS0 unit (Figure 4.39). Considering that the increase of built-up area in both periods is roughly comparable (10.600 vs 10.300 km^2, see Task 2.1), this must be due to the location of built-up areas in the period 2000-2030 in areas with larger values of the effective soil water storage capacity. The effect may be partly explained by the fact that NUTS3 units with urban zones not covered by the SWSC_eff map are more likely to have missing values of the SWSC_eff in cells with land cover flows leading to soil sealing in the period 1990-2000 than in the period 2000-2030. This is because the SWSC_eff map was based on soil information dating from before 2006. This probably explains a part of the large difference between the change in SWSC_eff in 2000-2030 compared to 1990-2000 in the UK (Figure 4.39). In this country, the SWSC_eff map contains relatively many missing values in NUTS3 units with urban zones, where soil sealing is projected to occur in the period 2000-2030 (Figure 4.16).

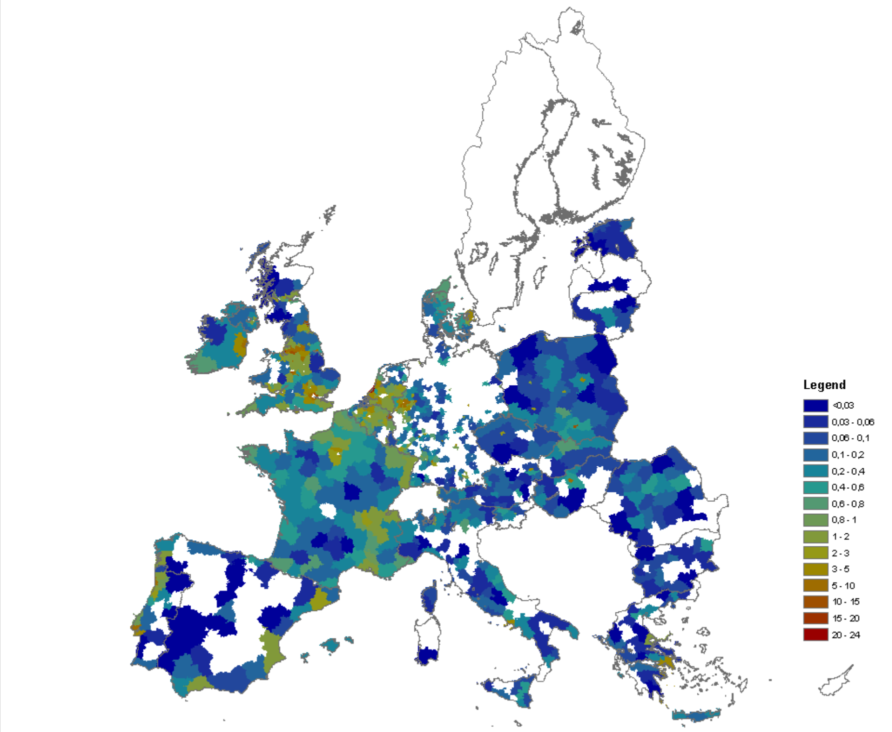


Figure 4.37. Maximum potential change in effective soil water storage capacity (SWSC_eff) (mm in the first 100 cm of soil) as a result of soil sealing in countries of the EU as a % of the total SWSC_eff in NUTS3 units, projected for the period 2000-2030 based on the Global Cooperation scenario (B1).

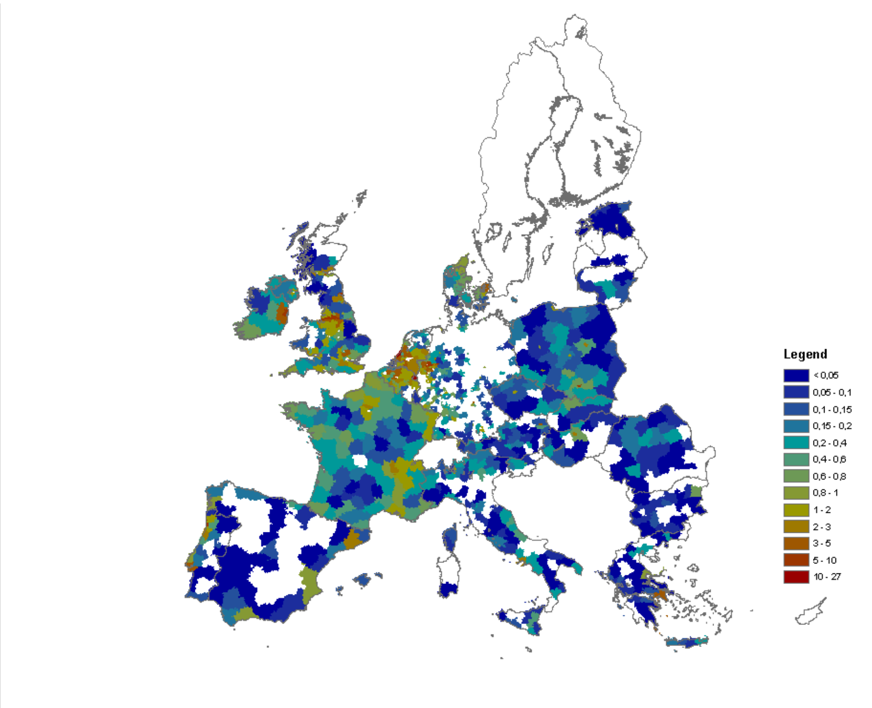


Figure 4.38. Maximum potential change in effective soil water storage capacity (SWSC_eff) (mm in the first 100 cm of soil) as a result of soil sealing in countries of the EU (mm per km^2 in NUTS3 units) for 2000-2030 based on the Global Cooperation scenario (B1).

The average change in the effective soil water storage capacity due to soil sealing is 0.5% in the NUTS0 units considered for the period 1990-2000, versus 0.8% for the period 2000-2030. The largest changes were observed in The Netherlands (3.2% in 1990-2000, 3.6% in 2000-2030), followed by Portugal (resp. 1.6% and 1.3%) and Ireland (resp. 1.4% and 1.6%) (Figure 4.39). This observation is in line with the large relative increase in built-up areas observed for these countries (Figure 4.14). Relatively small changes in SWSC_eff in both periods were observed in the new member states Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovenia and Slowakia (Figure 4.39). This can be explained by the relatively small increase in built-up area in these countries compared to other countries in the EU (Figure 4.14). For Romania, the small change may also be due to the originally small values of SWSC_eff (Figure 4.34).

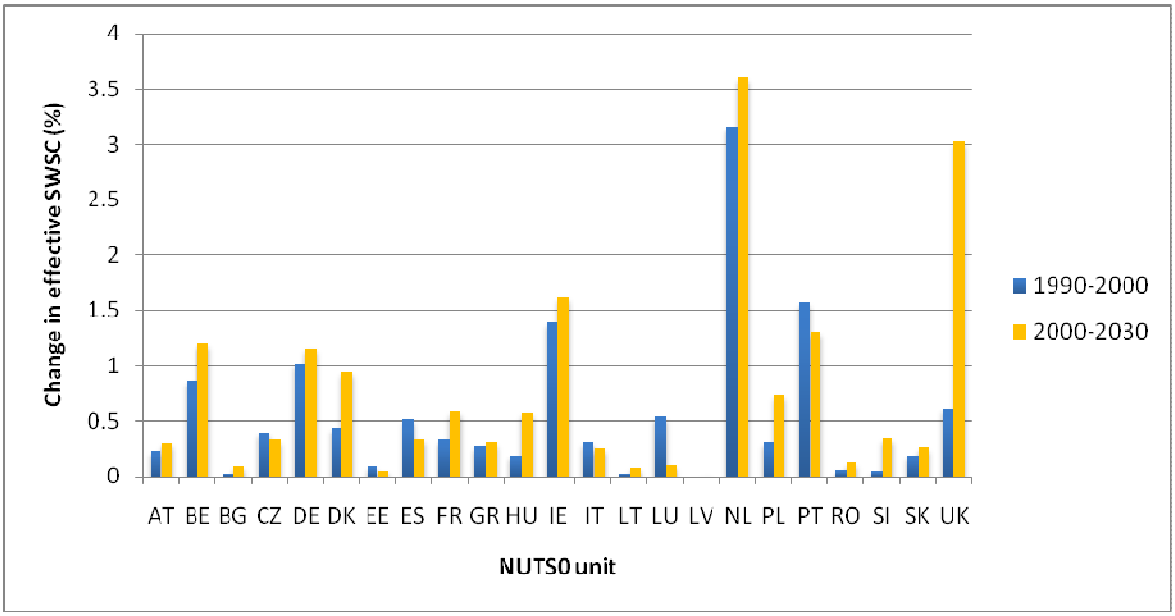


Figure 4.39. Change in effective soil water storage capacity (% of total in NUTS3 units) due to soil sealing, averaged for NUTS0 units.

When the reduction in effective soil water storage capacity is expressed in mm per km^2 of NUTS0 units, no account is taken of the absolute values of SWSC_eff (mm) occurring in the NUTS0 units. In this case, reversed trends were observed for the periods 1990-2000 and 2000-2030 for some countries compared to the expression in % of the total storage in NUTS units: Germany, Greece, Hungary and The Netherlands. In these countries, the reduction in SWSC_eff was smaller in the period 2000-2030 than in the period 1990-2000. For Germany and The Netherlands this can be explained by the fact that the absolute growth in built-up area in these countries was smaller in the period 2000-2030 (resp. 594 and 599 km^2) than in the period 1990-2000 (2168 vs 957 km^2). For Hungary and Greece the explanation is that these countries, although having similar absolute extensions of built-up area in both periods, the procentual change of the SWSC_eff with regard to the storage volume available is larger due to the small intrinsic values of soil water storage capacity in these countries (Figure 4.34).

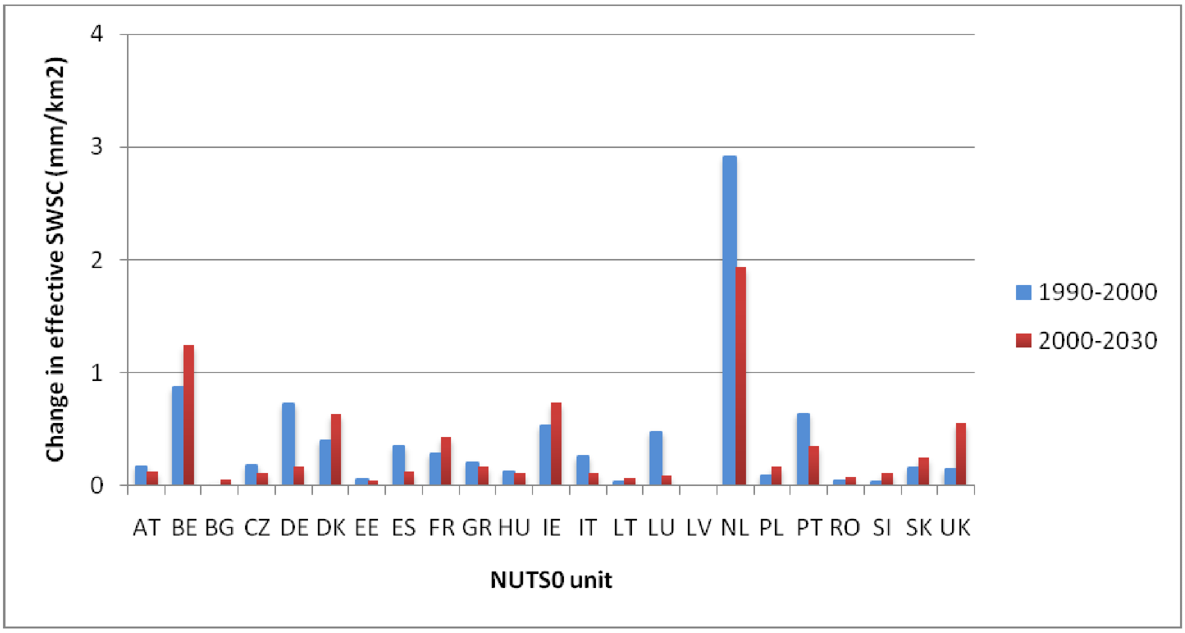


Figure 4.40. Change in effective soil water storage capacity due to soil sealing (in mm per km^2 area of NUTS0 units).

Many studies report on the decline of water retention in soils due to soil sealing in general (e.g. Collin and Melloul, 2003; Emmerling and Udelhoven, 2002), but few report quantitative results on the reduction in soil water storage capacity. Therefore it is difficult to compare the potential changes in effective soil water storage capacity derived in this study to values found in other studies. Most studies report on effects on other components of the water balance, which are more easily modeled or monitored, like direct surface runoff, evapotranspiration and groundwater recharge (e.g. Haasse, 2009; Hejazi and Markus, 2009; Wessolek, 2008; Xiao *et al.*, 2007). A study by Haasse (2009) on the change in water balance components in the city of Leipzig reports that direct runoff had increased by 44% in the period from 1985 till 2007 due to land use change and surface sealing. Evapotranspiration decreased by 6%, and groundwater recharge by 9%. Wessolek *et al.* (2008) developed hydro-pedotransfer functions for partly sealed areas in Germany, using data from lysimeter studies and inner-city percolation experiments. These relationships can be used to calculate water balance components of urban sites, like the annual percolation rate, the net precipitation infiltrating into the soil of partly sealed sites, and the annual actual evapotranspiration. According to the hydro-pedotransfer functions, reductions of infiltration in built-up areas range from 75 to 80% for asphalt streets and roofs to 5 to 10% for open concrete stones filled with grass vegetation (Table 4.12). Dunnett and Clayden (2007) report reductions from 16% for areas with 10-20% sealed surface to 70% for areas with 75-100% sealed surface. These reductions in infiltration cannot be compared to the reductions in effective soil water storage capacity observed in this study, because the former refer to infiltration coefficients in unsealed soils (=mm infiltration/mm total rainfall), and the latter to depths of soil water which can be stored in unsealed soils.

Table 4.12. Infiltration coefficients for sealed surfaces. Source: adapted from Wessolek *et al*., (2008).

Degree of surface sealing	*Infiltration coefficient*	*Type of soil sealing*
Class I (low: <10%)	0.90-0.95	Open concrete stones filled with grass vegetation
Class II (medium: 10-50%)	0.80-0.85	Mosaic cobble stones
Class III (high: 90-95%)	0.55-0.60	Concrete pavement
Class IV (severe: >90%)	0.20-0.25	Asphalt street, roof

For the EU as a whole, no studies were found reporting the influence of soil sealing on water balance components, and therefore neither on soil water retention. With regard to the surface runoff component, the potential flood hazard and risk mapping at the Pan-European scale (De Roo *et al*., 2007) might be used to this end. This map was based on a flood hazard map, a flood exposure map and a flood vulnerability map, aggregated at NUTS3 level. The exposure map was derived from a population density map, and the flood vulnerability map from GDP data. In order to assess effects of soil sealing on flood risk, relationships between sealed area and population density and GDP would be required. Likewise, the European Flood Alert System could be used, which directly incorporates effects from soil sealing in calculations of flood hydrographs through the LISFLOOD model (Thielen *et al*., 2009; Van der Knijff and De Roo, 2008). However, LISFLOOD assumes zero infiltration and zero soil water storage in pixels with impervious cover, which results in an underestimation of the actual soil water storage in sealed soils. Applications of these models were outside the scope of this study.

It should be noted that the reported values of change in the effective soil water storage capacity in this study refer to a situation in which 1) the areas converted into built-up land are assumed to be completely sealed, and 2) no infiltration takes place in these areas. With respect to the proportion of sealed surfaces within urban areas, values of 52% were reported for Germany (EEA, 2006). Values between 60 and 90% were reported for residential areas in Dutch towns (van Dooren and Kunst, 2009), and between 20% and 80% for respectively non-urban area and strongly urbanized area in The Netherlands (Maas, 2009, in: TCB, 2009a). In sealed surfaces, infiltration of rainfall is reduced depending on the rainfall intensity, the proportion of the area sealed, the type and the age of the sealed cover. According to the studies cited before, reductions in infiltration may vary from 5 to 80% depending on these factors. Therefore the reported values of change in the effective soil water storage capacity should be interpreted as the maximum soil water storage which would be made unavailable due to soil sealing. A geospatial analysis of the proportions of sealed area, cover type and age along with long-term records of climatic variables and runoff in urban areas would be required to provide more accurate quantitative estimates of the actual reductions in effective soil water storage capacity in built-up areas. The hydro-pedotransfer function approach proposed by Wessolek *et al*. (2008) may be useful to estimate annual or longer term water balance components for partly sealed areas in urban environments.

The reduction in effective soil water storage capacity quantified in the present study for the periods up till 2000 and 2030 imply that soil sealing due to urban development, urban residential sprawl and the sprawl of economic sites and infrastructure potentially lead to an increased flood risk produced by increasing direct runoff and a resulting higher release of water out of the urban system. This will require technical adaptations in urban areas, which may become extremely expensive. The reduction in the effective soil water storage capacity due to soil sealing may also result in reduced evapotranspiration, with negative consequences for the urban climate (e.g. Pauleit *et al*., 2005).

Haasse (2009) showed that the long-term effects of urban land uptake on the water balance in particular, not only depend on the amount but also the distribution of the land to be developed, or the spatial pattern of soil sealing, as well as the previous quality of this land, referring also to studies from Newman (2000), Burchell and Mukherji (2003) and Nuissl *et al*. (2008). The previous quality refers to the infiltration and soil water storage capacity of the soil before mixing and sealing.

For the period 2000-2030, a more compact city growth is projected by the Global Cooperation (B1) scenario. This type of growth may seem to be the most desirable from an environmental point of view, because it allows a preservation of the largest possible patches of 'natural' landscape. However, larger areas of sealed surface with less connectivity to unsealed surfaces within urban areas result in increased direct runoff and decreased evapotranspiration compared to more dispersed patterns of sealed and unsealed surfaces. Therefore, this pattern of urban development will also result in increased direct runoff and decreased evapotranspiration, with associated increased costs for urban flood management and decreased quality of life in urban areas due to negative effects on the urban climate.

4.4.6 Impacts of soil sealing on soil organic matter

According to our calculations the total soil organic carbon stocks of mineral soils till a depth of 30 cm is about 25 Gton (=Pg) C for the EU27 countries. Soils in wet and colder climatic zones have higher SOC stocks (Figure 4.41) with more than 90 ton C per hectare. In Mediterranean countries SOC stocks are much lower, about 30 ton C/ha.

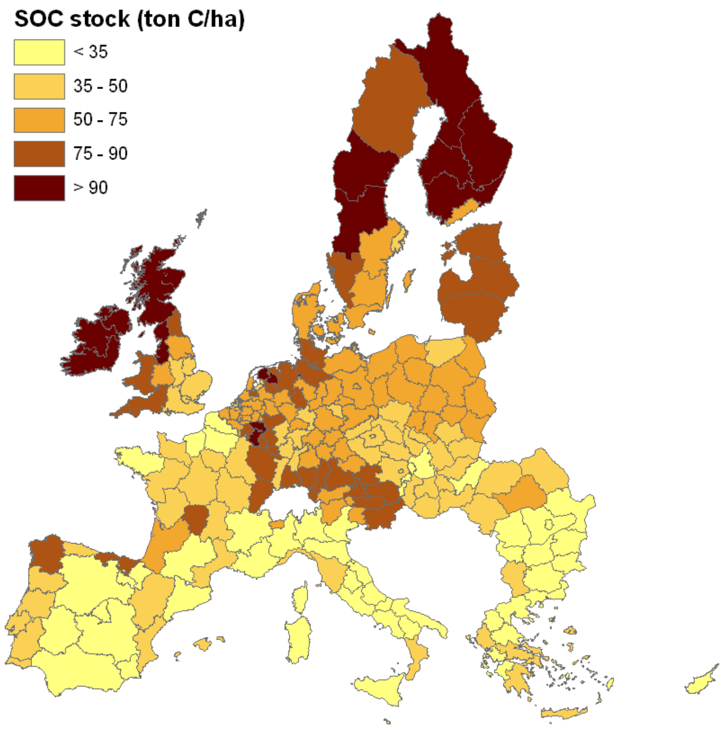


Figure 4.41. Distribution of soil organic carbon stocks for mineral soils in Europe

For the period 1990-2000 the total loss of soil organic carbon was 4.6 Mton C for 23 EU countries (Sweden, Finland, Malta and Cyprus are not included in the CORINE 1990 map), which is an annual emission of 1.7 Mton CO_2. The highest losses occurred in The Netherlands, Belgium, Ireland and Germany, but also some urban NUTS2 regions in southern Europe (e.g. Madrid and Athens) have higher SOC losses (Figure 4.42). When SOC loss is expressed as percentage of the SOC stock the losses are higher in southern Europe, because of their lower SOC content.

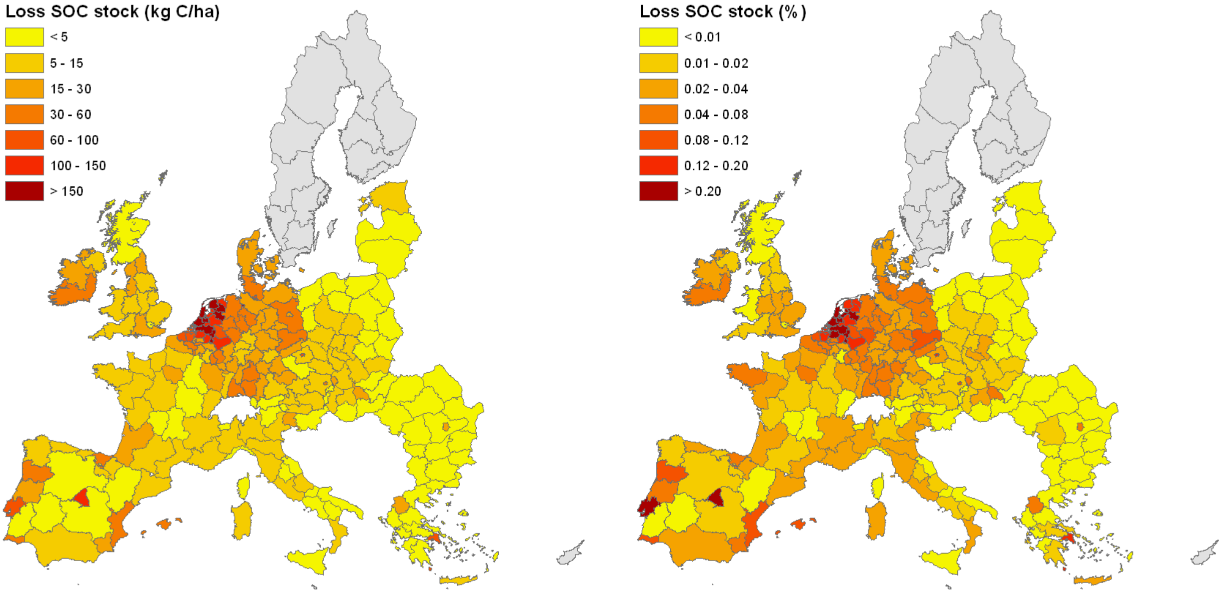


Figure 4.52. Loss of SOC stocks due to soil sealing for the period 1990-2000, expressed in kg C/ha (left) and as percentage of the original SOC stock (right)

In Figure 4.52 the SOC losses due to soil sealing are aggregated per country. Germany has the highest absolute losses, but in comparison to country size the losses are highest for The Netherlands. These high SOC losses can be explained by the high degree of urbanization in the Netherlands and the presence of soils with high SOC contents. Especially the soils in the densely populated western part of the country have high SOC contents and the main land use is grassland, which has generally the highest SOC contents. Also Ireland, Belgium and Portugal have relatively high SOC losses due to soil sealing.

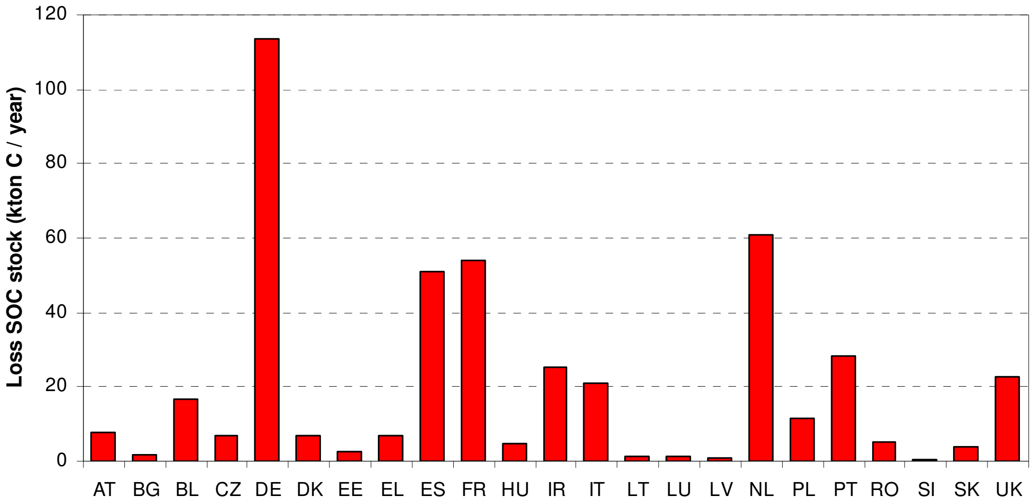


Figure 4.43. Aggregated SOC losses per country due to soil sealing for the period 1990-2000

For the period 2000-2030 the total loss of soil organic carbon was 5.8 Mton C for the 27 EU countries, which is an annual emission of 0.71 Mton CO_2. The highest losses occurred in The Netherlands, Belgium, Ireland and United Kingdom (Figure 4.4). But also several regions in France, Poland and Slovakia have high SOC losses due to soil sealing. In Figure 4.45 the SOC losses are aggregated at country level. The resulting graph is quite different from the graph for the period 1990-2000. Overall the SOC losses per year due to soil sealing are almost a factor three lower, but also the distribution over Europe is different. The most remarkable differences are the lower degree of urbanization for Germany and The Netherlands, compared to the 1990-2000 period, whereas for the United Kingdom and France the degree of urbanization is much higher. Also east-European countries (e.g. Poland and Slovakia) have more urbanization and associated SOC losses. These differences can be explained by the area of soil that is sealed during the period 2000 to 2030, which is relatively low for the Global Cooperation (B1) scenario. In this scenario, spatial urban planning is restricted, leading to compact urban growth compared to the other IPCC-SRES scenarios.

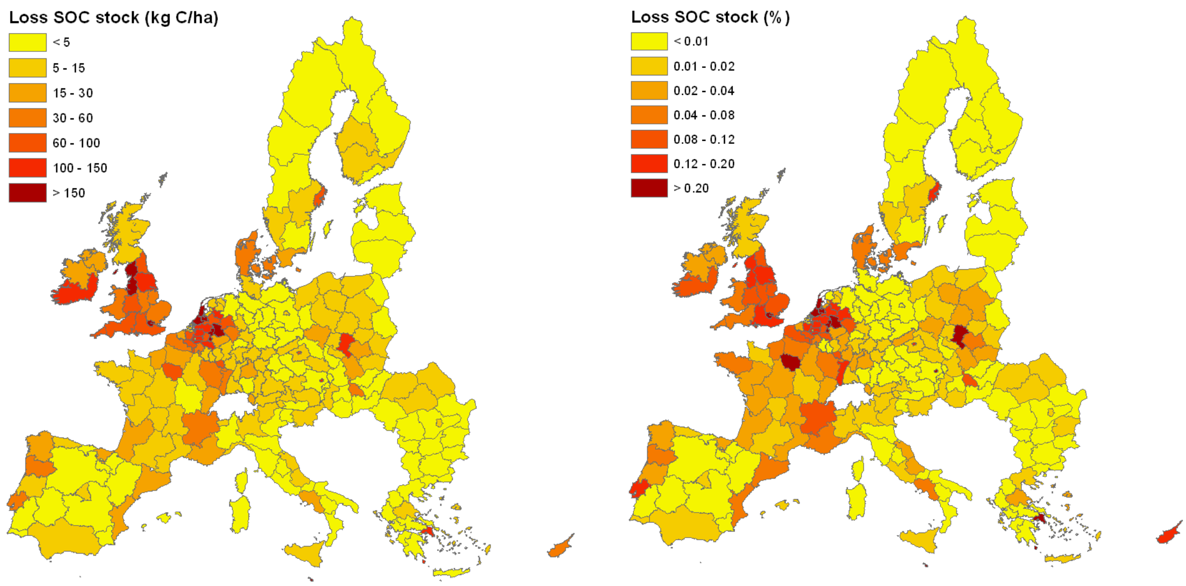


Figure 4.44. **Loss of SOC stocks due to soil sealing for the period 2000-2030, expressed in kg C/ha (left) and as percentage of the original SOC stock (right)**

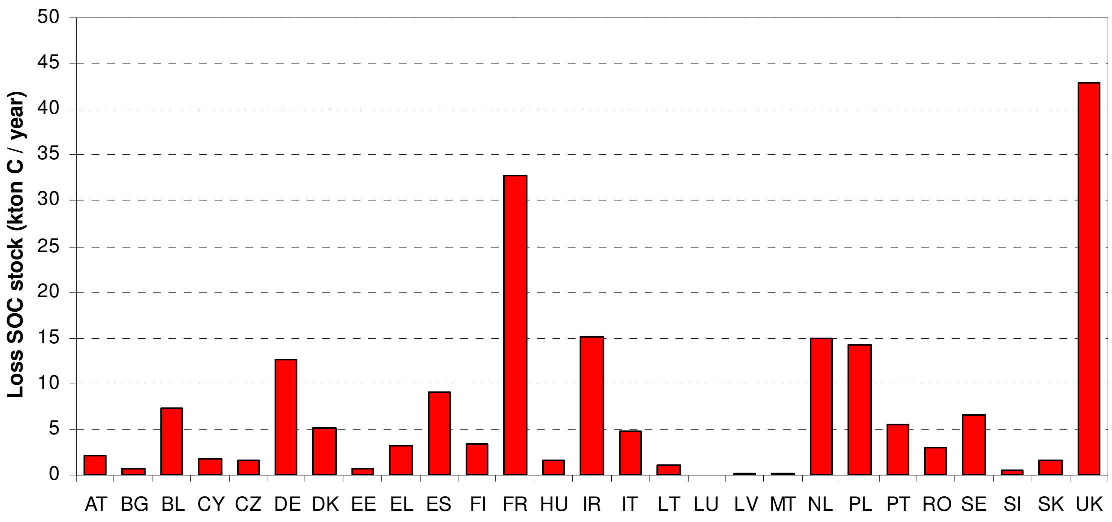


Figure 4.45. Aggregated SOC losses per country due to soil sealing for the period 2000-2030

As explained in the methodology section the previous land use determines the change in SOC stocks due to soil sealing. In Table 4.13 the relative contribution of the previous land use is expressed in terms of SOC loss and the land use area. For the period 1990-2000 mainly arable land was used for urbanization (67%), but also a significant part of the nature area (forest and (semi-) natural vegetation) was converted to built-up area (16%). For the period 2000-2030 still most land for newly built-up area comes from the agricultural sector, however the area grassland that is converted is much higher (45%). In contrast the conversion of nature areas is much lower (4%), which is in line with the focus of the B1 scenario on environmental sustainability and biodiversity. Table 4.13 also shows that SOC losses and converted areas are not a one to one relationship. SOC losses due to soil sealing of grasslands result in relatively higher SOC losses than the conversion of arable land.

Table 4.13. Relative contribution of the previous land use in terms of SOC losses and land use area

	Nature	Grassland	Arable land	Perennials
1990-2000				
SOC losses	16.3	22.9	58.1	2.7
Land use area	15.7	14.0	66.9	3.5
2000-2030				
SOC losses	4.4	55.7	35.3	4.6
Land use areas	4.4	45.3	44.0	6.3

Only few other studies project changes in soil carbon stocks due to land use change. Schulp *et al*. (2008) modelled the effect of land use change on carbon sequestration for the four IPCC SRES scenarios. Carbon sequestration rates are expected to decrease by 4% in 2030 relative to 2000 if land use remains unchanged. For the B1 scenario an increase in sequestration rate is predicted in 2030. However, in they do not report the specific carbon sequestration rates due to soil sealing. Another study by Zaehle *et al*. (2007) does report specific emissions for soil sealing. However, their approach is quite different and is based on land-atmosphere interactions. They predict for the EU15 (and Norway and Switzerland) a loss 3.3 Mton C per year due to urbanization for the 1990s. This is somewhat higher than our result but in the same order of magnitude. Metzger *et al*. (2008) found a decrease in soil carbon in cropland up till 2080 in the principal environmental zones in Europe under the B1 SRES scenario, expressed in several units of a potential impact score. The decrease is caused by the increased decomposition of soil carbon due to climate change, and the decreased area under agriculture. Part of this decrease can be attributed to soil sealing.

In this analysis we did not include the organic soils (peat soils). Although these soils contain large amounts of organic carbon, they are usually not used for settlements because of their low bearing capacity and high groundwater levels. However, in some areas, e.g. Western Netherlands, these soils are used for settlements, with high carbon losses, due to the intensive drainage, which causes oxidation of the peat.

4.5 SYNTHESIS OF IMPACTS OF SOIL SEALING ON LAND USE SERVICES IN THE EUROPEAN UNION

4.5.1 Impacts of soil sealing on food production

Impacts of soil sealing on food production were assessed from the loss of suitable land for arable cropping and permanent grassland. Soil sealing was observed to result in a loss of suitable land for arable cropping and permanent grassland amounting to 5% of the land area at the level of NUTS3 units, and to 1% of the land area in EU countries in the period from 1990 to 2000. The sprawl of economic sites and infrastructure has the largest impact on the availability of suitable land for food production. The impacts were largest in Western Europe, with high losses in The Netherlands, Ireland, Belgium, Germany and Portugal, amounting to 0.4-1.2% of the land area. The smallest losses of suitable land for food production (<0.1% of the total land area) were observed in Bulgaria, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia and Slowakia. No other studies were found reporting quantitative areal losses of suitable land for agriculture over the EU specifically due to soil sealing. Studies from the US indicate a higher loss of agricultural land due to urbanization (up to 3%) (Imhoff *et al*., 2004). Generally, the suitability for arable cropping is more critical to impacts of soil sealing, with areas of lower suitability in Spain, Northern Greece, Austria and Hungary.

The projected loss of suitable land for agriculture from 2000 to 2030 according to the Global Cooperation (B1) scenario is comparable to the loss observed for the period 1990-2000, i.e. up to a few percent of the land area in NUTS3 units. This implies that the decadal loss rate is smaller than in the period 1990-2000. The patterns of loss are different for the period from 2000 till 2030, with relatively higher losses of suitable land for agriculture in Central and Eastern European member states (e.g. Poland, Romania, Hungary). This may be due to the economic development of these countries after accession to the European Union.

The largest loss of suitable land for agriculture was observed in The Netherlands (3.0 and 3.2 % for arable cropping and permanent grassland resp.), followed by the UK (1.5% and 1.5%) and Ireland (1.2% and 1.4%). Impacts from changes in climate and technology are expected to increase the agricultural productivity of regions in north-western Europe (Ireland, the UK, northern Germany, Denmark, The Netherlands and Belgium) under the A1 and B2 scenarios of global change up till 2050 (Hermans and Verhagen, 2008). If the B1 scenario considered in the present study has similar effects on productivity, a loss of agricultural land in these parts of the EU due to soil sealing will therefore have relatively large impacts on food production, compared to losses in regions with lower productivity, like southern Spain, southern Italy and southern France.

Though the loss of suitable land for agriculture seems small compared to the total stock of agricultural land in the EU27 (46% of the land area in 2000, 40% in 2030 according to the Global Cooperation scenario), the loss may be significant in terms of net primary productivity. In situations where the EU may be more dependent on food and biomass production in its own land area, the loss of suitable land for agricultural land due to soil sealing therefore may become an issue. The global issue of land resources is relevant to Europe, because Europe is a major producer of bulk and high-value goods, and a large importer and exporter of agricultural commodities (PBL and Stockholm Resilience Centre, 2009).

The global demand for increased food and biomass production does not show in an increase in agricultural land in the EU until 2030: the agricultural area in the EU has been declining for many decades as a result of urbanization, nature development and recently bioenergy cropping, and is projected to do so up till 2030. This observation contrasts with the projections from the FAO study Agriculture Towards 2030 (FAO, 2006), possibly due to different assumptions in the scenarios used (Worldbank Baseline scenario versus the Global Cooperation scenario in this study). In the Global Cooperation scenario considered in the present study, the driving forces for the declining agricultural area are lower demographic and economic growth in combination with environmentally focused land use planning in the EU.

4.5.2 Impacts of soil sealing on biodiversity

Impacts of soil sealing on biodiversity were assessed for the period 2000-2030 using the MSA index as an indicator. Over the EU27, the MSA biodiversity indicator is projected to increase as a result of all modelled land use changes under the Global Cooperation scenario. This is thought to be due to projected increases in the nature friendly management of forests, more organic farming in agriculture in place of intensive agriculture, and the decrease in agricultural land due to land abandonment. But as noted above (and see Section 8.2), this conclusion must be treated with caution as the MSA is insensitive to the potential detrimental impacts of abandonment. Furthermore, the MSA does not take into account the high threat status and therefore nature conservation importance of many farmland species.

In areas projected to be converted from non-built up area to built-up area from 2000 to 2030 a decrease in biodiversity is expected in all Member States of the EU27. The largest decrease in biodiversity due to soil sealing was observed in Estonia and Latvia (-34 resp -35%), followed by Belgium (-29%), Greece (-28%), Hungary (28%), and Lithuania (-26%). These values represent a decrease in biodiversity in areas affected by soil sealing, irrespective of their extent within the NUTS3 or NUTS0 unit, and can be interpreted as an expression of the detriment caused to biodiversity in areas affected by soil sealing. Comparisons of the change in MSA index found in this study for the period 2000-2030 (-21% point) with the EU Ruralis projections for the EU27 (2%) and the OECD Baseline scenario (-0.23% point/year) show that the MSA index decreases in areas converted into built-up land to a much larger extent. This is attributed to the fact that the change in MSA index was considered solely in areas with conversion to built-up land, while in the EU Ruralis and OECD Baseline Scenario studies, changes in the MSA index were considered in relation to all types of land use change.

The Global Cooperation scenario applied in the present study has several characteristics which reduce the potential effects of soil sealing on biodiversity: the ban on residential development in NATURA2000 areas, incentives to limit fragmentation of habitats by infrastructure in natural areas, and strong spatial planning that encourages compact cities (Westhoek *et al*., 2006). Given the large difference between the projections of the change in biodiversity for the area subject to soil sealing and the total land area, this leads to the conclusion that the policies and incentives of the reference scenario may have positive effects for the conservation of biodiversity in areas not subject to urbanization, but do not affect areas converted into built-up land.

Consequently, the conclusion may be justified that the protection of biodiversity in built-up areas will require larger attention from governments and the EU. If there is political will to conserve biodiversity in urban areas, likely ways to realize this include new concepts of interwoven, multifunctional land use in urban areas, economic sites and infrastructure, like green roofs and ‘red-green-blue transition zones’ (DSP, 2008; redgreenandblue,org).

4.5.3 Impacts of soil sealing on water retention

Effective soil water storage capacity (SWSC_eff) was used as an indicator of the land use service water retention in the assessment of impacts from soil sealing. Averaged over the EU, the effective soil water storage capacity decreased by 0.5% in the period 1990-2000, compared to 0.8% in the period 2000-2030. The largest changes were observed in The Netherlands (3.2% in 1990-2000, 3.6% in 2000-2030), followed by Portugal (resp. 1.6% and 1.3%) and Ireland (resp. 1.4% and 1.6%), in line with the large relative increase in built-up areas observed for these countries in both periods. Relatively small changes in SWSC_eff in both periods (<0.3%) were observed in the new member states Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovenia and Slowakia, due to either small relative increases in built-up area in these countries, or small intrinsic values of the effective soil water storage capacity of the soils.

The reduction in effective soil water storage capacity for the periods up till 2000 and 2030 imply that soil sealing potentially leads to an increased flood risk produced by increasing direct runoff and a resulting higher release of water out of the urban system. Increased flood risk due to soil sealing will require technical adaptations in urban areas, which may become extremely expensive. The reduction in the effective soil water storage capacity due to soil sealing may also result in reduced evapotranspiration, with negative consequences for the urban climate.

The impacts of soil sealing on water retention depend on the spatial distribution of sealed surfaces within developed areas. The compact urban growth projected in the Global Cooperation scenario will result in increased direct runoff and decreased evapotranspiration compared to more dispersed urban growth. The consequences are likely to be increased costs for urban flood management and decreased quality of life in urban areas due to negative effects on the urban climate.

Many studies report on the decline of water retention in soils due to soil sealing in general (e.g. Collin and Melloul, 2003; Emmerling and Udelhoven, 2002), but few report quantitative results on the reduction in soil water storage capacity. Most studies report on effects on other components of the water balance, which are more easily modeled or monitored, like direct surface runoff, evapotranspiration and groundwater recharge (e.g. Haasse, 2009; Hejazi and Markus, 2009; Wessolek, 2008; Xiao *et al*., 2007). In order to quantify impacts of soil sealing on water balance components that directly influence environmental quality in and around urban zones (direct runoff, evapotranspiration, groundwater recharge), a significant research effort in spatially distributed and physically based hydrological modeling would be required. This was beyond the scope of this study. However, the observations of the decrease in soil water storage capacity in this study could be used to estimate the water storage potential of urban soils for the redevelopment of urban drainage systems to facilitate the uncoupling of rainwater discharge systems from sewerage systems. This is a recent development in urban planning to mitigate the effects of soil sealing on the land use service water retention (e.g. STOWA/RIONED, 2009).

4.5.4 Impacts of soil sealing on soil organic matter

Impacts of soil sealing on soil organic matter were assessed using soil organic carbon as an indicator. Soil organic carbon content of urban soils is highly variable and depends on previous land use, current land use and soil type. Due to the high variability of SOC and lack of sufficient studies on impacts of soil sealing it is difficult to make generalizations. However, based on the IPCC guidelines we assumed a general decrease in SOC stock of 10% compared to the previous land use. Soil sealing in the period 1990-2000 resulted in a loss of 4.6 Mton C in the 23 EU countries, which is an annual CO2 emission of 1.7 Mton. The highest losses occurred in Northwest Europe, i.e. The Netherlands and Germany. For the period 2000-2030 the projected SOC losses due to soil sealing are almost a factor three lower, i.e. an annual emission of 0.7 Mton CO2. These lower losses can be explained by the scenario assumptions, since spatial urban planning is restricted in the B1 scenario, which leads to more compact urban growth. Also the distribution of SOC losses is different, with highest losses now being projected for United Kingdom and France, whereas Germany and The Netherlands had the highest losses in the period 1990-2000.

4.5.5 Overall conclusions

Soil sealing is threatening Europe's environmental, social and economic balance by consuming natural resources according to numerous (non-)scientific and policy publications. The environmental impacts are perceived to reach far beyond the use of land for construction and required infrastructure (e.g. EEA, 2006). Yet, few studies report quantitative impacts of soil sealing on land services. This study may help to fill this lack of information by providing quantitative impacts on the land services food production, biodiversity, water retention and soil organic matter.

Soil sealing resulted in a decreased performance of all land use services according to the impact assessment of the selected indicators in the periods 1990-2000 and 2000-2030. For all land use services, average impacts of soil sealing over the EU27 (or a subset of countries, depending on data availability) observed over the 1990-2000 10-year period were larger than the projected changes under the B1 reference scenario for 2000-2030 (Table 4.14). This is explained by the larger growth of the built-up area in this period (10,600 km^2/10 y, versus projected 3,430 km^2/10 y in 2000-2030). The ratio of impacts for both periods corresponds to the 3:1 ratio of growth of the built-up area for the periods 1990-2000 versus 2000-2030 for the land use service soil organic matter. For food production and water retention, proportions are smaller (Table 4.14). This is partly explained by the different set of countries considered in the impact analyses on the land use services, and partly indicates that reductions in suitable land for agriculture and effective soil water storage capacity were relatively more important than the loss of soil organic carbon in the areas converted into built-up land between 2000 and 2030. According to the reference scenario of compact urban growth, these areas will be close to existing urban centers.

In the period 1990-2000, impacts of soil sealing on land use services were largest in western European countries (The Netherlands, Portugal, Belgium, Germany and France) (Table 4.15). These relate to large growth rates of built-up area in The Netherlands and Portugal, and to the large size of Germany, France and Spain with regard to the loss of total soil organic carbon stock. The smallest impacts of soil sealing were observed in Central and Eastern Europe (Latvia, Slovenia, Lithuania, Bulgaria). They are explained by the small growth of the urban area compared to the artificial land in 1990.

Table 4.14. Average or total impacts[50] of soil sealing on performance indicators of land use services in NUTS0 units in the EU27 in the periods 1990-2000 and 2000-2030.

Period	NUTS0 unit	Time basis	Loss of land suitable for food production		Change in biodiversity	Loss of SWSC		Loss of SOC stock	
			arable cropping (%)	permanent grassland (%)	(% point change of MSA index)	% (of total storage cap in NUTS unit)	mm per km^2 of NUTS unit	% of total stock	kton C/y
1990-2000	EU-27	10 y	0.43	0.46		0.55	0.37	0.025	455.1
2000-2030	EU-27	30 y	0.49	0.53	-20.9	0.75	0.33	0.023	193.0
2000-2030	EU-27	10 y	0.16	0.18		0.25	0.11	0.008	

50 Loss of SOC stock in kton C/y

Table 4.15. Synopsis of impacts of soil sealing on performance indicators of land use services in NUTS0 units in the EU27 in the period 1990-2000. EU27: average value for EU27 or subset of countries, or total value (loss of SOC stock in kton C/y).

NUTS 0 unit	Loss of land suitable for food production		Loss of effective soil water storage capacity (mm/100 cm topsoil)		Loss of SOC stock	
	arable cropping (%)	permanent grassland (%)	% (of total storage capacity in NUTS unit)	mm per km^2 of NUTS unit	% of total stock	kton C/y
AT	0.18	0.22	0.24	0.17	0.013	7.7
BE	0.73	0.73	0.87	0.87	0.068	16.6
BG	0.03	0.04	0.02	0.02	0.004	1.6
CY						
CZ	0.35	0.35	0.40	0.18	0.018	6.7
DE	0.82	0.85	1.02	0.72	0.049	113.4
DK	0.40	0.40	0.44	0.40	0.026	6.8
EE	0.02	0.05	0.09	0.05	0.007	2.7
ES	0.32	0.42	0.52	0.34	0.026	50.9
FI					0.022	
FR	0.25	0.26	0.33	0.28		54.0
GR	0.17	0.19	0.27	0.20	0.017	7.0
HU	0.11	0.12	0.19	0.12	0.013	4.6
IE	1.11	1.15	1.39	0.53	0.039	25.5
IT	0.29	0.29	0.31	0.25	0.019	21.0
LT	0.02	0.02	0.02	0.03	0.003	1.4
LU	0.61	0.64	0.54	0.47	0.058	1.3
LV	0.00	0.00	0.00	0.00	0.001	0.8
MT						
NL	2.57	2.87	3.16	2.92	0.233	61.0
PL	0.19	0.19	0.31	0.09	0.007	11.7
PT	1.22	1.26	1.56	0.64	0.075	28.3
RO	0.05	0.05	0.05	0.03	0.005	5.0
SE						
SI	0.03	0.04	0.04	0.03	0.002	0.4
SK	0.17	0.18	0.19	0.15	0.017	3.7
UK	0.32	0.33	0.62	0.14	0.012	22.9
EU-27	**0.43**	**0.46**	**0.55**	**0.37**	**0.025**	**455.1**

Table 4.16. Synopsis of impacts of soil sealing on performance indicators of land use services in NUTS0 units in the EU27 in the period 2000-2030. EU27: average value for EU27 or subset of countries, or total value (loss of SOC stock in kton C/y).

NUTS 0 unit	Loss of land suitable for food production[51]		Change in biodiversity[51]	Loss of effective soil water storage capacity (mm/100 cm topsoil)[51]			
	arable cropping (%)	permanent grassland (%)	(% point change of MSA index)	% (of total storage cap in NUTS unit)	mm per km² of NUTS unit	% of total stock	kton C/y
AT	0.22	0.28	-20.3	0.30	0.12	0.010	2.1
BE	0.87	0.88	-13.0	1.19	1.24	0.090	7.3
BG	0.05	0.07	-28.6	0.09	0.06	0.006	0.8
CY			-22.8			0.169	1.7
CZ	0.28	0.28	-19.7	0.32	0.12	0.013	1.6
DE	0.79	0.85	-12.5	1.16	0.16	0.016	12.6
DK	0.87	0.88	-14.9	0.94	0.63	0.059	5.1
EE	0.01	0.02	-34.8	0.05	0.05	0.005	0.6
ES	0.20	0.27	-19.8	0.33	0.12	0.014	9.0
FI	0.06	0.06	-22.1			0.003	3.5
FR	0.45	0.47	-17.2	0.58	0.43	0.040	32.8
GR	0.17	0.19	-27.7	0.30	0.17	0.023	3.2
HU	0.18	0.18	-27.6	0.57	0.11	0.014	1.6
IE	1.24	1.38	-7.0	1.62	0.73	0.070	15.2
IT	0.23	0.24	-17.2	0.25	0.11	0.013	4.8
LT	0.06	0.06	-26.3	0.07	0.06	0.006	1.0
LU	0.05	0.07	-7.5	0.10	0.09	0.007	0.1
LV	0.00	0.00	-34.1	0.01	0.00	0.001	0.2
MT			-25.0			0.983	0.3
NL	2.98	3.19	-15.3	3.60	1.93	0.171	14.9
PL	0.43	0.43	-23.8	0.73	0.17	0.025	14.3
PT	1.00	1.03	-18.9	1.30	0.35	0.044	5.5
RO	0.10	0.10	-16.0	0.12	0.07	0.009	3.1
SE	0.15	0.17	-20.9			0.006	6.7
SI	0.14	0.32	-24.1	0.34	0.11	0.011	0.6
SK	0.21	0.25	-23.8	0.26	0.25	0.023	1.6
UK	1.48	1.54	-23.2	3.02	0.55	0.070	42.9
EU-27	0.49	0.53	-20.9	0.75	0.33	0.023	193.0

For the period 2000-2030, the largest impacts on the loss of land for food production and the loss of effective soil water storage capacity were observed in The Netherlands and in the UK (Table 4.16). This relates to the relatively high projected growth rate of the built-up area, but also to the high percentage of suitable land for food production in the areas converted. High

[51] Values for conversions from non built-up to built-up area are reported; conversions from built-up area to built-up area are not included.

impacts of soil sealing on biodiversity were observed in Estonia and Latvia due to the large biodiversity in the areas converted to artificial land. For soil organic matter, relatively large impacts were observed in Malta and The Netherlands, relating to the large relative increases of the built-up area in these countries. Large impacts on the loss of total SOC stock were observed for France and Ireland. Estonia and Latvia were the countries with the smallest impacts on land use services, except for biodiversity.

In order to assess impacts of soil sealing in an integrated sense for multiple land use services, weighting of the importance of each land use service by stakeholder groups and policy makers would be required among sectors, regions and development pathways (Dilly and Hüttl, 2009). This could be based on a vulnerability assessment of the land use services using for example the ATEAM methodology for global environmental change in Europe (Metzger and Schröter, 2006), using the impact maps of the present study as input.

Europe is one of the continents with most land consumption on earth, with approximately 75% of its population living in urban areas in 2006. This figure is expected to increase to 80% by 2020 (Science for Environment Policy, 2006). This study showed that soil sealing still continues in the future, be it at a lower rate than in the past decade. Yet, this is a matter of great concern because it is having an important impact on the natural environment by influencing the performance of land services.

In the EU, there is a political ambition to enhance the supply of land services. This study showed that most land converted to artificial surfaces since 1990 takes resources from soil groups that are likely to include soils with a high importance for the land services food production, biodiversity and water retention. As land conversion, especially in the case of soil sealing, is often irreversible or only reversible at high cost and at long term, it is a key challenge to avoid unnecessary and large-scale conversion of land use systems (PBL and Stockholm Resilience Centre, 2009). However, most people live in built-up environments, and most economic development is taking place there, so the built-up environment is a given. The challenge is to exploit the land use services that the built-up environment may provide, for example to store water, energy and CO2, and to provide biomass flows. For this purpose, a trade-off analysis is required based on the performance of urban soils on the land services that we merit, and those that are yet undiscovered. Given the fact that the nature and potential of urban soils are insufficiently known and mapped (e.g. Lorenz and Lal, 2009), research on urban ecosystems and specifically urban soils is of vital importance to guide policy actions in view of long-term goals of the use of land in the EU.

5 ANALYSIS OF THE EFFECTS OF PROJECTIONS OF LAND USE CHANGE ON HABITAT FRAGMENTATION AND ITS SUBSEQUENT IMPACT ON THE PROVISION OF LAND SERVICES

Rob Bugter, Michiel van Eupen, Irene Bouwma and Arjan Griffioen, Alterra Wageningen UR

5.1 INTRODUCTION

This chapter provides an account of the quantitative components of Task 3 of the study specification, namely:

- *"assess the role of drivers that cause fragmentation, of current (EU) legislation favouring or hindering the setting up of biodiversity corridors";* and
- *"assess the likely impacts of (trends in) biodiversity corridors on the land services; to the extent it is feasible, this assessment should be quantitative".*

The other components of Task 3, relating to assessment of current instruments used by Member States to avoid or limit habitat fragmentation, and the success of measures to promote biodiversity corridors are combined in Chapter 6 as they are closely interlinked.

5.2 ASSESSMENT OF DRIVERS AND PROJECTIONS OF FUTURE FRAGMENTATION

5.2.1 General approach

DPSIR

The DPSIR method is used by the EU for reporting on environmental assessments and describes the complete Drivers, Pressures, State, Impact and Response chain of effects. In these tasks, we use the framework to describe the changes in fragmentation status for the habitat categories 'forest', 'semi-natural non-wet nature' and 'wet nature' between the present situation and the projected changes in land cover according to this study's Reference Scenario (described in Section 3.4 with respect to Task 1). The *drivers* of fragmentation change are in this case the socio-economic developments that are incorporated in the Task 1 scenarios and they are described in that section. The CLUE model translates these drivers into *pressures* causing land use change and produces maps with the *states* (i.e. the spatial configuration) of the habitats that are present and projected from the *modeled* Reference Scenario. The maps of present and predicted road networks and traffic densities represent the *states* of these important factors. *Impacts* can be assessed from the differences between the maps of the present situation and projections for 2030. Policy instruments establishing ecological networks and protecting corridors are representative *responses* to increasing fragmentation, but are in this study not directly linked to the changes between the present and the 2030 situation. They are not discussed in this section but in Chapters 6 and 9.

Incorporating road network and increasing traffic densities pressures

A known pressure on biodiversity resulting from socio-economic development is the effect of roads and traffic intensity (Trombulak and Frissell, 2000; Fahrig and Rytwinski 2009). This pressure was therefore also incorporated into the land-cover projections based assessment of fragmentation. This assessment was based on the road map produced by the TEN-STAC project (TEN-STAC, 2004), because this is the only one available that includes a 'present' (2000) state of the network of main roads and traffic densities as well as the changes predicted for 2025 (which we used for 2030). See Annex 3.1 for details. The number of new roads in the map is negligible, but as Figure 5.1 shows a pronounced increase in traffic density is generally projected across much of Europe.

Assessing fragmentation impacts

Figure 5.2 provides an overview of the land cover changes that are the main pressures resulting in fragmentation of habitats. To assess the impact of these land use changes combined with the traffic density changes on fragmentation, we modeled habitat connectivity for 'forest', 'wet nature' and 'semi-natural non-wet nature' (the three general habitat types we were able to identify with acceptable accuracy; for a detailed explanation see Annex 3.2) for four general species group profiles (or 'ecoprofiles'), respectively representing species with small and medium/large dispersal ranges that are sensitive or insensitive to the barrier effect of roads (see Annex 3.3 for a detailed explanation of the approach). The LARCH connectivity model (Groot Bruinderink *et al*, 2003) we used, identifies isolated habitat clusters based on the dispersal and barrier sensitivity characteristics defined in the species group profiles, so in fact predicts the number of functional habitat networks in Europe for each of the species groups (for a detailed explanation see Annex 3.2). Fragmentation impacts are then assessed from the projected changes between the present situation and 2030. Increasing fragmentation of a certain habitat type will firstly show as an increase in the number of isolated habitat clusters / networks (due to clusters splitting up) and will usually (not necessarily, but especially when fragmentation is due to roads) be accompanied by a decrease in the total amount of the habitat type. Fragmentation will also show through a decrease in the average population size that clusters can support.

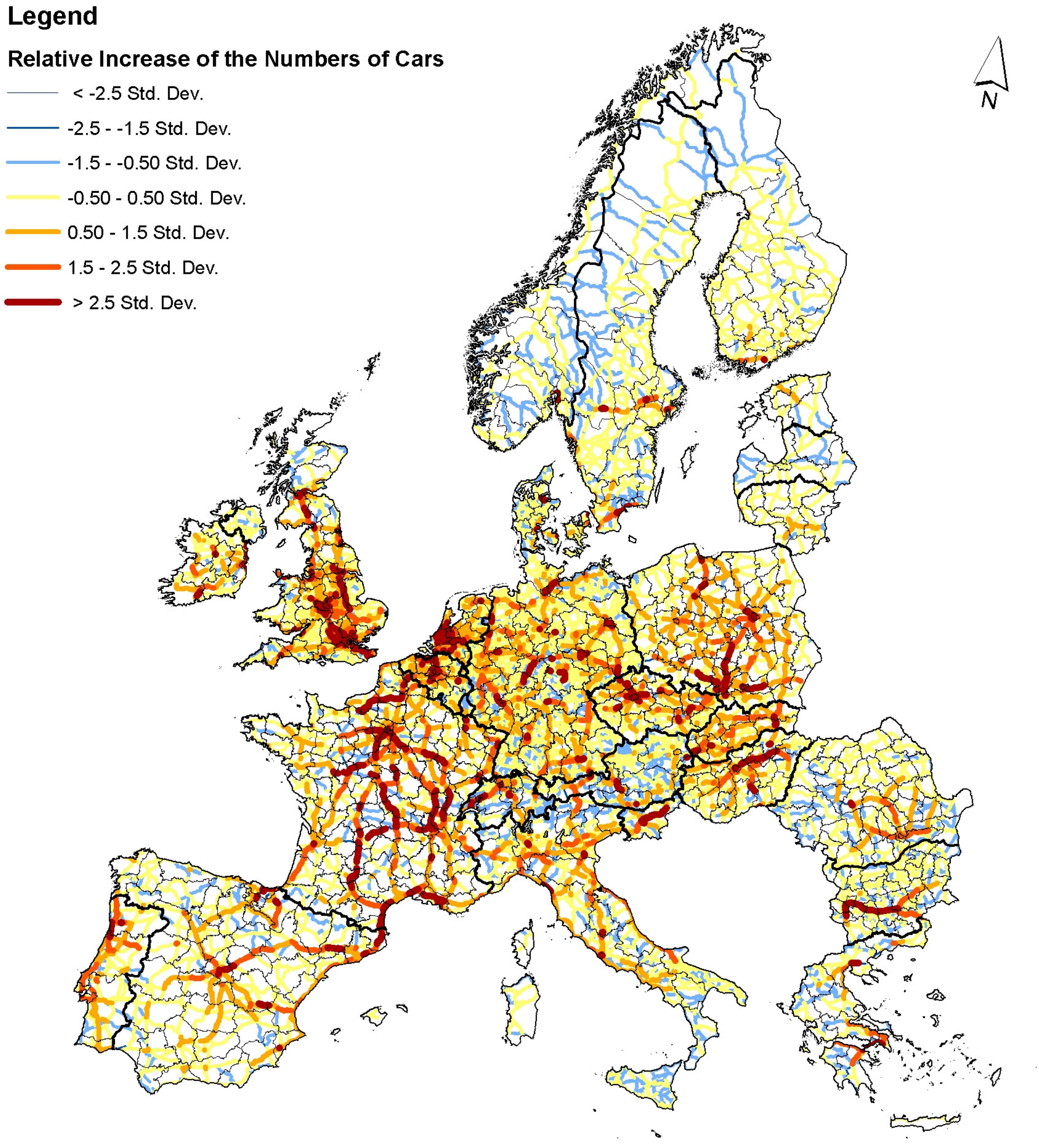


Figure 5.1. The relative increase in traffic density used in connectivity modelling depicted as deviation from the average increase. Source: TEN-STAC 2004.

5.2.2 Results

Overview

Table 5.1 quantifies the changes in total habitat area, number of isolated clusters and average supported population size that were discussed in the previous section. The table shows that there is a general predicted increase in the amounts of forest and semi-natural non-wet habitats of 11% and 6% respectively by 2030, while the total area of wet habitats is predicted to decrease by 17% by that year. The maps in Figures 5.3-5.7 show that the effects that these changes will have on fragmentation are not equally distributed over Europe but that there are severe local differences.

Table 5.1. Predicted changes from present to 2030 in total habitat area, number of isolated habitat clusters / networks and in the average supported population size per cluster / network for the whole assessed area, per species group and habitat category

TOTAL HABITAT AREA

Dispersal range	Change Forest (%)	Change Dry (%)	Change Wet (%)
Small and Large	11%	6%	-17%

NR OF ISOLATED HABITAT CLUSTERS / NETWORKS

	Dispersal range	Change Forest (%)	Change Dry (%)	Change Wet (%)
Terrestrial	Small	-8%	5%	
	Medium to large	3%	27%	
Flying	Small	-3%	0%	7%
	Medium to large	-7%	-10%	-6%

AVERAGE SUPPORTED POPULATION SIZE PER HABITAT CLUSTER / NETWORK

	Dispersal range	Change Forest (%)	Change Dry (%)	Change Wet (%)
Terrestrial	Small	3%	20%	
	Medium to large	7%	-36%	
Flying	Small	10%	9%	-52%
	Medium to large	11%	6%	-21%

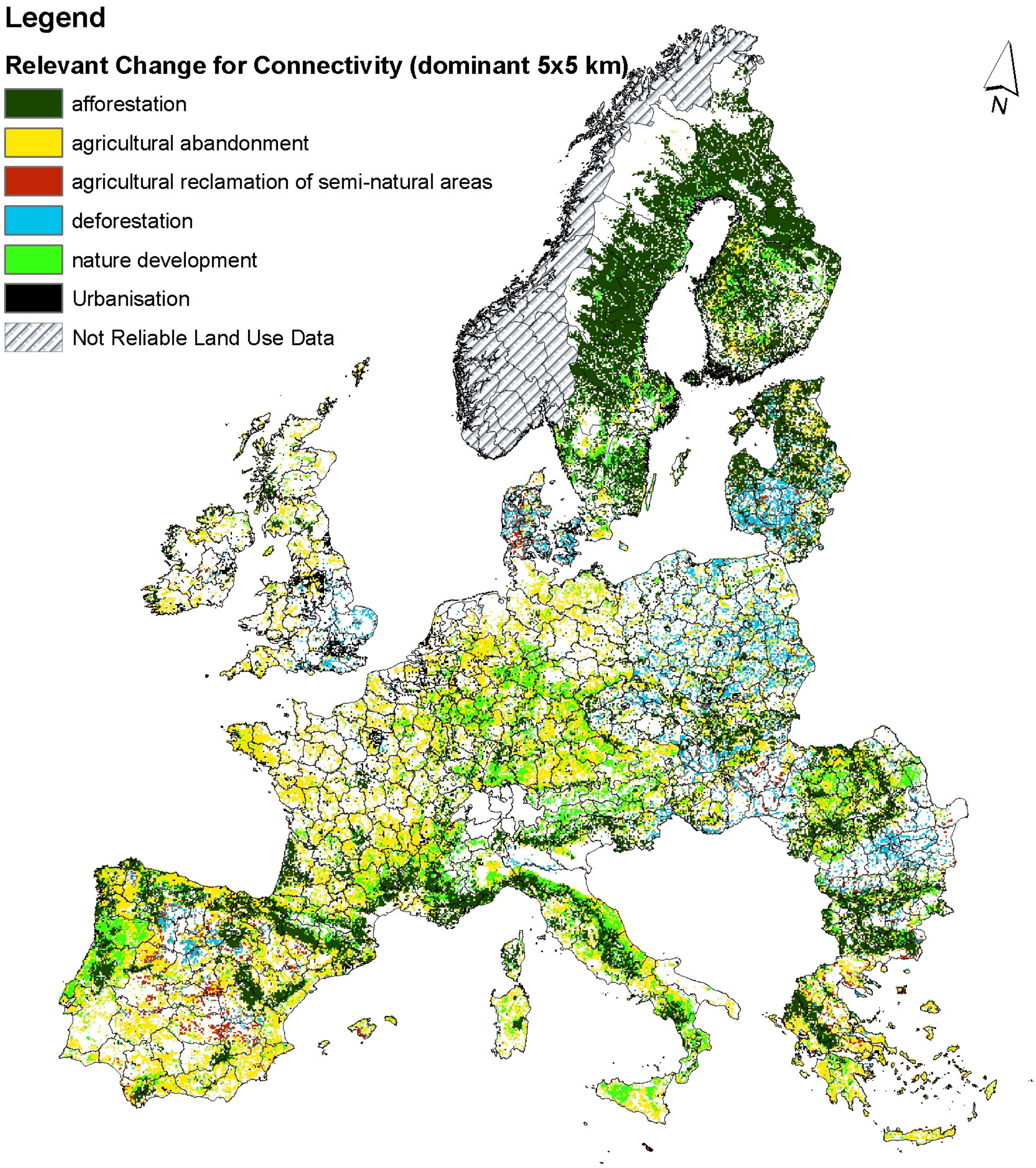


Figure 5.2. Overview of the land use changes incorporated in connectivity modelling. For visibility reasons changes are depicted as the dominant ones in 5x5km squares.

Forest habitats
Over the whole of Europe, an increase in forest area of 11% is predicted. Due to this increase fragmentation will generally decrease, which shows in the decreased number of isolated habitat clusters for all species groups, except for the medium to large terrestrial species. This is a logical outcome because due to their size, the habitat networks of large terrestrial species are relatively more often split up by increases in traffic density then the ones for smaller terrestrial species. Nevertheless, the increase in forest habitat amount is large enough to increase the average size of the population supported by habitat clusters even for this group. For small terrestrial species, the considerable decrease (-8%) in the number of isolated habitat clusters is little reflected in an increase in the average supported population size. This probably indicates a quite severe effect of roads splitting up the larger, higher capacity clusters which is only just compensated for by a large number of smaller ones being joined up by the creation of new habitat.

Figure 5.2 shows that the predicted changes in forest habitat consist of large scale afforestation in Sweden, Finland, Estonia and Latvia, a mix of mostly smaller scale afforestations across the rest of the EU and a number of local deforestations in North-Eastern England, Spain, Denmark, Lithuania/Latvia, Poland, the Czech and Slovak republics, the area around Bucharest in Romania and the Po delta. Figures 5.4 and 5.5, which show the changes in forest connectivity between the present situation and projections for 2030 for the four species groups, indicate widespread small improvements (blue dotting), especially for small terrestrial species from the afforestations, but relatively severe negative effects from the deforestations. This appears to be because all large-scale afforestations are expected to occur in areas with existing high forest density where connectivity is already good, whilst deforestations are generally predicted in mixed landscapes where they will have a large effect on connectivity.

Semi-natural non-wet habitats
For semi-natural non-wet habitats, the picture is somewhat different. There is a considerable predicted increase of 6% in habitat area, but as the number of habitat clusters for all but the medium to large flying species group shows, this is countered by an expected large impact from increased road traffic. As before, the road barrier effects are most pronounced for the medium to large terrestrial species group (see also Figure 5.5) where they cause a decrease of 36% in the average supported population size. As Figures 5.5 and 5.6 show, there is a pronounced increase of semi-natural non-wet habitat connectivity in Finland, Estonia and Latvia for mainly the small terrestrial as well as flying species while the rest of Europe shows in general small scale decrease effects for large terrestrial species and increase effects for small species (mainly Finland and the Baltic states) as well as large flying species. While connectivity tends to decrease at the edges of areas with a relative high amount of habitat, it tends to increase inside them, which is probably due to agricultural abandonment mainly occurring in less suitable areas. Especially in Lithuania and Spain, the decrease in connectivity for the barrier sensitive terrestrial species is pronounced (Figure 5.5). As Figure 5.5 shows, this effect is also linked to abandonment. Abandoned areas are considered to be marginal habitat in 2030. In Lithuania and Spain, ‘normal’ semi-natural non-wet habitats apparently decrease or get more fragmented while relatively large amounts of this ‘new’, low quality semi-natural non-wet habitat appears. Within the assumptions of our connectivity modeling, this new habitat apparently offers enough compensation for barrier insensitive, but not for barrier sensitive species.

Wet habitats

The amount of wet habitat is predicted to decrease by 17%. The effects of changes in wetland connectivity were only evaluated for non-barrier sensitive, i.e. flying species because the terrestrial species using wet habitats (e.g. Otter *Lutra lutra* and Beaver *Castor fiber*) use habitat elements for dispersal that are not represented in our base map. This means that for terrestrial species connectivity changes for wet habitat can not be modeled in a meaningful way.

As can be seen in Figure 5.7, there is a very mixed trend in expected developments across Europe with in general large negative changes in Spain, Greece, the south of France, Eastern and Northern Europe (in particular in Finland) and improvements in Italy, the rest of France, Germany and parts of Poland. The largest changes are predicted for Finland (Figure 5.2) where the total amount of wet habitat nevertheless remains high (gray areas in Figure 5.7). However, a large part of the predicted losses coincide with predicted afforestations (see Figure 5.2), and forest is in our methodology always assumed to be some form of non-wetland habitat. The decrease effects in Figure 5.7 are therefore likely to be inflated.

Improved connectivity amongst wetland habitats is mainly predicted in areas with little wet habitat where connectivity is easily increased, especially for large flying species (green areas in Figure 5.7). Most of these improvements are due to the creation of new nature in river or stream valleys (in western Europe the abandonment of potentially wet and therefore less suitable agricultural grounds in these areas gives the same effect). Since these locations are potentially wet but not likely to all develop into real wetlands, the connectivity improvements for wet nature are also likely to be inflated. Taking the discussed positive and negative uncertainties into account, the overall effect is likely to be rather negative and does not yet incorporate any climate change effects (climate change was not incorporated in our modeling due to the short prediction interval).

5.2.3 Discussion

This assessment of the general impacts of the changes in socio-economic drivers on fragmentation necessarily worked with generalized habitat types and species group profiles. As the assessments for the present situation and the BAU 2030 scenario are both based on the same materials and assumptions, inaccuracies will to a large extent cancel each other out. The result is that the magnitude of the fragmentation effects we found is difficult to value in absolute terms but that results are clear in relative terms. I.e. they indicate with reasonable reliability whether fragmentation developments are negative or positive, and where developments are relatively large or small, given the assumptions contained in the base maps.

The effects of changes in road and traffic densities could also only be incorporated at a very general level, i.e. as an estimated 'average' barrier effect for terrestrial species groups that was very crudely adjusted for higher terrain (altitude is correlated to relief, which creates more passing options due to underpasses for streams, viaducts etc.). Road effects are therefore also only accurate in a qualitative sense.

For the terrestrial species groups, where two basically qualitative effects are added, the results therefore need to be especially carefully interpreted, especially when land use change and barrier effects are working in opposite directions. However, the effects of both pressures can be assumed to be in about the right order of magnitude, and therefore large resulting effects are certainly meaningful.

The effect of increasing traffic is most visible in the results of the medium to large terrestrial species group, due to the fact that the TEN-STAC roadmap only contains the larger roads which tend to affect larger habitat clusters more than small ones. This is therefore likely to be a methodological artefact, as small terrestrial species will also suffer from increased traffic densities on minor roads and, as their slower traversing speed is an important risk increasing factor (van Langevelde and Jaarsma, 2004), are in reality likely to be at least as strongly affected as larger ones.

Looking at the general picture of the impacts of the land use change and traffic density pressures on fragmentation, a number of patterns emerge:

- Afforestation causes the amount of forest habitat to increase, but occurs for a large part in already forested areas where the effects on connectivity are limited. Within those areas, the afforestation of the wetland parts increases as well, it is uncertain wether or not this causes wetland loss.
- Deforestation mainly occurs in a limited number of clearly distinguishable, mixed landscape areas, where the negative impact on forest connectivity is relatively large.
- The habitat area of semi-natural non-wet habitat increases, but general trends point at a net loss of higher quality habitats and a gain in presently low quality 'new nature' developing on abandoned agricultural grounds.
- Due to the inaccuracy of the base maps concerning wet habitats, impacts on connectivity are hard to predict for this category. There seem to be potentially negative as well as potentially positive developments, however, which makes this category especially sensitive to successful conservation planning, and more so since it will probably be the most affected by climate change impacts.
- The effect of increasing traffic is very generally visible for the medium to large terrestrial species and is in reality likely to be at least as strong for small terrestrial ones. Although it is impossible to quantify accurately in an assessment as general as the present, it is a pressure that is consistently increasing everywhere and therefore has the most certain overall negative effect on connectivity.

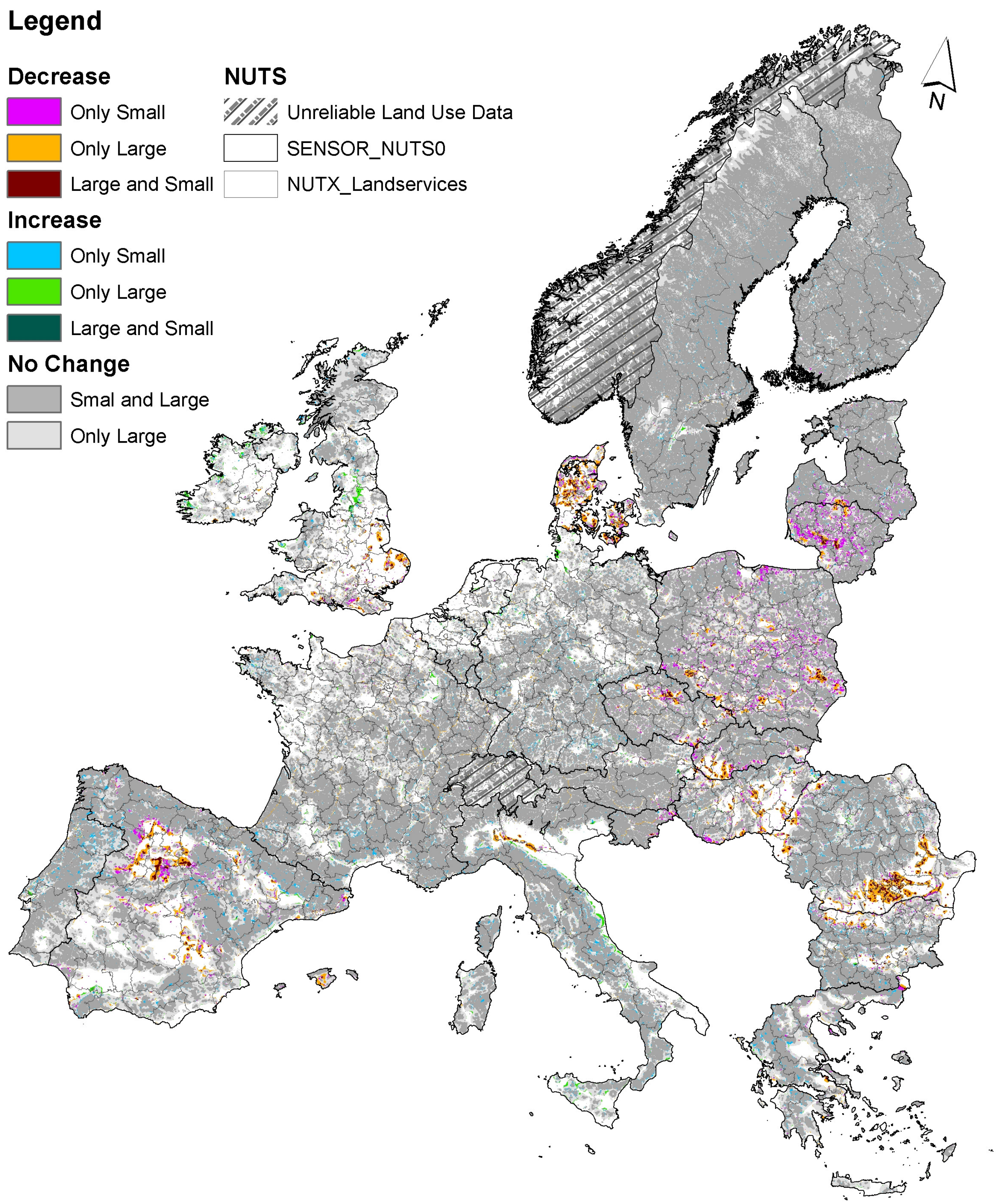


Figure 5.3. Map of relative changes in modelled forest connectivity for small and large barrier sensitive (terrestrial) species. Effects are represented per NUTSx region

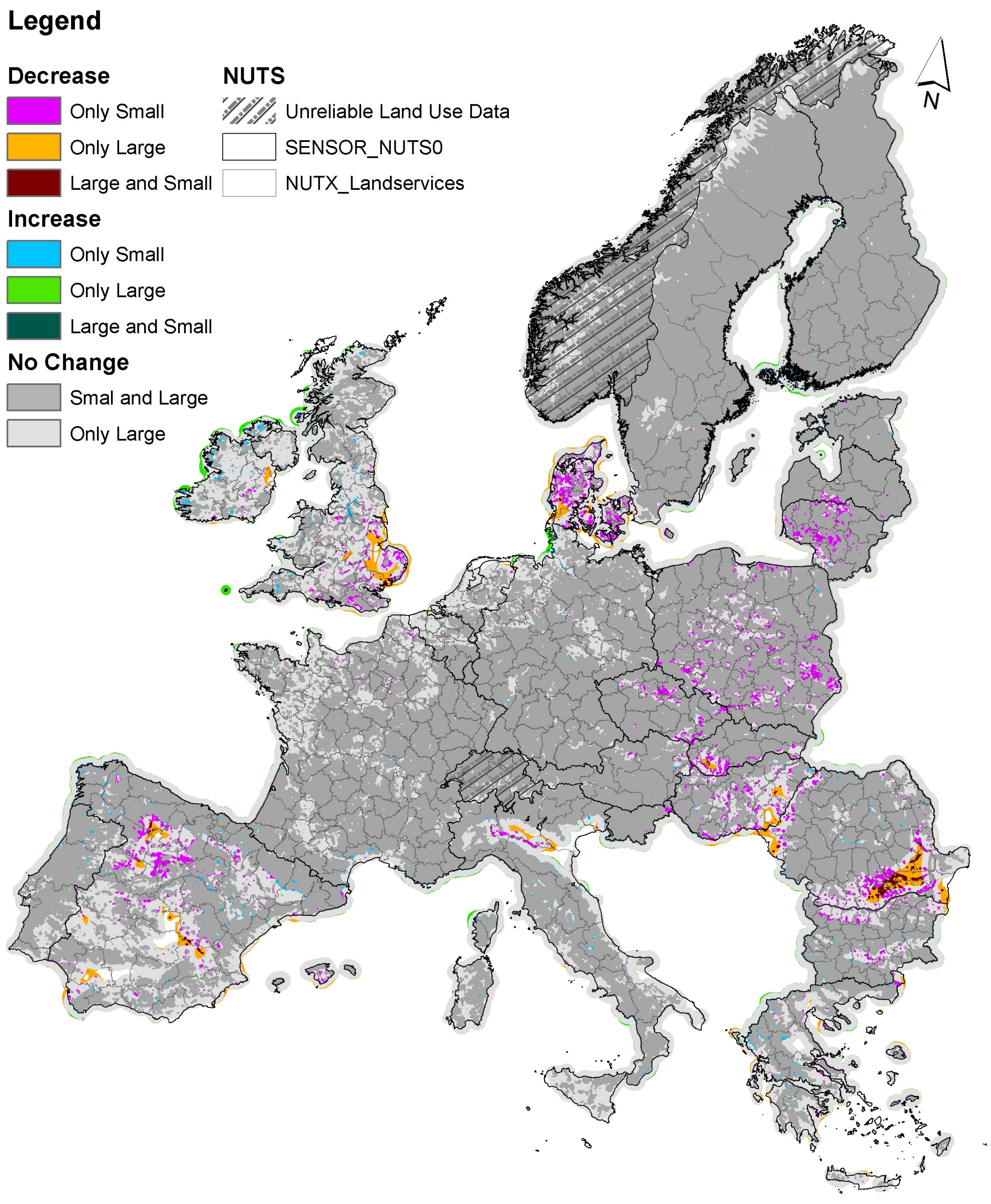


Figure 5.4. Map of relative changes in modelled forest connectivity for small and large barrier insensitive (flying) species. Effects are represented per NUTSx region

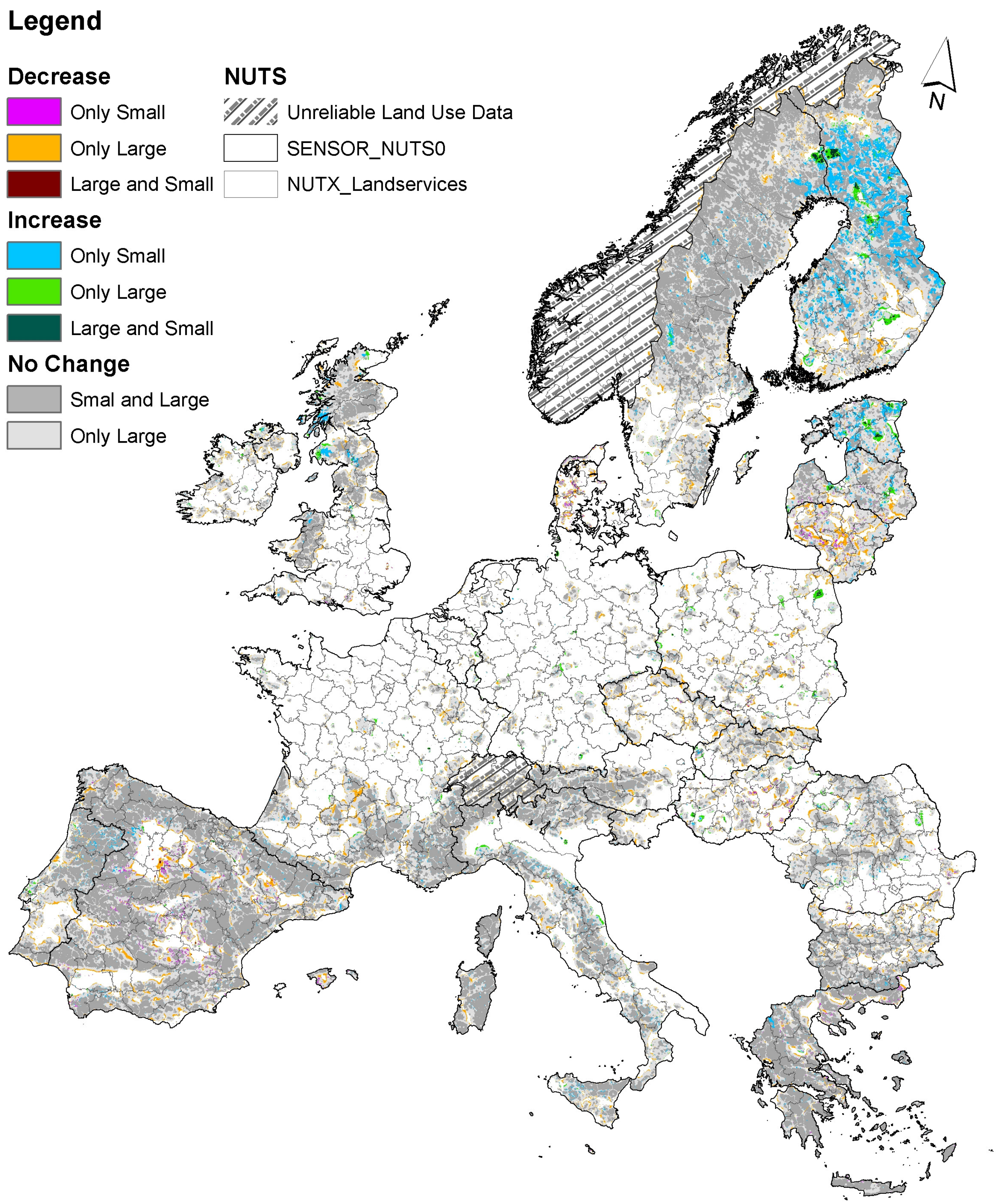


Figure 5.5. Map of relative changes in modelled semi-natural non-wet habitat connectivity for small and large barrier sensitive (terrestrial) species. Effects are represented per NUTSx region

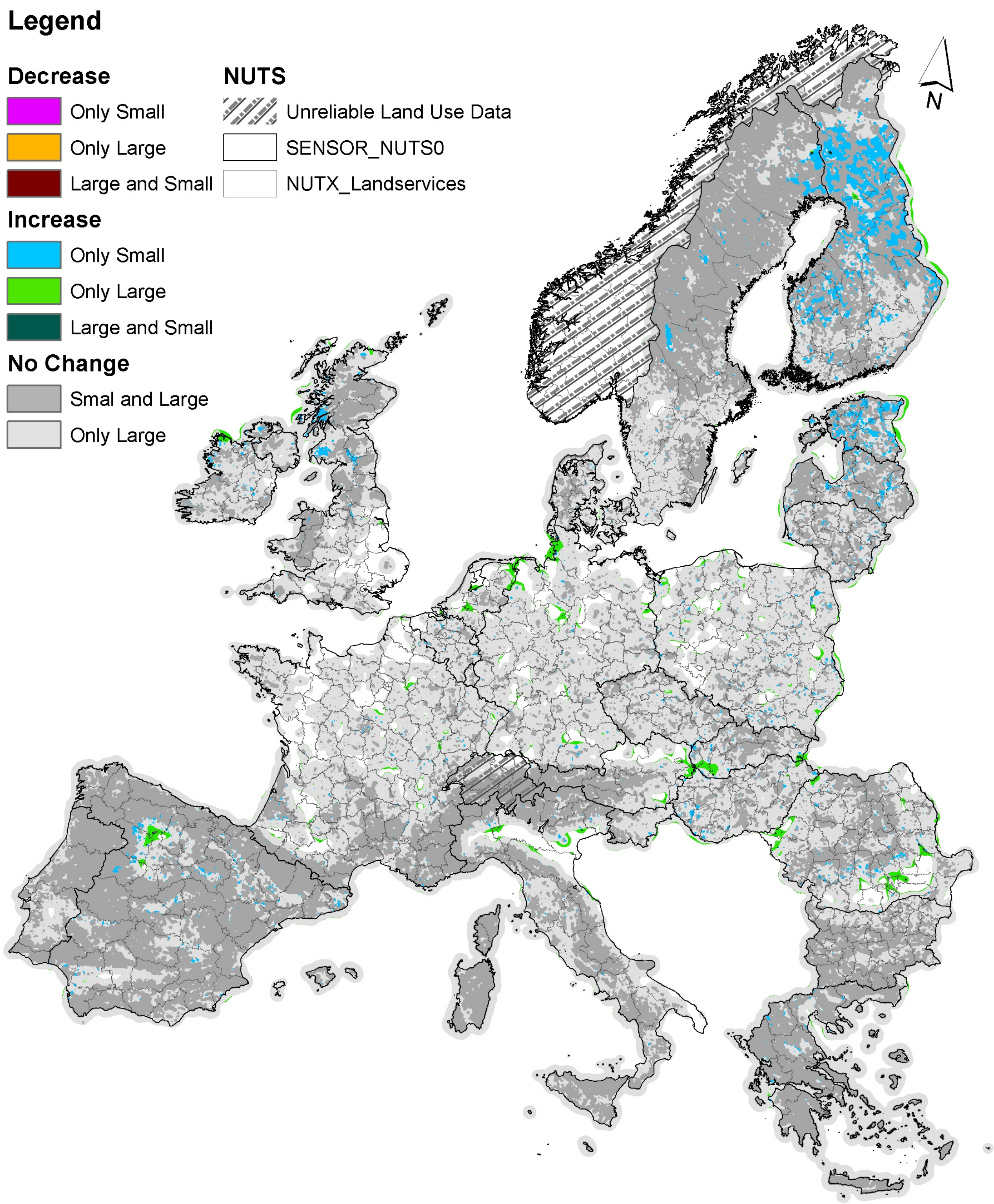


Figure 5.6. Map of relative changes in modelled semi-natural non-wet habitat connectivity for small and large barrier insensitive (flying) species. Effects are represented per NUTSx region

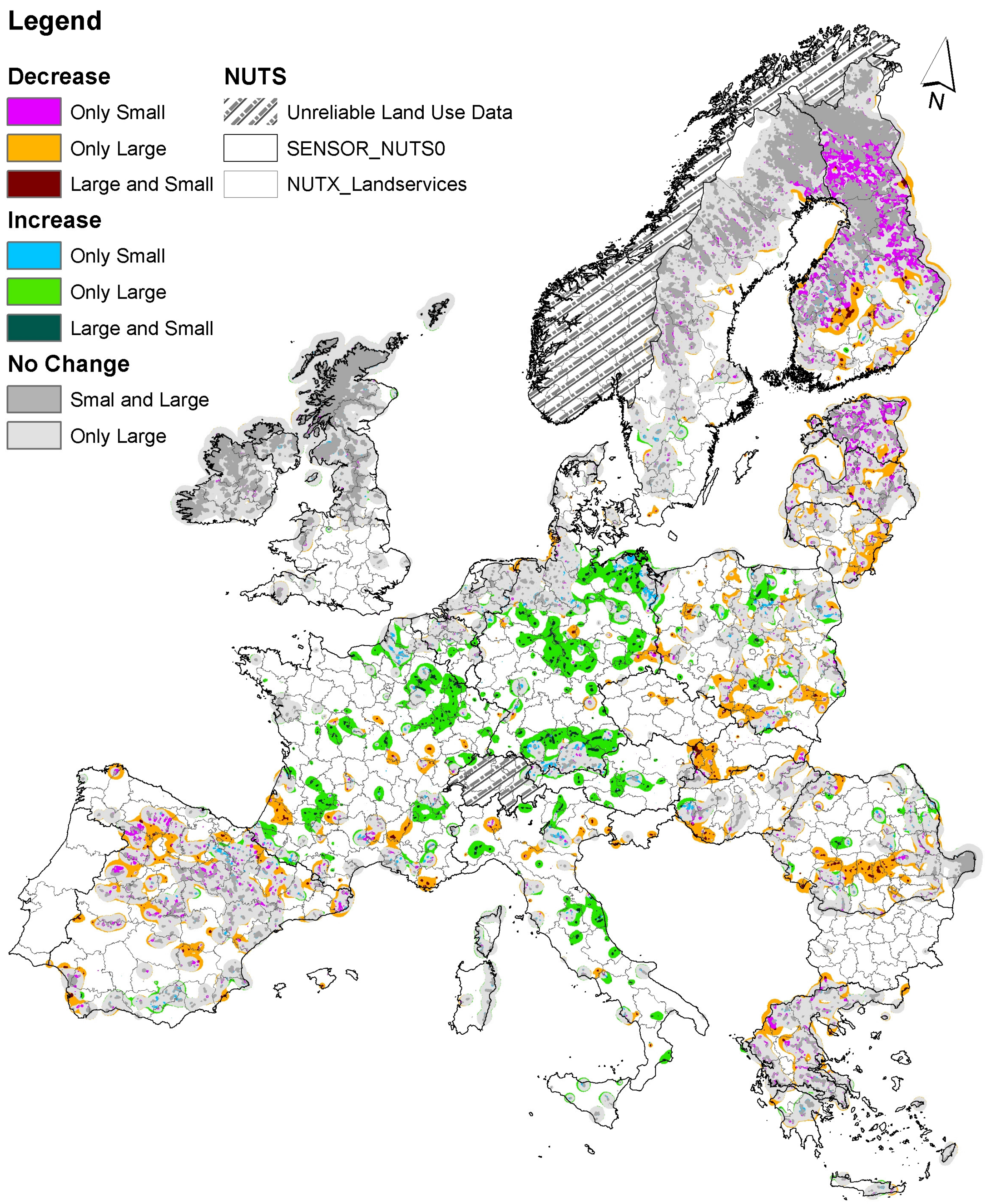


Figure 5.7. Map of relative changes in modelled wet habitat connectivity for small and large barrier insensitive (flying) species. Effects are represented per NUTSx region

5.3 ASSESSMENT OF THE LIKELY IMPACT OF FRAGMENTATION ON CORRIDORS AND LAND SERVICES

5.3.1 General approach

With respect to this task, it is inappropriate to define corridors in a narrow physical sense as '*linear landscape elements that connect two or more patches of natural habitat and function to facilitate movement*' (Soulé and Gilpin, 1991), simply because the resolution of the available spatial land use change information and the generality of the available ecological network and corridor plans do not allow a proper identification of actual physical corridors. Instead a functional definition of corridors is adopted, where corridors are '*avenues along which wide ranging animals can travel, plants can propagate, genetic interchange can occur, populations can move in response to environmental changes and natural disasters, and threatened species can be replenished from other areas*' (as defined by the Ninth U.S. Circuit Court of Appeals, Walker and Craighead, 1997; see also Hilty *et al,* 2006). This definition allows an assessment of what corridors do, without making assumptions on their number or shape. This functional view incorporates naturally existing as well as constructed corridors and is consistent with the general ecological network concept, in which networks are usually seen as a collection of habitat patches interconnected by further unspecified 'ecological corridors' (e.g Jongman and Pungetti, 2004). In networked landscapes, which are the most vulnerable to (further) fragmentation, connectivity will mainly be provided by these 'corridors' and fragmentation effects on their functioning can conveniently be assessed through the impact on general connectivity. Within this task, we therefore interpret 'the likely impact of fragmentation on *corridors*' as 'the likely impact of fragmentation on *corridor function*'.

In the previous task, the maps delivered by Task 1 (Chapter 3) are used as the basic source of land use change and habitat information. The TEN-STAC map (TEN-STAC, 2004, see also Figure 5.1) is used as the source for changes in traffic densities. For the overlays with NUTS areas we used the NUTSx map that was used for EU15 in the IRENA project (EEA, 2006) which we extended for EU27. This map generally uses NUTS3 units, but for the Netherlands, Belgium, Germany, Austria, Greece, Italy, Luxemburg, Portugal and the UK NUTS2 units. For these countries NUTS3 units are relatively small and do not correspond to the regional governance levels relevant to corridor policies anymore.

The impact of fragmentation on other land services than biodiversity is assumed to act through changes in the surface area of land use types (e.g. from agricultural to woodland) and is therefore taken into account in other components of this study (see Section 9.1 for overview).

No useable GIS maps for existing natural corridors or corridor plans for the whole of Europe were available. The map compiled by ECNC (Bonnin, 2007) provides a complete picture of existing ecological network plans in one map but is not suitable as a base for analysis (for explanation see Annex 3.5). For this task, we therefore analyzed changes in corridor functioning per habitat category and NUTSx unit, to determine where these changes would be most important to connectivity conservation and then to confront these results with the existence of 'connectivity preserving', i.e. ecological network and corridor plans. In this way we can determine if policies and plans to countermand the predicted risks to corridor functioning are likely to be in place already.

5.3.2 Methodology

The assessment involved the following procedures:

1. Development of maps of the (changes in) corridor functioning per habitat category.
2. Establishment of the importance of each NUTSx unit for corridor functioning.
3. Combination of the change and importance maps to produce a corridor function impact map.
4. Development of an overview map of existing corridor plans translated to NUTSx regions.
5. Confronting the maps made in the previous three activities.

An overview of interrelationships amongst the procedures is presented in Figure 5.8 below.

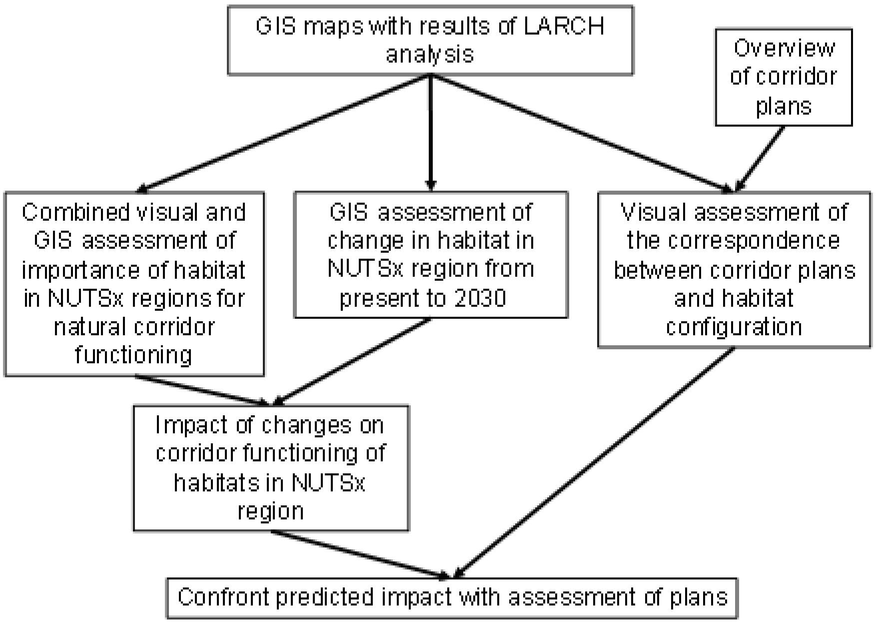


Figure 5.8. Representation of the assessment process

A short overview of each of the activities is presented below, with detailed descriptions of procedures and methods described in Annexes 3.1 – 3.5.

1. Development of maps of (changes in) corridor functioning

Natural habitats are not evenly distributed across Europe, but form patterns of larger and smaller patches at different spatial scales. How much a particular habitat type is considered to be fragmented (in a particular area) depends on the size of its patches as well as extent to which they are isolated from each other. The 'isolation' of patches is species specific and depends on the distance (within or outside dispersal range) as well as on the characteristics of the area (amount of resistance for the species, including possible barriers) in between them. The fragmentation of the same habitat configuration will therefore vary considerably for e.g. small ground dwelling or large flying organisms. To capture the impact of fragmentation on corridor functioning, we must therefore include impacts for species with different mobility characteristics. We identified changes in corridor functioning through the following steps:

1. Extract GIS maps of relevant habitat categories from the Task 1 map.
2. Create connectivity maps for each habitat type for a number of generalised species groups.

3. Produce maps summarizing changes in corridor functioning per NUTSx unit.

Habitat categories
Taking the limitations of the Task 1 map and the available extra GIS maps into consideration, we could identify three general habitat types with acceptable accuracy:

- <u>Forest</u>, which is taken straight from the Task 1 maps for the present as well as the business as usual (BAU) 2030 scenario. For 2030, we added the 'new nature' category (abandoned arable land and pastures) as marginal forest habitat.
- <u>Wet nature</u>. In the Task 1 map, 'inland wetlands' is the only category representing wet nature areas. Overlays were made with the CORINE map and with the potential vegetation of Europe to extend the wet nature category for the present situation and to identify potential new wet nature in the 2030 map.
- <u>Semi-natural non-wet nature</u>. This category consists of the combination of the 'semi natural vegetation' and 'heather and moorlands' classes from the task 1 map minus the areas indentified as wet in the previous step. 'New nature' is added as marginal habitat for 2030.

Habitat category selection is described in detail in Annex 5.2.

Production of connectivity maps with the LARCH model
Because the three habitat categories that could be indentified from the Task 1 map are too general to allow meaningful modeling with the characteristics of 'real' species, we used generalised species group characteristics to analyze connectivity in a standardised and uniform way. A detailed explanation of this approach can be found in Annex 3.3. For every region, results can be seen as representing connectivity for the local species with the same mobility characteristics. This approach has already been used by Alterra in previous projects (e.g.. the SENSOR FP7 project (www.sensor-ip.eu)). An overview of the modeling setup is given in Table 5.2.

Species groups			Habitattype		
Barriers		Dispersal range	Forest	Dry	Wet
Terrestrial	Small	5km	P,F	P,F	-
	Medium to large	25km	P,F	P,F	-
Flying	Small	5km	P,F	P,F	P,F
	Medium	25km	P,F	P,F	P,F

P = connectivity modelled for the present situation
F = connectivity modelled for the future (2030) situation

Table 5.2. Overview of the setup of the connectivity modelling

We used two mobility categories, representing species groups with dispersal ranges of 5 km and 25 km. Each mobility class has a barrier insensitive (corresponding to flying species) and a barrier sensitive (corresponding to terrestrial species) variety. For wet nature we omitted the barrier sensitive category because very few if any real species would realistically be represented by that profile (mid-range wetlands species, such as Beaver *Castor fiber* or Otter *Lutra lutra*, use habitat elements for their dispersal that are not distinguishable in the presently available map).

A full overview and explanation of the species group characteristics and the settings used for modeling is provided in Annex 3.3.

Habitat connectivity for each species group / habitat category combination was analysed with the LARCH model. With this model, habitat connectivity for species with specific characteristics (type of habitat used, dispersal range, sensitivity to barriers) can be modeled. The description of the model given in Groot Bruinderink *et al*, (2003) for Red Deer *Cervus elaphus* is provided in Annex 3.3. In summary, the LARCH model calculates for every point on a map the amount of habitat that is available within the dispersal range of the species or species group in question, taking resistance and barrier effects into account. Locations within areas with large habitat amounts thus get a high score, while locations with no habitat at all within dispersal range score zero. The model can be used with the characteristics of real species, like for the Red Deer in Groot Bruinderink *et al,* (2003), but as in our case also with more generalised species group characteristics called 'ecoprofiles'. For specific species like the Red Deer it is possible to determine a relatively accurate threshold value for this score, meaning that locations with a score below that threshold are unusable for the species. For 'ecoprofiles', an 'average' value for the species it represents is chosen.

The model produces connectivity contour map like the one in Figure 5.9 from Groot Bruinderink *et al,* (2003) where the red shades indicate good connectivity (large habitat amount within reach), the pink shades lower connectivity (lesser habitat amount within reach) and the white no connectivity (not enough habitat within reach to be usable). In this way, areas with high importance for corridor functioning can be indentified, like the one for Red Deer in Northern Germany that is extremely important for the connection between Dutch and German populations.

Basically the same methodology was also used in the SENSOR FP7 project (www.sensor-ip.eu).

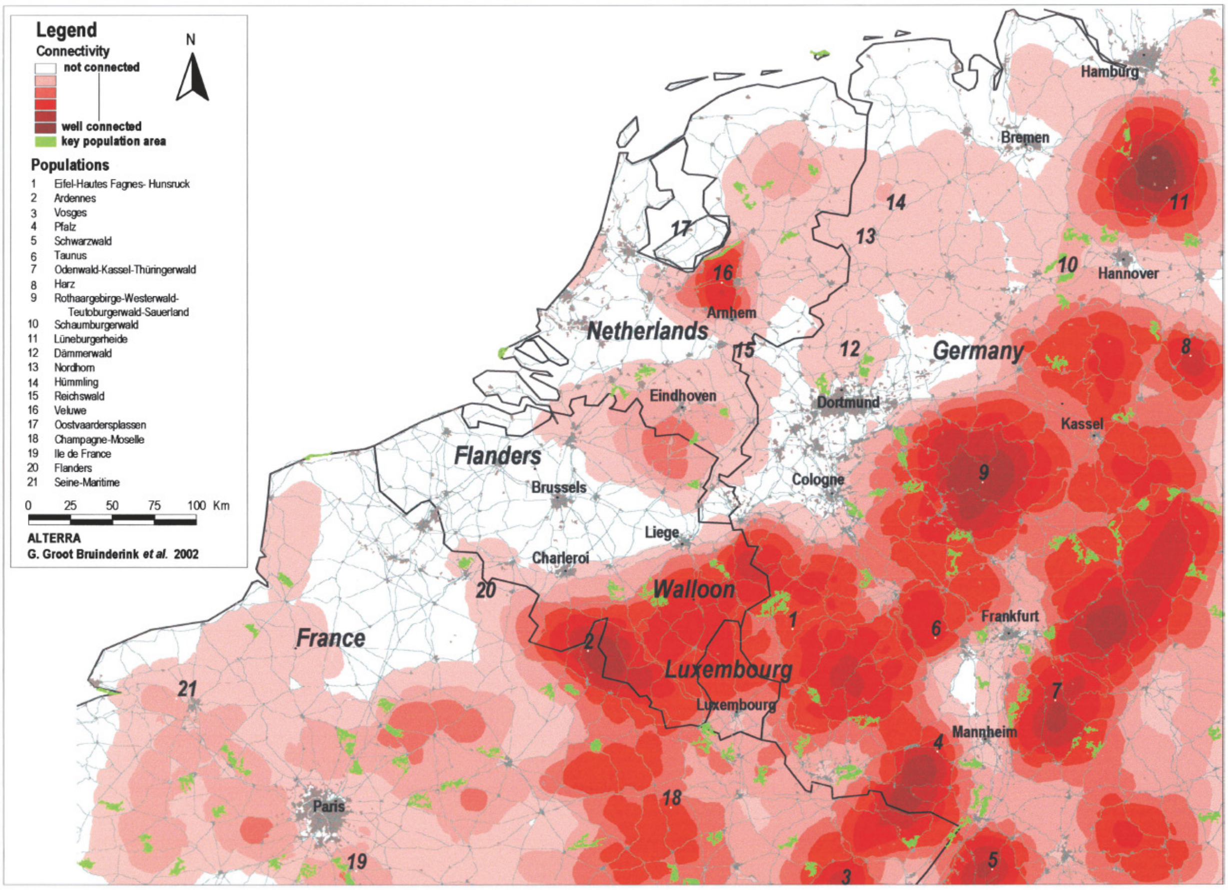


Figure 5.9. Results of the LARCH model for Red Deer on the level of connectivity. Source: Groot Bruinderink *et al.,* (2003)

We used the TEN-STAC map of major roads (TEN-STAC, 2004) to incorporate road barrier effects. This map contains traffic densities for 2000 and estimates for 2025. A detailed explanation of the way the barrier effect was incorporated is given in Annex 3.1.

The results of the LARCH runs for the present situation and the future (2030) situation were subtracted from each other to produce the maps of connectivity changes for the previous Task 3.1 described in Section 5.2 above (Figures 5.3-5.7), and general change patterns are discussed there.

For the present task, we summarised corridor functioning per NUTSx unit by overlaying the connectivity change maps with the NUTSx map. Connectivity change results for all four species groups profiles were simply combined and averaged per NUTS region. The resulting map for forest is represented in Figure 5.10, the maps for wet and semi-natural non-wet habitats are included in Annex 3.4.

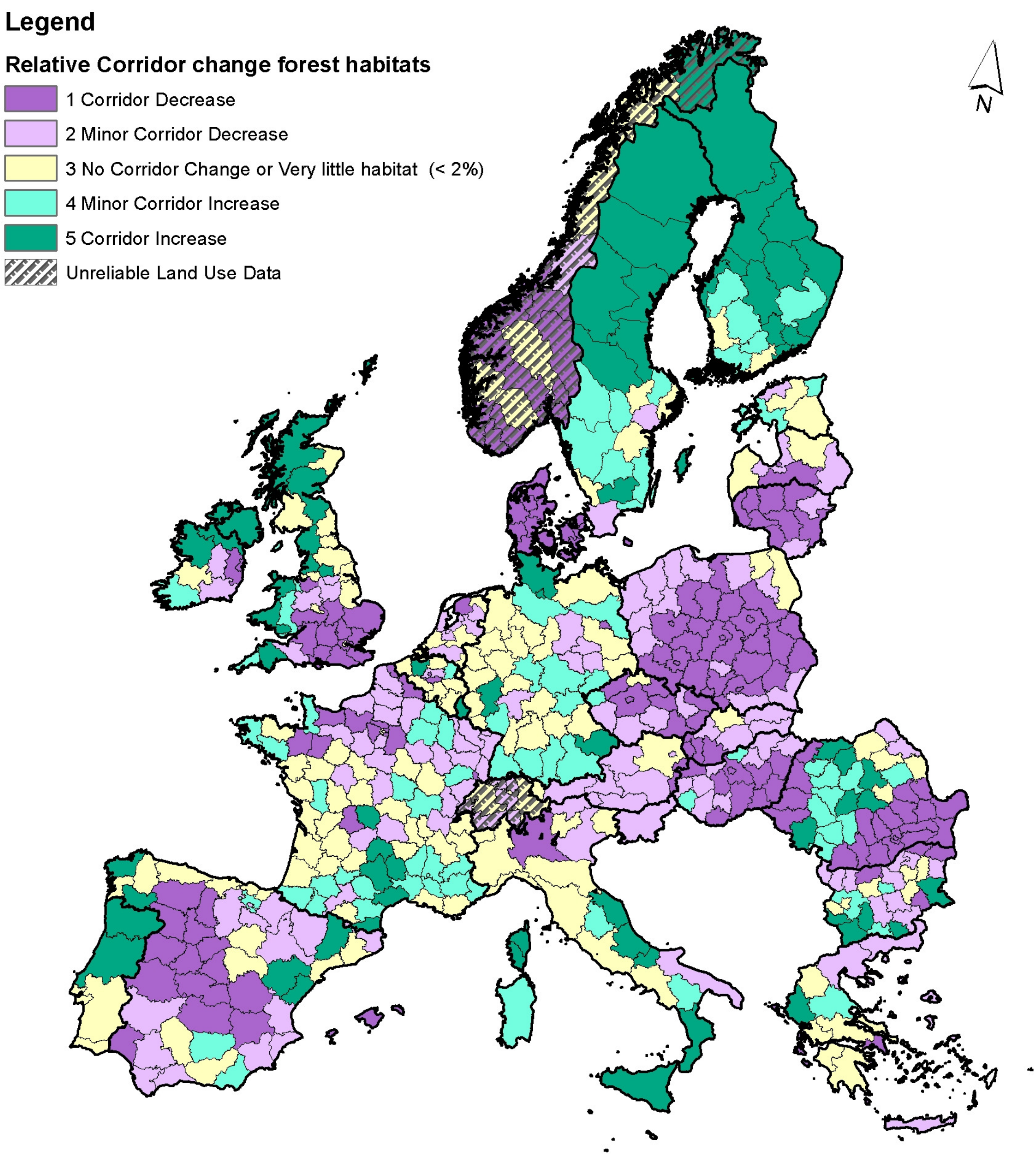


Figure 5.10. Relative connectivity change for forest per NUTSx unit. This map is a synthesis per NUTSx unit of the maps in figures 5.3 and 5.4.

2. Establishment of the importance of each NUTSx unit for corridors

The important areas considering the aim of this task are not the ones with large changes in connectivity in an absolute sense, but the ones where these changes are likely to have the largest impact on corridor function. We therefore needed to identify the NUTSx units that were deemed to be the most important for corridor function. These are not the ones with very large or very low amounts of habitat, but the ones with intermediate amounts, where changes will have the largest impact on connectivity. We produced maps of corridor importance using an automatic classification based on the present habitat situation of each NUTS unit (detailed methodology explained in Annex 3.4). The map for forest is given in Figure 5.11, the maps for wet and non-wet nature are included in Annex 3.4.

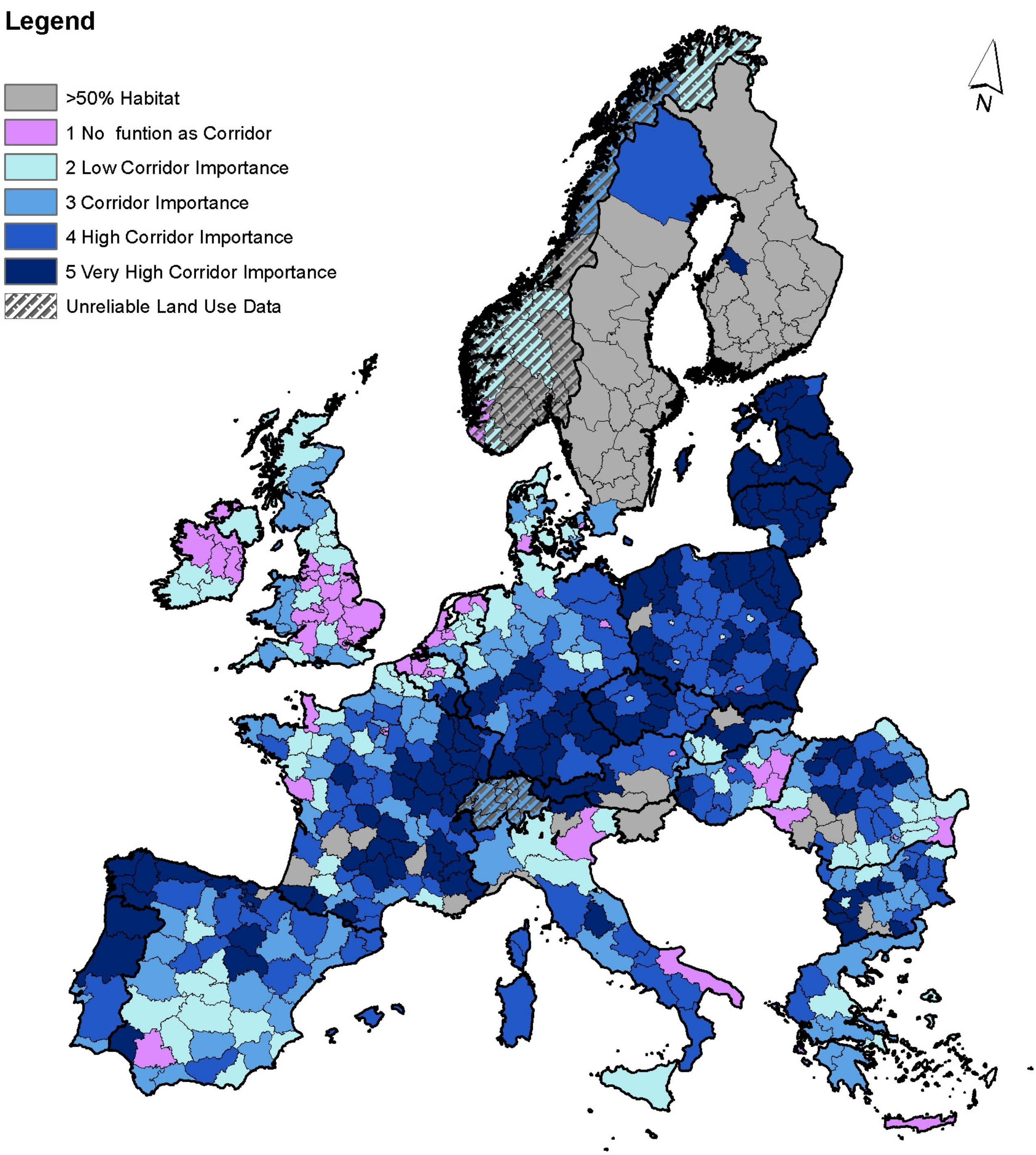


Figure 5.11. Results of a GIS classification of NUTSx units on corridor importance for forest habitat. See text above for explanation

3. Establishment of corridor functioning impact maps
We combined the maps of relative connectivity change and corridor importance to maps of the predicted impacts of changes on corridor function. The results for the three habitat categories are presented in Figures 5.12-5.14.

The impact map for forest in Figure 5.12 clearly shows that the NUTSx units in which the predicted changes in land use and traffic density are most likely to have a high negative impact on the corridor functioning of forest lie in Poland, the Czech and Slovak republics, Latvia and Lithuania and to a lesser extent in Spain and Romania. What these areas have in common is that they consist of mixed landscapes in which forest is now present in a still relatively well connected network of patches, which is threatened by deforestation (generally) and agricultural reclamation of semi-natural areas (only in Spain - loss of semi-natural habitats decreases forest connectivity) (Figure 5.2). In Romania, a corridor across the Danube plain that is still more or less functional is threatened.

Semi-natural non-wet habitat is mostly present in quantities large enough to form connected habitat networks in the Northern and Southern regions of Europe (Figures 5.5 and 5.6), and corridor function is not surprisingly mostly at risk in those areas. The main impacts on corridor function are in Spain, the south of France, Ireland, England, Denmark, the south of Sweden, Switzerland and western Austria, the Czech republic, Latvia, Bulgaria and Greece. Most impacts are caused by semi-natural habitat being lost to afforestation or urbanization. In Spain the reclamation of semi-natural areas by agriculture is also a factor and some effects (e.g. Wales) are caused by traffic increases (main effect is on large terrestrial species, see Figure 5.5).

Negative impacts on connectivity for wet nature are also limited to areas with a fair amount of the habitat, in other words with the ability to loose connectivity. In most cases, the loss of corridor functioning is connected to afforestation which, as was already explained in Section 5.2, might partly be a methodological artefact because forest was assumed to never include wetland habitats.

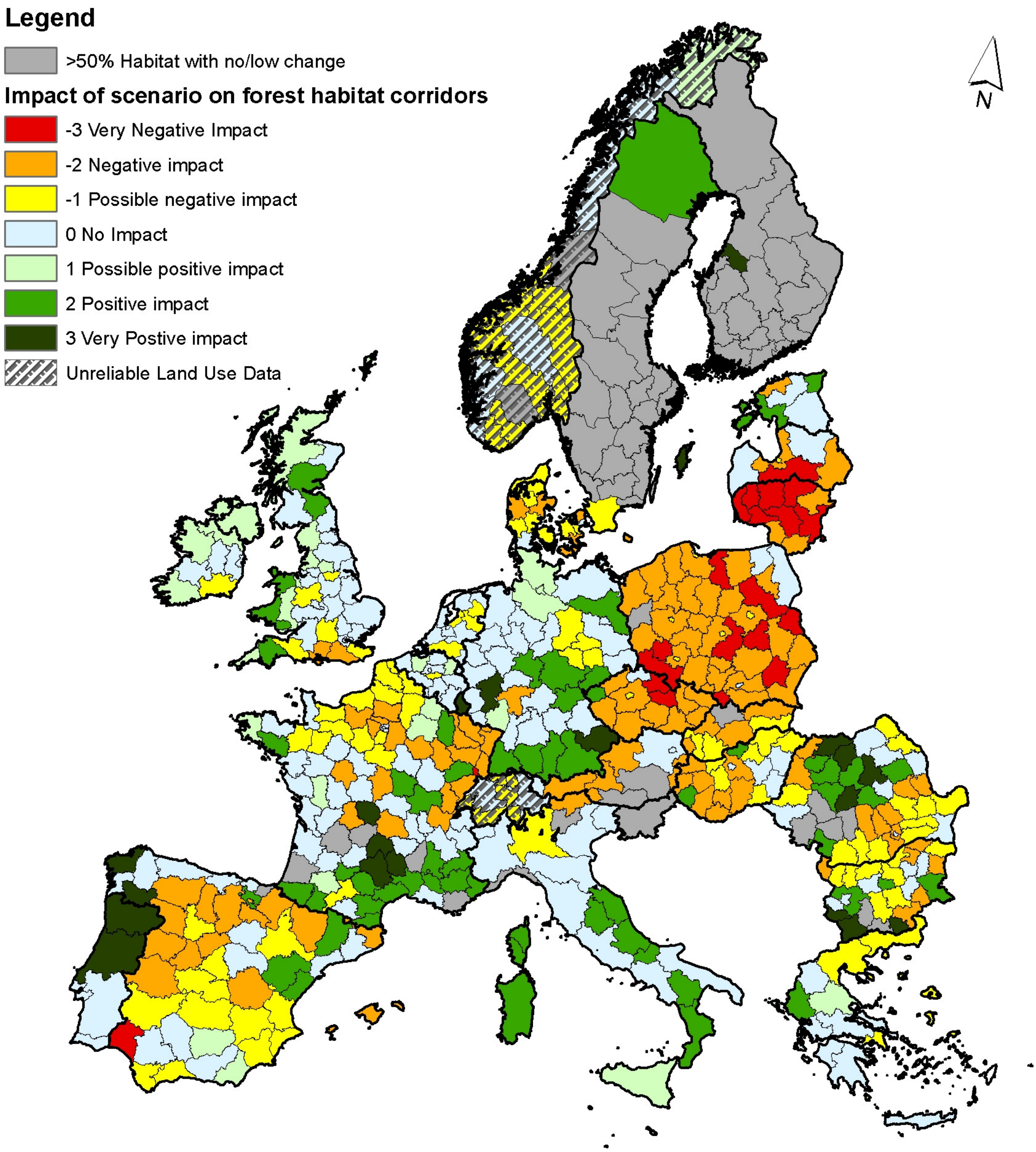


Figure 5.12. Impact of land use and traffic density changes on corridor functioning for forest habitat

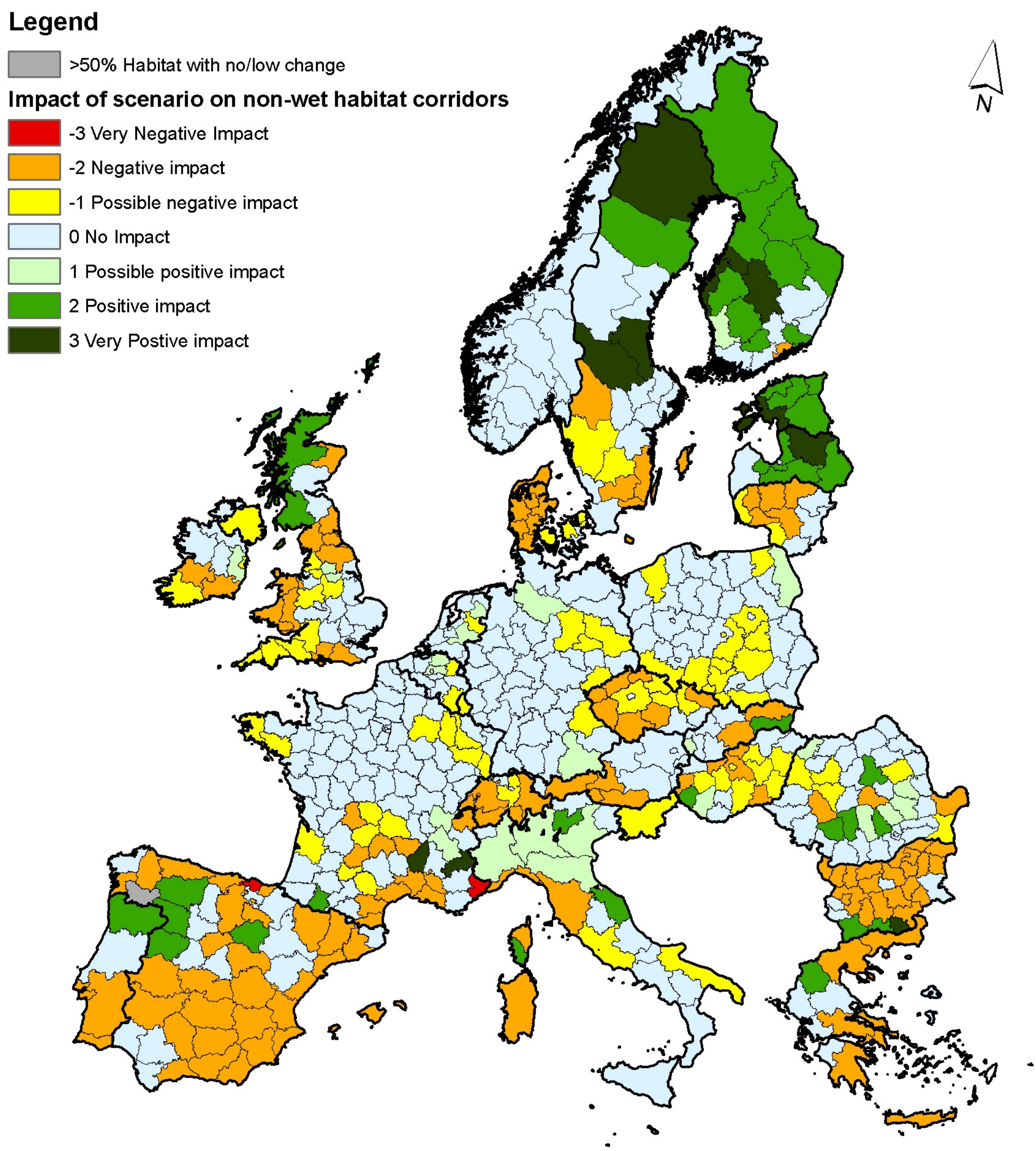


Figure 5.13. Impact of land use and traffic density changes on corridor functioning for non-wet semi-natural habitat

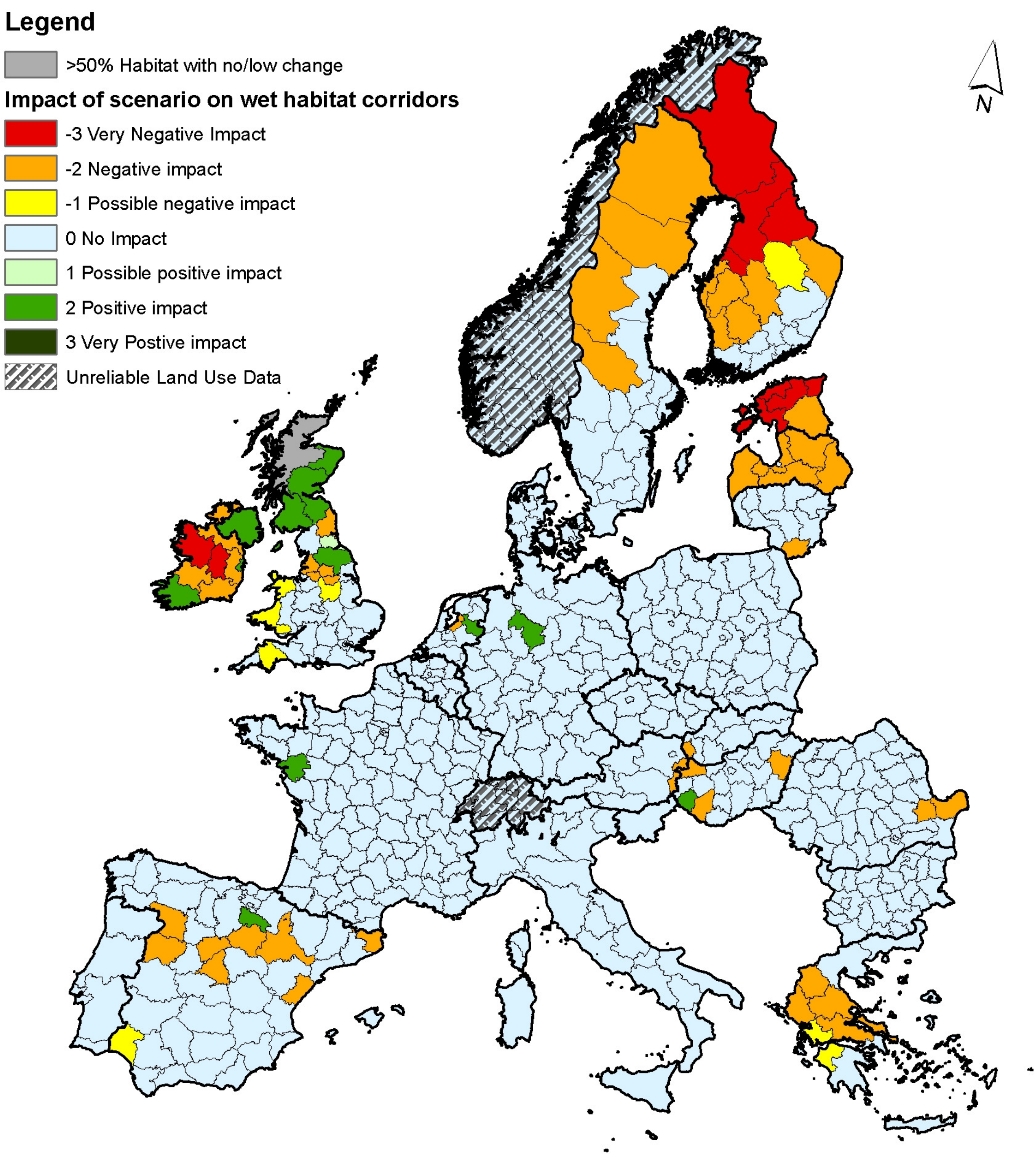


Figure 5.14. Impact of land use and traffic density changes on corridor functioning for wet habitats

4. Development of an overview map of the existence of national and regional network plans
Based on a literature review existing maps (paper or digital) of national and regional networks were gathered. Important information sources were Jongman and Kristiansen, 2001; Bennett and Wit, 2001; Bonin *et al*, 2007).

In general in Europe four situations occur:

- Ecological network plans are developed as environmental or spatial planning documents at the national level.
- Ecological network plans are developed as environmental or spatial planning documents at the national level that taken up at the regional level and worked out in more detail (for instance in Estonia, the Netherlands and Germany).
- The responsibility for nature / spatial planning is allocated at the regional level. Depending on the interest of regional governments those plans are developed (for instance in Flanders, UK and Spain).
- No ecological networks plans (either on national or regional level) are developed.

As much of the analyses in the project are undertaken on NUTS-level a map was produced indicating which NUTS areas currently have national or regional network plans (see Figure 5.15).

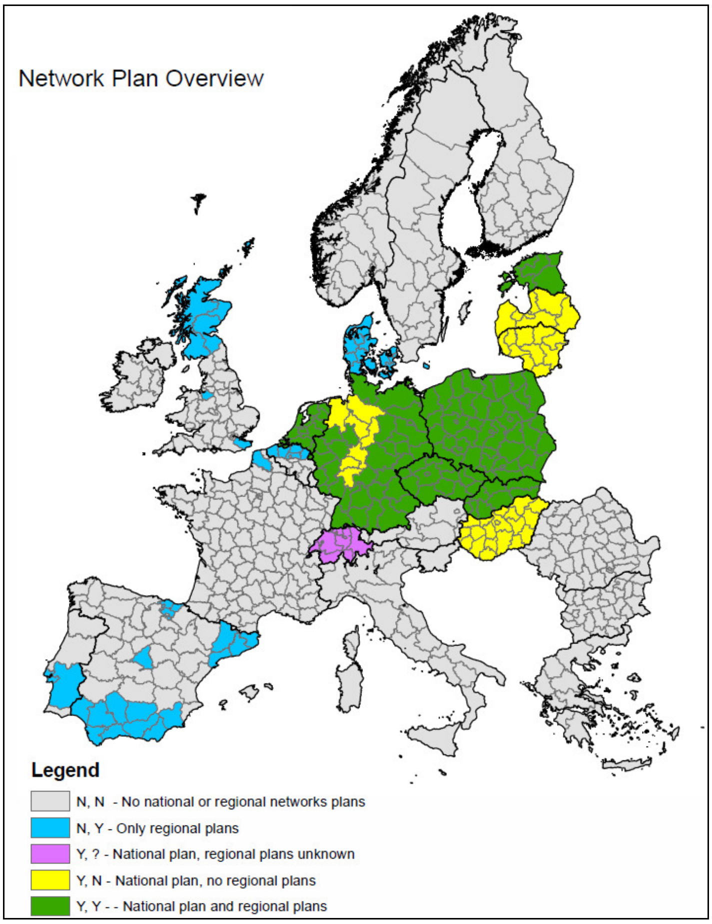


Figure 5.15. Existence of national or regional network plans based on NUTS 2 level.

5. Confront modelling results with corridor plans and policies for each NUTS unit and the amount of predicted change between present and 2030

In this step we made an assessment of the correspondence of national or regional plans for ecological networks with the present habitat structure, for the NUTS units for which plans exist (see previous step).

We choose to undertake a visual comparison between the maps of national ecological networks and the outcomes of the LARCH modeling (regional maps were not available, for further explanation of method see Annex 3.4). The result for forest is represented in Figure 5.16.

This match-map for forest does not show much differentiation. Since we did not expect clearer results for the other two habitat categories we did not produce maps for them.

5.3.3 Results

For those countries that have ecological network plans that could be checked by visual comparison between the network maps and the LARCH modeling results, the match between the indicated important connections / corridors and the important connectivity zones identified by LARCH was in general assessed as good. However, because most plans are very general and our general habitat categories do not necessarily match those that are locally important, this match basically just indicates that the important locations for protection and actions have been identified. How well connectivity at these locations will be preserved or reinforced in future completely depends on the adequacy of implementation of the plans. For most of these plans this will depend on final political approval, finances and actual local planning procedures (see discussions in Chapter 6).

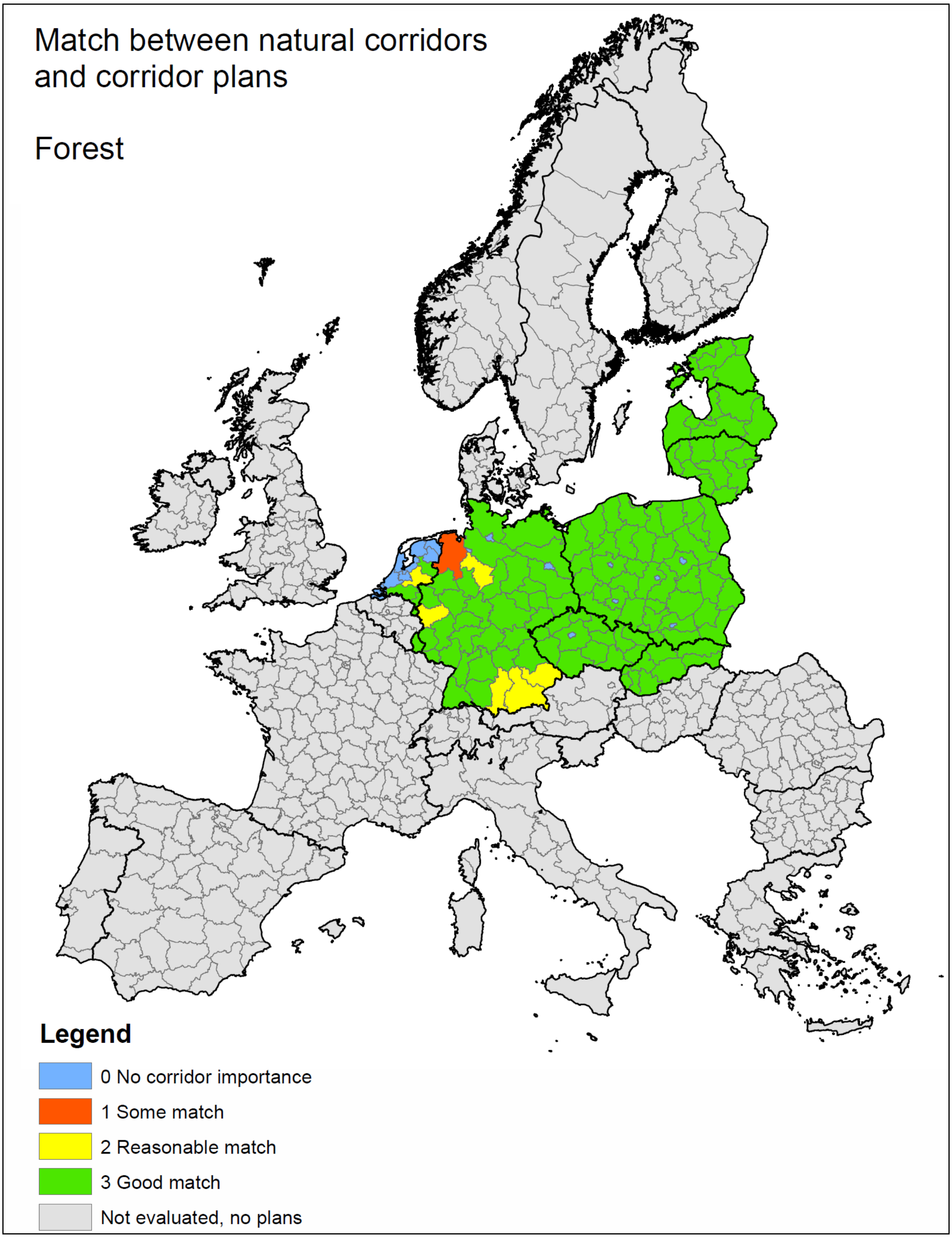


Figure 5.16. Match between national ecological network plans and the 'natural' corridors identified by the LARCH modeling, per NUTS x unit for the forest habitat category.

5.3.4 Discussion

An EU wide assessment of the effect of fragmentation on corridors at the moment faces a number of limitations:
a) spatial data with a uniform land cover classification is needed. The digital map material that is at the moment available for the whole assessment area contains little information (has a low thematic resolution) on natural habitats; b) this material is limited to a highest spatial resolution of $1km^2$; c) due to the low thematic resolution, predictions of the effect of land use changes on a number of important habitat categories are very general; and d) there is low uniformity in detail, availability and status of existing ecological network and corridor plans. Given these limitations, we were only able to evaluate fragmentation effects for species with dispersal ranges varying from 5 to 25km, and for 3 habitat categories that are difficult to relate to existing species. However, under the assumption that these categories in general do represent the important natural habitats in Europe, indicated fragmentation effects will be relevant (although in varying degrees) for all fragmentation sensitive species occurring at the problem locations. As the resulting maps (Figures 5.12-5.14) show, the main areas where the possible impacts of increasing fragmentation are considerable are Latvia/Lithuania, Poland and the Czech and Slovak republics for forest and the southern part of Europe (except Italy) for non-wet semi-natural habitats. In general, fragmentation impact is largest in areas / countries with mixed habitat landscapes. Fragmentation effects on wet habitats need a better detailed study to be of real use.

We choose to identify possible fragmentation problems by combining the predicted effects of land use and traffic density changes on connectivity with an assessment of the importance of the habitat structures in an area for corridor functioning, thus producing an assessment of the possible impact of the changes on that corridor functioning. This novel approach has the advantage that it estimates the actual impacts of changes on local corridor functioning and thus identifies the locations where corridor function in general is most sensitive, or alternatively, most at risk. As Figures 5.12-5.14 show, this produces a clear overview of the high impact areas. However, these results represent impacts for three broad habitat categories that were averaged for four already very general species groups. Although this approach is logical given the very general input data, the question can be asked in how far they are meaningful for real species. As connectivity change patterns were basically the same for all four modeled species groups (which was the reason for averaging them), we can safely assume that in an area with high indicated impact all species will experience a relatively large effect if compared to lower impact areas. The absolute impact that species in that area will experience will however vary, and will depend on species fragmentation sensitivity and on the way that the specific habitat of the species in the area is affected.

The broad habitat categories we identified in reality consist of a number of more specific habitats that vary with region. Under the reasonable assumption that the indicated impacts on corridor function will apply to the more specific habitats as well, we can also assume that all (local) species using these habitats will be most affected in the (local) high impact areas. Forest results will for instance be meaningful for the Brown bear *Ursus arctos*, Red deer *Cervus elaphus* , Eurasian lynx *Lynx lynx* (useful overlays with results from Bloemmen and Van der Sluis, 2005 and Groot Bruinderink *et al*, 2003), Marbled Polecat *Vormela peregusna* , Red Squirrel *Sciurus vulgaris*, Yellow-necked Mouse *Apodemus flavicollis*, Black and Middle Spotted Woodpeckers *Dryocopus martius* and *Dendrocopos medius*, Woodlark *Lullula arborea*, Bechstein's Bat *Myotis bechsteinii* and Purple Emperor butterfly *Apatura iris*, and those for non-wet semi-natural impacts for instance for species with varying dry habitat preferences as Brown Hare *Lepus europaeus*, Great Bustard *Otis tarda*, European Bee-eater *Merops apiaster*, Dartford Warbler *Sylvia undata*, European Stonechat *Saxicola torquata*, Red-backed Shrike *Lanius collurio*, Great Grey Shrike *Lanius excubitor*, European Ground Squirrel *Spermophilus citellus*, Green Lizard *Lacerta viridis*, Western Whipsnake *Coluber viridiflavus* and the Chalkhill Blue *Lysandra corydon*.

Confronting the impact maps with available maps of the existence of corridor and ecological network plans shows that virtually all plans have a good match with the local green structure and therefore can offer a solid base for conservation in general and preservation or restoration of corridor function in particular. On the other hand however, most of the available plans are very general and/or still lack firm policy backing, while plans for the by far the largest part of EU countries as well as surface area are unavailable, lack national backing or simply do not exist. Although the existing plans do cover most of the sensitive areas for corridor function for forest and therefore for probably the most important habitat category at the European level, the general conclusion can only be that the present level of *existence* (let alone *implementation*) of conservation plans is clearly insufficient to be confident about the prevention of the predicted impacts of land use and traffic density changes.

Corridor and ecological network plans are national or regional responsibilities in the EU, and are at these spatial levels an extremely important part of the preservation of local biodiversity and its related services. But for spatial resolution reasons alone already, this study is primarily focused on connectivity at the transregional and transnational level. At the moment, network and corridor plans are not spatially coordinated above the national level. It is however clear that an integrated European approach would have an advantage for a number of species, larger mammals in particular, and for countering climate change effects in general. One of the clear advantages of an integrated approach would be that priority areas for the preservation of corridor function could be selected. When for example the NUTSx areas with predicted high impact for forest corridor functioning are overlaid with the Pan European Ecological Network (PEEN) (Council of Europe) map, the result as shown in Figure 5.17 below, shows that possible priority areas could easily be identified.

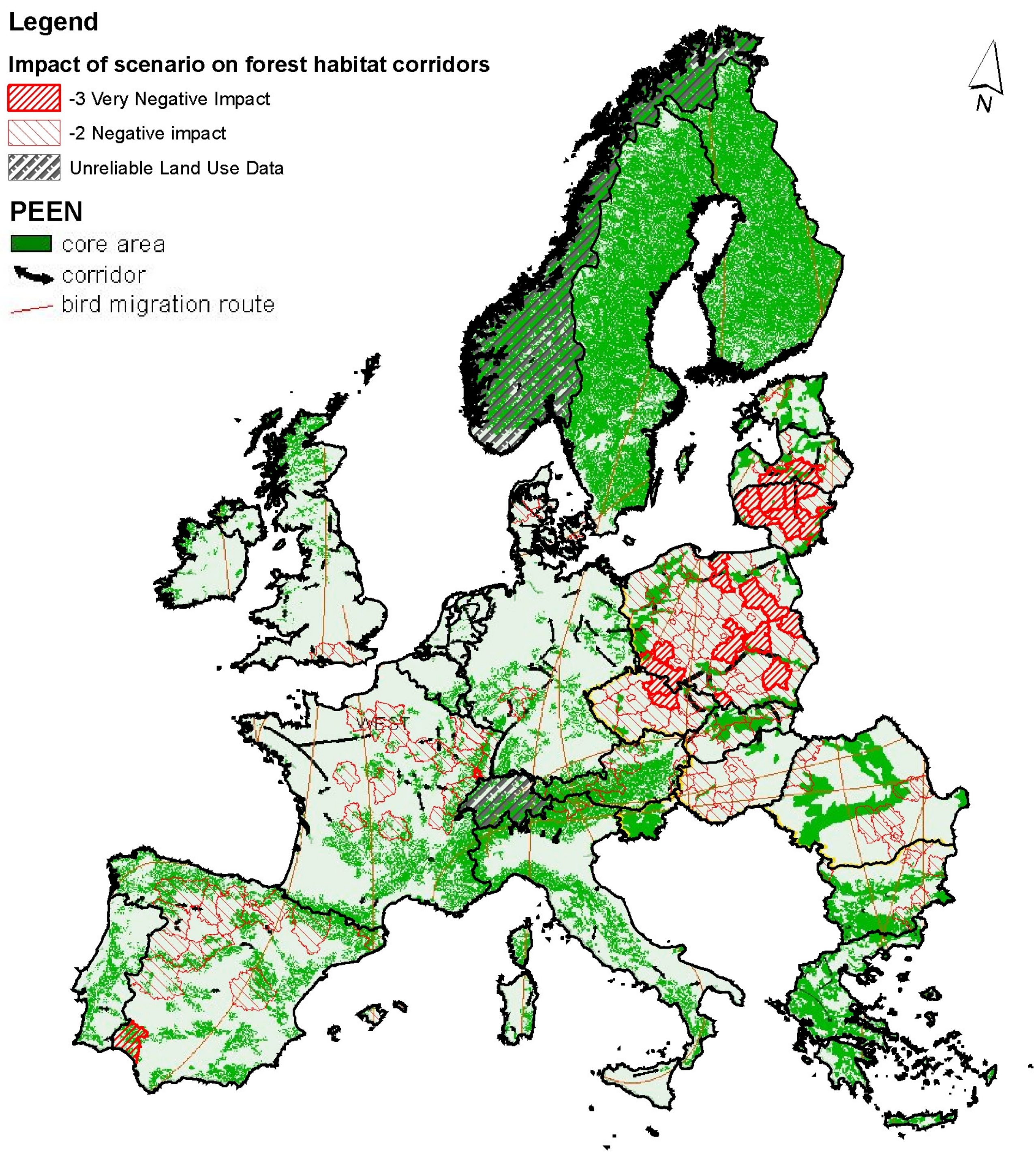


Figure 5.17. Overlay of the PEEN general habitat map with the NUTSx units with highest predicted negative impact for forest corridor functioning.

Conclusions

- The absence of EU wide information on the spatial distribution of natural habitats in a reasonably high spatial as well as thematic resolution clearly still hampers European scale corridor and network analysis. Especially for wet habitats, the available information is unsuitable for more than possible risk indication.
- The combined effects of the predicted land use changes and increase of road traffic densities can, if not counteracted by conservation efforts, have large negative impacts on the connectivity / corridor function of important natural habitats in large parts of the European Union, especially in areas with mixed landscapes.
- The absence of corridor and ecological network plans with national level policy support for the majority of EU countries makes an assessment of the likelihood of adequate preservation or prevention measures problematic. Results are incomplete but the conclusion can only be that the development and implementation of conservation plans is in this respect at the moment clearly insufficient.

Recommendations for the improvement of future assessments

- Increase the thematic resolution of basic maps
  For a proper fragmentation analysis of habitats used by real species, a base map containing detailed habitat information is essential. The same is true when the spatial coherence of (specific habitats in) the Natura 2000 network needs to be assessed. But as the review of the available land cover and land use change data that is reported in chapter 3 shows, it is at the moment impossible to produce an EU-wide map with a detailed thematic resolution for natural habitats by simply overlaying available data sources. A predictive habitat modeling methodology (Mücher *et al,* 2009a), quick field surveys (Bunce *et al,* 2005 and 2008) integrated with satellite imagery (Mücher, 2009b) and a lot of the necessary local and thematic datasets to make improved habitat maps are already available. For the Pan European Ecological Network (PEEN) for instance, a much better map for the western part of Europe (Jongman *et al*, 2006) was produced by cross-referencing the CORINE land cover map with environmental zones and a Digital Elevation Model (DEM). Extending this map for the rest of the EU would already greatly improve assessment quality, but to actually produce a state of the art base map for the whole of Europe a considerably larger effort and investments are need.

- Increase the spatial resolution of basic maps
  The spatial resolution of the CLUE map used in this project of 1 km^2 limits the modeling of species with small dispersal ranges because there habitat simply is not represented with enough spatial detail and is also far to crude to show anything but really large natural as well as constructed corridors. Present EU-wide assessment mostly use or are based on the CORINE land cover map. The spatial resolution of this map would allow for a slight increase of the spatial resolution of 1 km^2, but the smallest mapping unit for CORINE is still 25ha (see chapter 3). It is however possible to produce much higher resolution maps from the same satellite imagery that the CORINE land cover map is based on by using the methodology tested in the ECOCHANGE project (Mucher *et al*, 2009a), but a large investment in both time and funds for the gathering of the needed high resolution additional and calibration (‘ground truth’) data would be needed.

- Incorporate small landscape elements
  More then half of the EU surface area consists of agricultural landscapes. The green veining (green infrastructure) in these landscapes serves as main or additional habitat for a lot of species and therefore has a large impact on biodiversity (Billeter *et al*, 2008). Apart from that, Green Infrastructure (GI) improves connectivity and is seen as very important to maintain connectivity between Natura 2000 sites (see www.greeninfrastructure.eu). But to use GI in fragmentation analysis in a correct and meaningful way it is absolutely necessary to be able to correctly indentify and classify them. Even when using very large resolution digital imagery this is still difficult and more effort still needs to be put in improving automatic classification procedures (Mücher *et al*, 2007, 2008 and 2009b; Renetzeder *et al*, 2010). An additional way to help solve this problem would be to urge the correct mapping of these landscape features in topographic map making procedures across the EU.

6 THE EFFECTS OF POLICY INSTRUMENTS AND ECOLOGICAL NETWORK INITIATIVES ON HABITAT FRAGMENTATION

Andrew McConville, Graham Tucker and Marianne Kettunen, IEEP

6.1 INTRODUCTION

This chapter addresses the following components of Task 3 of the study as described in the study specification as follows:
The contractor shall:

- *assess current instruments used by Member States to avoid or limit habitat fragmentation;*
- *choose, in agreement with the Commission services, a number of existing initiatives promoting the setting up of biodiversity corridors, and summarise the key elements that have contributed to their practical implementation or that have hindered their development.*

These two tasks are closely linked and have therefore been separated from the analysis of fragmentation and its impacts in the Chapter 5.

6.2 THE ROLE OF CURRENT (EU) LEGISLATION AND INSTRUMENTS

6.2.1 Policy and legislative requirements to maintain connectivity and reverse habitat fragmentation

Measures to maintain and restore ecological connectivity have been included in EU nature conservation legislation. In this respect the establishment of a coherent network of protected areas (the Natura 2000 network) is considered to be of particular importance together with other connectivity conservation measures in the wider environment. The Commission Communication on Halting the Loss of Biodiversity by 2010 and Beyond (COM 216/2006) also calls for actions to address habitat fragmentation and climate change. However, before considering these measures a number of key principles need to be taken into account with respect to the maintenance and restoration of connectivity by biodiversity corridors and related initiatives. These principles draw mainly on studies for DG Environment on fragmentation (Kettunen *et al.*, 2007) and adaptation needs with respect to the impacts of climate change on the Natura network (Tucker and de Soye, 2009).

It is firstly essential to carefully assess connectivity requirements for biodiversity before embarking on potentially difficult and costly practical actions (see Section 6.3). In accordance with Articles 3 and 10 of the Habitats Directive, a high priority should be given to assessing the coherence of the Natura 2000 network with respect to species and habitats that are vulnerable to fragmentation. This should include the identification of current functional connectivity amongst the network for these species and habitats on the basis of empirical evidence where available.

Wherever feasible, expert-based approaches to assessing functional connectivity should be complemented by more rigorous empirical studies and modelling. Functional connectivity models should take into account the properties of the intervening landscape and each species ability to move through it, such as through ‘least-cost’ analysis (Adriaensen *et al.*, 2003; Bunn *et al.,* 2000). The functional connectivity of habitats can also be assessed using ‘least-cost’ approaches, e.g. by using ‘generic focal species’ (*sensu* Lambeck, 1997) for each habitat type to represent typical movement costs; a method used to develop ecological networks in England (Catchpole, 2006) and in this study (see Chapter 5).

Particular care should be taken in assessing the functional importance of landscape features that appear to be of high connectivity value. Many narrow habitat corridors and linear features, such as hedgerows, may provide valuable habitat but have limited functional connectivity value (Davies and Pullin, 2007; Dawson, 1994; Donald, 2005; Donald and Evans, 2006; Hobbs, 1992; ITE, 1994; Spellerberg and Gaywood, 1993). Nevertheless the precautionary principle should be applied so that in cases of doubt such features should be retained.

The assessment of existing connectivity should be complemented with an evaluation of the adequacy of existing connectivity. Typically this may consider the species’ demographic ecology, current conservation status and possible future threats from fragmentation. For example, the carrying capacity or actual population size within each identified functional network should be assessed in relation to recommended minimum habitat areas or minimum viable population sizes. Such assessments may often need to be carried out by expert evaluations. However, as before these should take account of all available empirical data and expert approaches should be complemented by modelling analysis where feasible and appropriate. The use of spatially explicit population models and stochastic patch occupancy models may be particularly useful in this regard (Carroll, 2006). However, in practice such models are often unsupported by empirical data. Furthermore, sensitivity analysis of spatial population models such as LARCH (as used in the Task 3 analysis – see Chapter 5) indicate that they are highly sensitive to small alterations in parameter values (Verboom and Pouwels, 2004). The outputs of such models should therefore be treated cautiously and expert evaluations, and ideally some field validations, should be carried out before they are used as a basis for defining biodiversity corridors and ecological networks or other connectivity conservation decisions.

Once an assessment of functional connectivity requirements has been completed then options for maintaining and increasing connectivity, if it is inadequate, can be considered. Assessments of options for alleviating inadequate connectivity should take into account all factors that affect the conservation status of the species or habitat in question, because connectivity measures need to be considered as part of a range of possible actions (Bennett, 2003). Increasing connectivity *per se* may not be the most appropriate solution. In particular, increasing connectivity should not be seen as a substitute for the conservation of large core areas of habitat (Noss and Daly, 2006). Instead connectivity features such as corridors should complement extinction-resistant core areas because these areas are likely to hold key populations that play a major role in maintaining metapopulations. A high priority should, therefore, be given to assessing the coherence of the Natura 2000 network for species that are considered to be at risk from fragmentation. Thus the relationship between Natura 2000 sites and their wider ecological networks (if present) should be established and their viability evaluated. The management of these sites should then take into account their wider ecological network, as for example suggested by Opdam *et al.*, (2002).

In most situations the first options for alleviating the impacts of habitat fragmentation that should be considered should be improving the quality of the existing habitat and the viability of their species’ populations. This may alleviate requirements for increasing connectivity. In particular, increasing the area of small habitat patches may increase population sizes, thereby reducing the risk of chance extinction and other threats associated with small populations. Such populations will become less dependent on functional connectivity and may be more resilient to fragmentation. Similarly, improvements in habitat quality may increase survival rates and reproductive productivity such that sink populations, which are dependent on immigration from functionally connected source populations, become source populations themselves. This may in turn benefit other functionally connected populations, especially where they operate as meta-populations.

Measures to improve the quality of existing habitat patches include:

- increasing the size of core areas, or amalgamating core areas with high quality habitats, to increase population sizes and habitat heterogeneity;
- improving habitat and species management within core areas; and
- reducing environmental pressures on core areas (e.g. from disturbance or pollution) by regulating land management practices within buffer areas (zones) and, where necessary, beyond.

If connecting structures are needed to increase functional connectivity between core areas (such as Natura 2000 sites) and other habitat patches then careful consideration needs to be given to the selection of options. As illustrated in Figure 6.1 and noted by many landscape ecologists, there are often many options for increasing habitat connectivity (Opdam and Wiens, 2002). The effectiveness and efficiency of connecting structures will vary according to the habitats and species being targeted and the landscape configuration present (i.e. the spatial distribution and quality of habitat patches, the properties of the surrounding habitat matrix and the possible presence of barriers to movement). For example, some woodland species may not use narrow woodland corridors because they are dominated by edge habitats, which they avoid. However, they may be able to utilise large stepping stones of habitat that are within their dispersal distance. Other species may benefit from wider scale measures that aim to increase the permeability of the intervening habitat matrix (i.e. to reduce its hostility), through measures such as reductions in agricultural intensity (use of fertilisers and pesticides), predator numbers and water pollution.

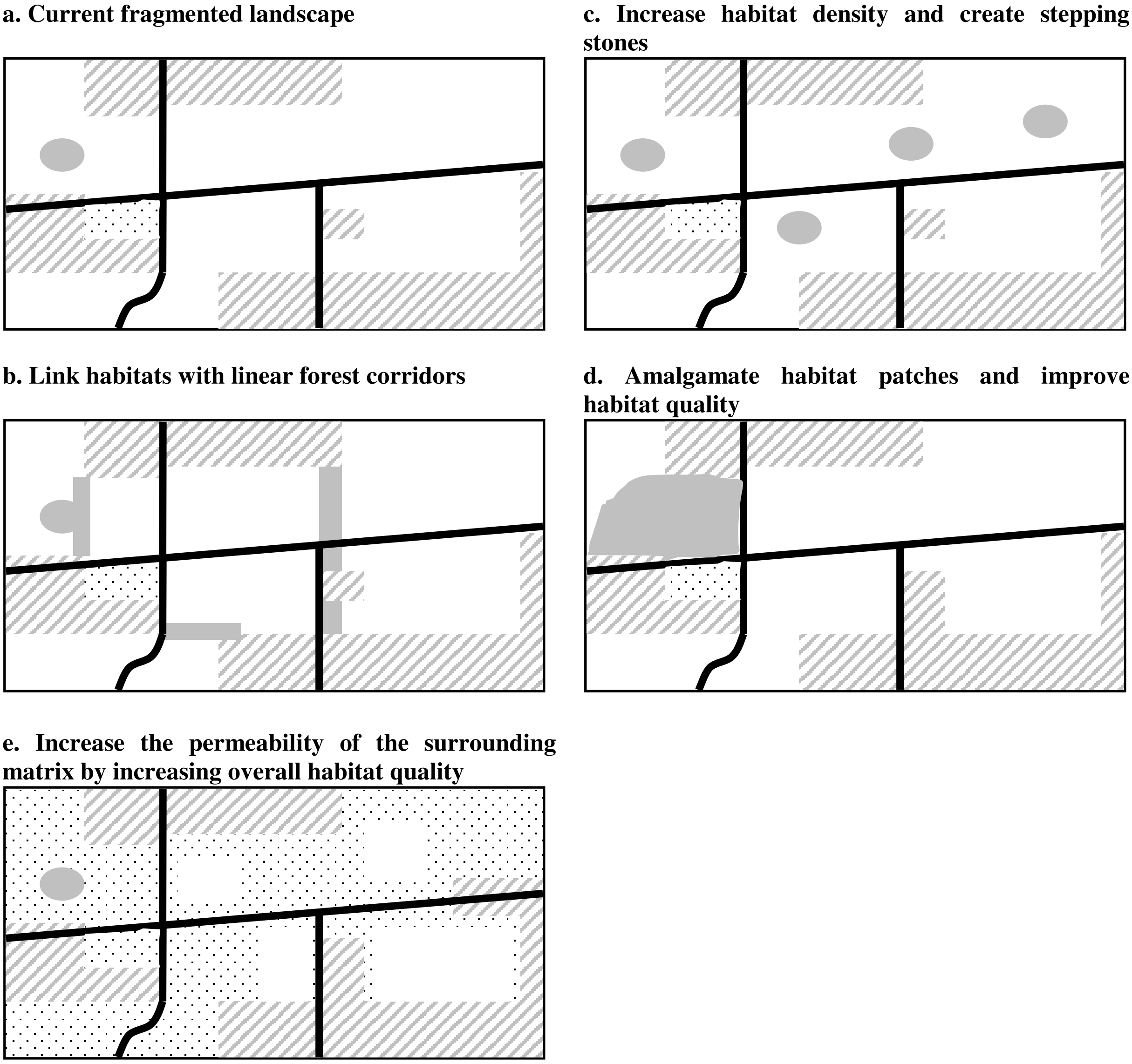


Figure 6.1. Options for improving connectivity within a fragmented landscape. Source: Kettunen *et al.*, (2007)

Key: Shaded = semi-natural forest. Hatched = Intensive managed forest. Stippled = semi-natural grassland with scattered trees (i.e. parkland). Unshaded = agriculturally improved grassland.

Consideration of future connectivity requirements should also be carried out for species that may need to move as a result of climate change. These species may initially benefit from connectivity measures, as described above, that aim to reduce current impacts from fragmentation. Such measures may increase the resilience of habitats and species populations to climate change (e.g. by improving habitat quality and improving the viability of populations) such that they remain in their current locations.

However, the scope for increasing resilience is likely to be limited for habitats and species in many locations. Therefore, as climate change pressures grow the long-term survival of a habitat patch or species population may become unsustainable in its current location. It may therefore become extinct if it does not move, at least in part, to another more suitable location.

Connectivity measures may, therefore, be increasingly required to facilitate adaptation by allowing habitats and species to move in response to movements in suitable climate space. In this situation the population relocates (in part or wholly) to another place.

But care needs to be taken before embarking on potentially costly and difficult connectivity conservation actions. For example Hodgson *et al.* (2009) warn that conservation practitioners should analyse the benefits expected to arise from increasing connectivity and compare them with alternative investments, to ensure as much biodiversity conservation and resilience to climate change as possible within their budget. Similarly, Halpin (1997) notes the need for firm ecological evidence upon which to base corridor design. Noss (2001) identifies similar priorities in a more recent review on management options for forests in the face of climate change. And more recenlty In recommendations to the Bern Convention, Huntley (2007) states that adaptation strategies should not focus on the provision of corridors as a means of increasing functional connectivity, but instead he promotes measures that aim to develop permeable landscapes of stepping stones. Similarly the advantages of wider scale measures to increase the permeability of the habitat matrix are promoted by Donald and Evans (2006), together with options for delivering such measures through agri-environment schemes.

It is also important to note that allowing and encouraging species to move in response to climate change will require some greater flexibility in the setting and monitoring of conservation objectives for Natura 2000 sites and in some cases other protected areas. In particular, greater emphasis may need to be given to maintaining habitats and populations across biogeographic areas, rather than preservation of species and habitats within specific fixed locations.

To be most effective, connectivity measures for species that are vulnerable to climate change should be assessed and planned on a case-by case basis, taking into account the latest modelled projections of climate change and responses etc. Nevertheless, the following generic measures to assist movements in response to climate change have been suggested (Bennett, 2003; Hobbs and Hopkins, 1991; Noss and Daly 2006) and should be considered, such as:

- maintaining habitat linkages parallel to latitudinal, altitudinal and coastal-inland gradients;
- minimising barriers to dispersal; and
- maintaining the continuity of species' populations across their present geographical ranges.

These measures should be in addition to conserving currently unfragmented landscapes. However, large-scale measures which aim to create extensive networks of habitat corridors aligned with anticipated climate changes are unlikely to be effective or realistic, particularly in already highly fragmented landscapes.

6.2.2 Biodiversity corridors and ecological networks

Key principles

Biodiversity corridors are typically part of more comprehensive ecological networks, which have developed over the past 30 years or so with the broad aim of maintaining the integrity of environmental processes (Bennett and Mulongoy, 2006; see Box 6.1).

Although such networks vary in concept and implementation etc, they share two generic goals, namely:

- 'maintaining the functioning of ecosystems as a means of facilitating the conservation of species and habitats; and
- promoting the sustainable use of natural resources in order to reduce the impacts of human activities on biodiversity and/or to increase the biodiversity value of managed landscapes (Bennett and Wit 2001)'.

The following elements characterize all ecological networks (after Bennett and Mulongoy, 2006):

- a focus on conserving biodiversity at the landscape, ecosystem or regional scale;
- an emphasis on maintaining or strengthening ecological coherence, primarily through providing for connectivity;
- ensuring that critical areas are buffered from the effects of potentially damaging external activities;
- restoring degraded ecosystems where appropriate; and
- promoting the sustainable use of natural resources in areas of importance to biodiversity conservation.

It is important to note here that maintaining connectivity within an ecological network does not necessarily require physical connections between all its components. It is now widely recognised that the key requirement is the maintenance of functional connectivity, which as described above may be enhanced by a number of means.

Typically ecological networks comprise the following components, which reflect their existing and potential ecological importance and functions:

- **Core areas** are areas of high ecological quality and conservation interest and therefore where the conservation of biodiversity is of highest importance. They normally cover all protected areas and often include other areas of high ecological quality as well.
- **Corridors** (or connecting structures) aim to maintain vital functional ecological connections between the core areas (see below).
- **Buffer zones** aim to protect the network from potentially damaging external influences by limiting acceptable land-uses.
- **Sustainable-use areas**, which according to Bennett and Mulongoy (2006) are 'where opportunities are exploited within the landscape mosaic for the sustainable use of natural resources together with maintenance of most ecosystem services' (see also Jongman and Pungetti, 2004).

Another common component of ecological networks is provided by nature restoration or creation areas which can be defined as areas with a high potential to develop into valuable habitats. They are often identified as a means of increasing, amalgamating or connecting core areas, such as in the National Ecological Network in the Netherlands (Jongman and Kristiansen, 2001).

Box 6.1. The development of the ecological network concept

The concept of ecological networks was pioneered in Central and Eastern Europe in the 1980s, with the first project worked into a national plan occurring in Estonia in 1983. These initiatives (notably Lithuania and former Czechoslovakia), influenced by the polarised-landscape theory of Boris Rodoman, were characterised by the strict demarcation of the landscape into zones for nature conservation and habitat restoration on the one hand and zones for intensive land uses on the other (Kavaliauskas, 1996). With their emphasis on both the anthropogenic uses of land and the need for ecological coherence, these plans developed into broad encompassing programmes, which today would be considered sustainable development plans.

In western European countries, the Americas and Australia-Asia, ecological-network approaches have been based on the equilibrium theory of island biogeography which showed that all other things being equal, larger islands that are closer to the mainland contain populations will contain more species and will have a lower vulnerability to extinction (MacArthur and Wilson, 1967). This and other research led to the inference that fragmentation increases the vulnerability of species to extinction, resulting in growing interest in Western countries in conservation approaches that promoted ecological coherence.

Interest in ecological networks was reinvigorated in the mid-nineties through the agreement of the Pan-European Ecological Network in 1995. The agreement marked the most ambitious ecological network programme attempted at the time in Europe. It set out to ensure the conservation of characteristic ecosystems and the natural habitats across the European range, increase the resilience of Europe's biological resources, strengthen the ecological coherence of Europe and ensure full public involvement in the conservation of biological and landscape diversity. It imagined the network to consist of a combination of core areas, corridors and buffer zones. Corridors were seen as vital tools to reverse loss of biodiversity by counteracting the fragmentation and isolation of habitats and ensuring that species have adequate opportunities for dispersal, migration and genetic exchange (Council of Europe, 2000).

Corridors within an ecological network

Although the term 'ecological corridor' is widely used, a standardised definition for them is lacking. Anderson and Jenkins (2006) review the popular and scientific literature to define five broad but overlapping groups of corridors:

- A "habitat corridor" is a linear strip of native habitat linking larger blocks of the same habitat to enhance the protection and increase the area of rare habitats.
- An "ecological corridor" which is focussed on retaining the ecological services upon which biodiversity conservation depends, such as restoring soil or water quality.
- A "movement, dispersal or wildlife corridor" designed primarily to facilitate the movements or migrations of species. These may be natural habitats or artificial connections (such as bridges or tunnels).
- A "corridor network" referring to a system of corridors in multiple directions usually established in hostile or highly degraded landscapes.
- "Biological, biodiversity or ecological corridors" can refer to large-scale landscape linkages covering hundreds to thousands of square kilometres.

An alternative way of categorising corridors is linear versus landscape corridors. Linear corridors are considered relatively straight-line connections between larger habitat blocks typically over distances of up to tens of kilometres. Anderson and Jenkins (2006) suggest that linear corridors are likely to be successful where:

- a large part of the landscape is modified and thus unfavourable for native species;
- the species of concern requires relatively undisturbed habitat; and
- the corridor itself can recreate the desired habitat or ecosystem, such as hedgerows or streams.

Landscape corridors refer to multidirectional connections at a landscape level that extend to areas of tens to thousands of kilometres. They constitute more a planning unit to maximise the connectivity of habitats, ecosystems and ecological processes (Conservation International, 2000; cited in Anderson and Jenkins, 2006), and may contain several linear corridors. From a biodiversity perspective, landscape corridors are more likely to be effective where:

- a significant portion of the landscape remains intact (although not exclusively; they can also prove useful in altered habitats);
- the species of concern require large areas of habitat; and/or
- the species or biotic communities have a high tolerance to the existing landscape matrix.

Landscape corridors require regional planning with land-use zoning, establishment of public and private protected areas and the incentivisation of environmentally benign resource and habitat use (Anderson and Jenkins, 2006).

Scientists from Alterra have proposed broadening the meaning of ecological corridor and network to include ‘a spatial concept for multifactor planning of sustainable landscapes’; thus taking it away from a pure ecological function (Opdam, Steingröver & van Rooij 2006; cited in van der Windt and Swart, 2007).

How have ecological networks been identified?

The delineation of ecological networks has encompassed a wide variety of methods (see Bennett, 2003; Hilty *et al*, 2006). The major differences in methodology tend to relate to the scale at which the ecological network is identified and the immediate objectives of the ecological networks which can vary significantly between countries and regions. In general terms there are two broad approaches based either on landscape structure or a species’ landscape ecology, which can be characterised as the difference between structural and functional connectivity respectively (Gergel and Turner, 2002; cited in Humphrey *et al*, 2005). Structural connectivity is the degree of physical connection between elements of the same type; therefore an attribute of landscape pattern. Functional connectivity, on the other hand, is an attribute of landscape connectivity that is defined by processes such as species movement and dispersal between patches. Therefore, it is possible to have high functional connectivity in a fragmented landscape with low structural connectivity provided the wider landscape supports the particular ecological processes (Farina, 1998, cited in Humphrey *et al*, 2005).

The structural connectivity approach is generally easier to implement but it makes assumptions about what is necessary to maintain functional connectivity and artificially over-emphasises the importance of certain structural features. Therefore this approach tends to identify one ideal type of corridor, but fails to recognise the range of corridors required to meet biological requirements of species (see Watts *et al*, 2005; Catchpole, 2006, cited in Kettunen *et al*, 2007). As a result, structural approaches may have a role in the identification of networks at a regional to continental scale, but at the sub-national level approaches should be based on functional connectivity (Humphrey *et al*, 2005, cited in Kettunen *et al*, 2007).

Approaches to identify networks based on functional connectivity are often based on quantitative models that define generic 'ecoprofiles' that represent a series of focal species (as in this study see Section 5.2 and Annex 3.2), with area requirements being the dominant factor determining extinction risk in landscape patches and dispersal distance as the main determinant of the ability to colonize patches (Vos *et al*, 2001). The focal species approach uses these traits to model the permeability of a landscape to different species as measured by the 'ecological cost' of movement, which is the probability of movement through the surrounding landscape matrix of a particular structure (Humphrey *et al*, 2005). The models then try to minimise the cost of moving through the landscape, but do not, however, advocate a single optimal landscape structure, which would be an oversimplification of connectivity requirements. Examples of this approach include the LARCH model developed in the Netherlands (see Annex 3.2).

Another possibility is the identification of ecological networks through spatially explicit population models which simulate the lifecycles of individuals or populations in specified areas. In theory, these approaches provide a more realistic representation of the modelled habitats, but the methods require substantial field data to be accurate and can only be conducted on a single species thus limiting its use in large-scale multi-species studies (Humphrey *et al*, 2005). The Macaulay Institute in Scotland has since begun two landscape models to construct better spatially explicit models of biodiversity (Humphrey *et al*, 2005).

6.2.3 Improving the ecological quality of the overall landscape

It is also important to note that an alterative or complementary approach to the identification and designation of ecological networks is the improvement of the ecological quality of the overall landscape; in other words, a reduction in the hostility of the wider environment to species. Whereas ecological networks advocate a targeted planning approach that focuses on defined core areas and connectivity features, another approach to increasing connectivity is to implement measures that improve the general ecological quality of the overall landscape. This view is based on the concept that a landscape is a mosaic of habitat patches that are utilised by a species within a matrix of surrounding habitat that is, to some degree, unsuitable or inhospitable to the species. In the past theoretical studies and island biogeographic theory made a clear distinction between homogenous areas of high quality patches surrounded by inhospitable matrix. However, this is not reflected in reality where both habitat patches and the surrounding matrix are rarely homogenous and where there distinctions between habitat patches and the surrounding matrix are often unclear (Donald and Evans, 2006; Ewers and Didham, 2006). It is now recognised that the structure of the surrounding matrix affects many factors such as movement between patches (Ricketts, 2001; Stevens *et al,* 2004b, 2006), colonisation rate (Bender and Fahrig, 2005), edge effects (reviewed in Ewers and Didham, 2006), breeding success (Lahti, 2001), as well as species composition, abundance and persistence (Tubelis *et al*, 2004). Thus for some species, the management of the wider environmental matrix may be more effective than managing habitats within defined corridors or may be an important supporting strategy.

Most studies of the effects of matrix habitat on species have been based on forested landscapes where there can be dramatic changes between forested and de-forested or afforested areas. However in Europe, the most widely felt impacts came from the conversion of natural grasslands to agriculture and then the subsequent intensification of agricultural practices on those areas, which had more severe impacts than the initial conversion (Donald, 2004).

As climate change causes range changes in species, focussing management attention on matrix habitat is likely to improve the ability of species to adapt to shifting conditions. For species this type of action is most likely to benefit those with intermediate dispersal ability, i.e. small to medium sized mammals, amphibians, reptiles and some invertebrates (e.g. butterflies; Ricketts, 2001; Sutcliffe *et al*, 2003; Donald and Evans, 2006).

Integration of ecological network concepts into conservation policies
From a review of the literature, it would appear that the concept of ecological networks has become widely embedded in conservation thinking. Indeed, a recent global review of experiences implementing ecological networks concluded that programmes to conserve biodiversity through landscape, ecosystem or eco-region scale systems of interconnected and buffered protected areas are becoming the mainstream (Bennett and Mulongoy, 2006). The authors point out that the changes being witnessed are more than simply the configuration of the land for conservation purposes, but extend to the setting of management objectives, the involvement of local communities and the way the initiatives are funded (see Table 6.1).

Debate surrounding the effectiveness of ecological corridors
While biodiversity corridors continue to be mainstreamed into conservation management, the scientific community remains divided on whether they contribute to connectivity and enhance population viability (see for example, Beir and Noss, 1998; Simberloff *et al*, 1992). A review that supports the principle of ecological corridors argue that of 12 studies from an original crop of 32 that allowed meaningful inferences of conservation value, ten offer persuasive evidence (mainly for birds) that corridors improve the viability of populations in connected habitats. Simberloff *et al*, (1992) stress that the role of ecological corridors varies considerably from species to species and from population to population. A study of the literature by (Vos and Smulders 2004; cited in van der Windt and Swart); reveals that of 18 species (butterflies, mammals and amphibians), nine are strongly dependent on a dispersion corridor and nine either to some or no extent. Beir and Noss (1998) acknowledge that many studies suffer from design limitations and agree that the question ‘do habitats provide connectivity?’ only makes sense in terms of a particular focal species and landscape.

Table 6.1. The changing paradigm of protected areas. Source: Phillips (2003)

Topic	As it was: protected areas were …	As it is becoming: protected areas are …
Objectives	• Set aside for conservation • Established mainly for spectacular wildlife and scenic protection • Managed mainly for visitors and tourists • Valued as wilderness • About protection	• Run also with social and economic objectives • Often set up for scientific, economic and cultural reasons • Managed with local people more in mind • Valued for the cultural importance of "wilderness" • Also about restoration and rehabilitation
Governance	• Run by central government	• Run by many partners
Local people	• Planned and managed against people • Managed without regard to local opinions	• Run with, for, and in some cases by local people • Managed to meet the needs of local people
Wider context	• Developed separately • Managed as 'islands'	• Planned as part of national, regional and international systems • Developed as 'networks' (strictly protected areas, buffered and linked by green corridors)
Perceptions	• Viewed primarily as a national asset • Viewed only as a national concern	• Viewed also as a community asset • Viewed also as an international concern
Management techniques	• Managed reactively within short timescale • Managed in a technocratic way	• Managed adaptively in long term perspective • Managed with political considerations
Finance	• Paid for by taxpayer	• Paid for from many sources
Management skills	• Managed by scientists and natural resource experts	• Managed by multi-skilled individuals

Despite this ongoing discussion in the scientific community and the apparent lack of agreement on the empirical basis, support amongst policy makers and government and NGO ecologists has been consistently strong (van der Windt and Swart, 2007). In 1980, the idea of ecological corridors was included in the World Conservation Strategy (IUCN 1980) and in the United States and Europe the concept was soon accepted by governmental bodies and NGOs (Simberloff *et al*. 1992; Jongman, Külvik & Kristiansen 2005; cited in van der Windt and Swart, 2007). Simberloff & Cox (1987; cited in van der Windt and Swart, 2007) state that 'corridors have been promoted outside the bounds of mainstream science'; so it appears that the concept of corridors has been a successful societal enterprise.

Despite societal resistance and ecological doubts, the notion of the ecological corridor remains enthusiastically supported by authorities and some stakeholders. One reason may be the metaphorical power of a 'corridor' that is analogous to transport, communication and institutional structures in our society (Keulartz, 2007; cited in van der Windt and Swart, 2007). Another aspect is its vagueness and openness to interpretation which allows a range of uses and functions and refers to different landscapes and species. However, if their function is to be more than purely ecological and include societal demands and pollution control, then this should be explicit from the beginning. Van der Windt and Swart (2007) recommend that research institutes, independent of government, are closely involved from the start of the process and promote the establishment of publicly operating regional platforms of scientists, governments, stakeholders and lay people to consider the environmental, economic and social features of the region in a transparent way.

This debate has important implications for policy makers with limited funds to invest in conservation. The literature seems to agree broadly that functional connectivity of landscapes applied to a single species is a very useful concept that can work in specific cases. But as Hodgson *et al* (2009) point out, conservation is a multi-species enterprise and the generalisation of structural connectivity measures without reference to specific species magnifies the uncertainty of the response. Hodgson *et al* (2009) state that uncertainties about connectivity tend to be high, a safer investment is likely to be in increases in habitat quantity and quality, which coincidentally also improve connectivity. There is a danger that those who seek to release areas from conservation for development could exploit connectivity measures to choose one that 'works' for them (Walker *et al*, 2009; cited in Hodgson *et al*, 2009) by using an increase in 'connectivity' to argue that a decrease in habitat is acceptable. This loss of habitat is certain to result in immediate decreases in population sizes, whereas the compensatory benefits of additional connectivity might be unknown and possibly small (Falcy and Estades, 2007; cited in Hodgson *et al*, 2009).

6.2.4 EU policies and instruments that support connectivity conservation measures

The rationale for the development of ecological networks (as described above) has been derived from scientific studies of population dynamics and island biogeography. Subsequently the concept has moved from scientific research to a conservation policy planning tool which can provide a framework for the integration of sectoral land use policies that can support and enhance ecological integrity. This framework is inherently scale-free and has therefore been applied from local to pan-European levels. There have therefore been a number of multilateral environmental agreements and other policy initiatives that support the establishment of biodiversity corridors and ecological networks as conservation tools, particularly in Europe, as listed below:

- Global: Convention on Biological Diversity, Ramsar Convention, Bonn Convention.
- European: Pan-European Biological and Landscape Diversity Strategy (PEBLDS) governed by the Council of Europe, European Union Habitats Directive, Bern Convention, European Landscape Convention, Alpine Convention, Carpathian Convention, Barcelona Conventions.
- National: national legislation and policy.
- Sub-national: regional legislation and policy (e.g. Federal States).

The key EU policy measures and instruments that support biodiversity corridors are outlined in Table 6.2 and further described in the next section. However, the implementation of proposed corridors and networks is complicated, especially for large scale initiatives, and actions are often constrained by practical and socio-political issues. These constraints and solutions to them are therefore the subject of further investigation in Section 6.3.

Table 6.2. EU Policy instruments that can support biodiversity corridor and other ecological connectivity initiatives

Key: HD = Habitats Directive; BD = Birds Directive; EIA = Environmental Impact Assessment Directive; LFA = Less Favoured Areas; SEA = Strategic Environmental Assessment Directive; RDP = Rural Development Programme; WFD Water Framework Directive. Protection of areas: including core areas, buffers and linear corridors and/ or habitat patches (stepping stones). Habitat Management: e.g. grazing, burning, farming and forestry operations and hydrology. External pressures: e.g. air and water pollution, and disturbance). Habitat creation / restoration, e.g. to increase habitat area, amalgamate fragmented habitats or create new habitat patches.

	Protection (e.g. loss from destruction		**Management**			**Habitat restoration/ creation**	**Other / notes**
Policy area	**Core areas**	**Corridors and stepping stone habitat patches**	**Core areas**	**Corridors and stepping stones**	**Wider environment (habitat matrix)**	**Core areas, corridors and stepping stones**	
Wildlife and countryside: Habitats Birds Directive, Habitats Directive and Environmental Liability Directive	HD and BD: Natura 2000 sites HD Art 6.3 and 6.4. ELD (Natura sites)	HD Article 10 re landscape features HD Art 6.3 and 6.4.	Natura sites HD Art 6.1	May be necessary to achieve FCS objectives for species and habitats of Community interest	May be necessary to achieve FCS objectives for species and habitats of Community interest	May be necessary to achieve FCS objectives for species and habitats of Community interest Compensation measures under Art 6.4	
Agriculture and forestry (see Chapter 7 for details)	Cross compliance – GAEC – retention of features	Cross compliance – GAEC – retention of features	RDP Axis 2 (Agri-env and Natura payments) Cross compliance (GAEC measures) LFA support in certain situations Potentially Art 68	RDP Axis 2 (Agri-env payments) Cross compliance (GAEC measures) LFA support in certain situations Potentially Art 68	RDP Axis 2 (Agri-env payments) Cross compliance (GAEC measures) LFA support in certain situations Potentially Art 68	RDP Axis 2 (Agri-env and Natura payments, afforestation measures*) Cross-compliance - habitat creation option and buffer strips	* but depends how applied
Energy	Protection of high carbon areas including HNV		Biomass targets* - management of forests for		Biomass targets:- low inputs on SRC	Biomass targets - if planting appropriately	*No legal req, but potential benefits if Nat Action

	Protection (e.g. loss from destruction		**Management**			**Habitat restoration/ creation**	**Other / notes**
Policy area	**Core areas**	**Corridors and stepping stone habitat patches**	**Core areas**	**Corridors and stepping stones**	**Wider environment (habitat matrix)**	**Core areas, corridors and stepping stones**	
	from biofuels		sustainable biomass production			located. Compensation for wind farms, e.g. on peatlands	Plans implement appropriately
Water (see also Section 7.3)	WFD - Potential protection of areas to achieve good ecological status	WFD – some where necessary, e.g. removal of weeds		WFD – any external pressure that affects ecological status (e.g. point discharges and diffuse pollution).	Maintaining water levels for wetlands (e.g. control of abstractions)	WFD - improvement of habitats that do not have good ecological status [good for connectivity] Removal of polluted sediments	WFD Specific interventions are not prescribed, but to be developed by MS to achieve good ecological status. Ecological measures under WFD go beyond those of Nitrates Dir
Impact assessment and planning	SEA and EIA	SEA and EIA				SEA (strategic planning of) and EIA - mitigation, offsets / compensation	
Other financial and economic instruments	LIFE+		LIFE+			LIFE+ Structural Funds: infrastructure actions	

Habitats Directives and Birds Directive: designation and management of protected areas, including buffer zones and ecological corridors

The designation and management of protected areas provides an important means of conserving sites of high conservation importance (i.e. core areas) and ecological corridors and other features that provide functional connectivity (irrespective of whether or not they are identified within a proposed ecological network).

The Birds Directive and Habitats Directive provide the legal EU basis for the protection and management of sites of particular importance for species and habitats of Community Interest. These comprise Special Protection Areas (SPAs) designated under Article 4 of the Birds Directive (for birds listed in Annex I of the Directive and for migratory species) and Special Areas of Conservation (SACs) designated under Article 4 of the Habitats Directive (for habitats and species of Community interest). These SACs and SPAs are combined under Article 3(1) of the Habitats Directive with the intention of forming 'a coherent ecological network' referred to as the Natura 2000 network, which forms the cornerstone of the nature legislation in the EU. In particular it should be sufficient, when combined with necessary conservation measures to maintain populations of Annex 1 birds and other migratory species of birds, and to maintain or restore FCS of habitats and species of Community interest. However, it is important to note that FCS has to be achieved across each species' and habitat's natural range, and not just within the Natura 2000 network.

The term 'coherence' in Article 3(1) of the Habitats Directive is of key importance as it indicates that Natura 2000 sites may not be seen as isolated ecological hot spots that can survive on their own, but as elements of a broader 'green infrastructure' system', with numerous functional links amongst sites. Similarly, Article 4(3) of the Birds Directive refers to the need for SPAs to 'form a coherent whole which meets the protection requirements of these species in the geographical sea and land area where this Directive applies.'

Once designated as SACs and SPAs, Member States must establish necessary conservation measures to maintain or to restore sites. The requirements related to the prevention of deterioration of sites and disturbance of species provide for a number of measures to be carried out outside Natura 2000 sites. According to the Habitats Directive any plan or project likely to have a significant effect on the site is to be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives. In such cases, the appropriate assessment should consider impacts on connectivity and the need to protect habitats that provide functional connectivity amongst Natura 2000 sites. In addition, Article 6(4) stipulates that if a plan or project with negative impacts on a Natura site is to take place (due to 'imperative reasons of overriding public interest') the Member States are to take 'all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected'.

There are also more explicit requirements to maintain corridors and other connecting elements in the Habitats directive. Article 3, states that Member States should:

> '*Where they consider it necessary … endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora*.' (Our emphasis).

In addition, Article 10 includes the following further provisions for Natura 2000 and more general connectivity provisions for flora and fauna:

> '*Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora. Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species*.' (Our emphasis).

However, it is important to note that Member States can exercise discretion as to whether it is appropriate or not to maintain and develop landscape features to meet the objective of ecological coherence. A key issue to consider is therefore when connectivity measures are deemed to be necessary. In this respect measures should be taken when Member States regard them as necessary to achieve the overall objectives of the directives (see above), especially for the maintenance or restoration of the species and habitats at FCS. Furthermore a European Commission paper (on reporting under Article 17 of the Habitats Directive) notes that 'Member States are expected to take all requisite measures to reach and maintain the objective of FCS'. Therefore, in principle Article 10 measures, and other connectivity provisions, should be implemented whenever they are necessary to maintain or restore FCS of habitats or species of Community interest.

A study found that as of 2000 a number of the EU-15 Member States had taken steps to respond to Article 10 (Table 6.3). But according to a more recent review Member States appear to be taking few measures (e.g. legal provisions) to conserve and increasing connectivity within and between protected areas (Kettunen *et al*, 2007). In addition, even when legal measures are in place implementation is patchy and inconsistent. For example, progress has been particularly slow with regard to practical implementation of ecological networks in most countries, primarily as a result of limited legal powers and the costs of large-scale land purchase and long-term management (see, for example Bennett and Mulongoy, 2006). This issue is investigated in detail through an examination of case studies in Section 6.3.

Table 6.3 Summary of Implementation of Article 10 of the Habitats Directive in the EU-15

Member State	Implementation of Article 10
Austria	Three of the nine Länder stress the importance of voluntary nature conservation measures, to enhance the coherence and connectivity of the Natura 2000 network. Little information was included on the specific measures taken to encourage the management of features of the landscape.
Belgium	In the Brussels Region, Flanders and Wallonia, different network activities have been established to connect green spaces and watercourses. The Flemish ecological network covers most of the Natura 2000 network and includes inter-connecting zones such as small landscape elements. It is not clear how the networks of the different regions are interlinked to enhance Natura 2000.
Denmark	Most county councils have planned to encourage the linking of ecological areas in open country through measures such as the creation of ecological corridors.
Germany	The concept of the 'Biotopverbund' (stepping stones and wildlife corridors) is transposed into federal law. In order to support a coherent system of habitat and species protection, a number of programmes (wildlife, water courses), plans (species and habitats recovery plans) and conservation measures have been established.
Greece	In accordance with Law 1650/86 a programme for the identification and recording of landscapes is under construction. The programme aims for the creation of a network of 'protected landscapes', including landscapes which could function as pathways.
Ireland	The National Biodiversity Plan and management programmes and policies for the coastal zone, rivers, lakes, wetlands and woodlands will support biodiversity conservation in general and serve to reinforce the Natura 2000 network.
Netherlands	The Structural Plan for the Rural Areas (SGR) stipulates that species which are subject to international agreements must be taken into account in district and land-use plans. Spatial planning and development activities have to consider the conservation and development of the habitats of such species. If disruption is unavoidable, compensation measures have to be taken (e.g. by minimising fragmentation and barrier effects). The SGR also provides for the implementation of the Main Ecological Structure (EHS), which aims to provide greater cohesion between spatially dispersed designated areas, under which 95% of the Dutch Natura 2000 network is being established. The EHS is evolving through the acquisition and development of farmland and management of nature areas.
Spain	The national law on nature conservation states that the public authorities should "promote the management of landscape elements that are of fundamental importance for wildlife, in particular those which, due to their linear and continuous structure (such as drovers' roads, rivers and their riparian vegetation, traditional field margins) or their function as stepping stones (ponds, patches of vegetation) are essential for the migration, geographic distribution and genetic interchange of wild species".
UK	The development of networks of statutory and non-statutory sites, and the landscape features which provide links from one habitat to another, is transposed into the Conservation Regulations. All Planning Authorities have to make such provisions in local and structure plans.

Source: For all countries except Spain - Composite Report from the Commission on the implementation of the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, Part II – Summaries and EU Member State Reports, 2003. (Period is 1994-2000. No reporting on Article 10 implementation took place in Finland, France, Italy, Luxembourg, Portugal, Spain and Sweden). Spain source is Beaufoy (2008).

Strategic Environmental Assessments and Environmental Impact Assessments

Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) are processes that aim to avoid, mitigate and compensate for potentially adverse environmental impacts that might arise from proposed programmes, developments or new activities. EIAs aim to identify, quantify and assess the potential impacts of individual projects (such as road, rail, port and large-scale industrial and residential construction or extraction projects). SEA is becoming increasingly important as a mechanism for ensuring that environmental and social concerns are integrated with the development planning process and also provides a mechanism for reducing uncertainty earlier in the planning process.

Impact assessments are required for major projects and programmes in the EU according to two key directives. The SEA Directive (2001/41/EC) requires authorities to undertake an environmental assessment of certain plans and programmes which are likely to give rise to significant effects on the environment. The process of assessing plans and programmes is generally referred to as 'strategic environmental assessment', although nowhere is this term used in the Directive. It sets out standard procedures for undertaking an environmental assessment, and complements Directive 85/337 on the assessment of projects (EIA) by requiring assessments at an earlier stage in the planning process.

The Directive refers specifically to biodiversity by covering all plans and programmes which have been determined to require an assessment under the Habitats Directive (92/43) in view of their likely effect on Natura 2000 sites. An environmental report has to be produced that contains the likely significant effects on biodiversity, population, human health, fauna, flora, soil, water, air, climate, material assets, cultural heritage, and the inter-relationship between these factors. In addition, it should include proposed mitigation and compensation measures for any significant adverse impacts on the environment, reasons for selecting the options chosen and a description of proposed monitoring measures.

The Environmental Impact Assessment Directive (85/337) stipulates that before consent can be given for certain development projects, such as large-scale industrial or infrastructure projects, an assessment must be made of potential impacts on the environment, so that the competent authority that grants consent is aware of the consequences. It acts as an embodiment of the preventative approach to environmental protection by ensuring the information regarding the potential impacts of the development are known before a decision is made. It requires the developer to supply information and to consult with the public and certain stakeholders. The Directive creates procedural rather than substantive obligations, and does not in itself require that Member States refuse to approve projects that are damaging to the environment. The study must cover the impact on specific factors including human beings, flora, fauna, soil, water, air, climate, the landscape, material assets and the cultural heritage as well as the interaction of all of these.

Despite some of the limitations associated with EIAs and SEAs (such as the adequacy of biodiversity related information), the processes provide many opportunities for avoiding significant impacts on connectivity, and in some cases can make a positive contribution to enhancing connectivity. Kettunen *et al*, (2007) noted that if carried out according to the best practice they can:

- Guide development programmes through SEA so that environmentally sensitive areas are avoided.
- Avoid fragmentation and other biodiversity impacts at the project level (through alternative projects, mitigation and if necessary project refusal).
- Provide connectivity and other biodiversity benefits through well designed and strategically located project compensation measures (e.g. habitat restoration).
- Improve understanding of connectivity impacts through research and post-project monitoring.

DG Environment currently has a research study underway on "Dealing with conflicts in the implementation and management of the Natura 2000 network – Strategic Planning" (Contract 070310/2008/515135/SER/B2). This is being carried out by Arcadis and IEEP, and is focussing on the treatment of fragmentation issues within SEA and EIAs. The study is expected to be completed in 2010 and should be able to complement the findings of this study.

Agricultural policies, regulations and agri-environment measures
Agriculture also has a major impact on functional connectivity, and hence the coherence of the Natura 2000 network, and other areas of nature conservation importance. This is because agricultural land makes up the majority of land outside protected areas in most countries (with the exception of some predominantly forested northern EU countries). In total, agricultural land covers about 50% of the total European land surface. As agricultural landscapes make up much of the habitat matrix through which species need to move, the quality of agricultural habitats is of profound importance in terms of maintaining and enhancing connectivity in the landscape (Donald and Evans, 2006).

Agricultural changes can have several impacts on the coherence of the Natura 2000 network and its potential for adaptation to climate change, including:

- Inappropriate management (i.e. intensification), or in some cases abandonment of agricultural management, of farmland habitats of high natural value, which reduces their resilience to fragmentation and climate change.
- Reduced functional connectivity amongst farmland and other habitats, as a result of habitat loss and general deterioration in the ecological quality of the farmland habitat matrix (e.g. as result of increased pesticide use).
- Impacts on other habitats, such as forests, rivers and other wetlands (e.g. from water abstraction, pollution and disturbance), which reduces their resilience and the capacity for their component species to adapt and disperse.

Various instruments within the Common Agricultural Policy (CAP), such as cross-compliance requirements for receipt of payments and agri-environment measures, funded under the European Agricultural Fund for Rural Development (EAFRD) have the potential to reduce and in some cases reverse some of these impacts. These measures and their relationships with the CAP are discussed in detail in Chapter 7, and are therefore not described here.

Forest strategies and support to forestry sector
Issues related to forest policy fall under the full competence of the Member States. Thus one of the main current policy documents guiding forest policy at the EU level is the EU Forest Action Plan (COM(2006)30) adopted in 2006. The implementation of the Action Plan is supported by an annual work programme developed by the Commission and relevant stakeholders. The Forest Action Plan introduces actions that aim to contribute to achieving the EU's biodiversity objectives for 2010 (and beyond) and enhancing the protection of EU forests. It does not directly address issues related to ecological coherence and connectivity but it does provide for monitoring of the impacts of forest fragmentation on biodiversity and supports improving coordination and cooperation within the forestry sector[52]. Improving

[52] Report on implementation of the FAP (2008) (http://ec.europa.eu/agriculture/fore/action_plan/progrep07_2008_en.pdf)

coordination can further support and facilitate initiatives aimed at preventing fragmentation and/or improving connectivity. However, no thorough assessment of the possible positive impacts of the implementation of the Forest Action Plan on the ecological connectivity of forests exists.

The support provided in the context of EAFRD could have important implications for preventing forest fragmentation and supporting connectivity in forest systems. However, recent report by Kettunen *et al.*, (2009) suggests that in comparison with the opportunities available, the uptake of biodiversity related funding possibilities for under EAFRD (e.g. funding to support sustainable forestry), has been limited. For example, Natura 2000 payments for forest land are only adopted by 11 Member States[53].

The Water Framework directive
As described below, in Section 7.4.12, the EU Water Framework Directive sets up the current basis for the protection of inland and coastal waters and groundwater resources in the EU. The Directive requires all inland and coastal water bodies to reach, as a minimum, 'good status' by 2015, taking into account aspects related to both ecological and chemical characteristics of the water body. In this context, the ecological status refers to the quality of the structure and functioning of aquatic ecosystems.

Although the Water Framework Directive takes into account the provisions of the Habitats Directive, it does not contain any particular requirements for implementing the Habitats Directive's provisions. Nevertheless, the Water Framework Directive's definition of good ecological status includes aspects related to maintaining or restoring morphological characteristics and the structure of inland water bodies, including preserving river continuity and enabling natural migration of species. The Directive my therefore help to maintain and enhance ecological coherence and connectivity of inland water ecosystems, including river basins. But, as the implementation of the Directive is still at an early stage it still remains to be seen if Member States will consider and act on connectivity related issues in the development of river basin management plans.

The Structural and Cohesion Funds
The aim of the EU regional policy is to promote coherent development within the EU and reduce gaps between the wellbeing of different regions within the Community area. Traditionally, the Community's regional policy has paid little attention to issues related to nature conservation and biodiversity. Furthermore, it has also been acknowledged that a number of activities funded from the EU regional and cohesion policy can have both direct and indirect negative effects on biodiversity (Kettunen *et al*. 2009). For example, EU funding has often been used to support infrastructure developments such as new roads and hydroelectricity schemes and these activities can significantly contribute to the fragmentation of habitats and landscapes, jeopardising the normal functioning of ecosystems. However, the promotion of the wider sustainable development agenda and the use of key tools such as SEA, has improved the inclusion of environmental issues, including biodiversity, into EU regional policy.

The EU regional policy is supported by three specific funding instruments: the European Regional Development Fund (ERDF), the European Social Fund (i.e. the Structural Funds)

[53] Although, a number of Member States have chosen to deliver management of Natura 2000 sites through other EAFRD forest measures instead.

and the Cohesion Fund. The Community co-financing for managing Natura 2000 during the 2007-2013 period will come from a mixture of existing funds (COM/2004/431), including the Structural and Cohesion Funds. This will increase possibilities for implementing measures that also support ecological coherence and connectivity in the context of regional development. In addition, support is also provided for transnational initiatives.

The programming of Structural and Cohesion Funds gives Member States a lot of freedom to develop policies and measures that suit their national and regional needs. Consequently, the actual level and types of funding in support of ecological connectivity under the ERDF and the Cohesion Fund in individual countries depends on decisions taken at a national level. Information to date indicates that a number of Member States (new Member States in particular) have used the ERDF to finance biodiversity measures (Torkler *et al*. 2008). However, no detailed assessment is available on the number and/or concrete impacts of biodiversity related activities carried out under the Structural Funds (e.g. possible positive impacts on ecological connectivity).

The European Financial Instrument for the Environment (LIFE+)
The EU LIFE programme, which was introduced in 1992 aimed to contribute to the implementation, development and enhancement of the Community's environmental policy and legislation as well as the integration of the environment into other EU policies. LIFE-nature projects have included a range of approaches and measures for increasing connectivity between habitats and species populations, some of the most common actions including:

- Increasing the size and productivity of source populations through habitat improvements and habitat expansion (for Capercaillie *Tetrao urogallus* and Fire-bellied Toad *Bombina bombina*).
- Reconnection and consolidation of fragmented habitats (e.g. for the Marsh Fritillary *Euphydryas aurinia* and Iberian Lynx *Lynx pardinus*).
- Creation / restoration of habitat patches as stepping stones for dispersal (e.g. for the Bittern *Botaurus stellaris* and Great Crested Newt *Triturus cristatus*).
- Creation / restoration of linear corridors of habitat to allow for dispersal, migration and gene-flow between populations (e.g. for the Brown Bear *Ursus arctos*).
- Removal of dispersal and migration barriers (e.g. for fish).
- Protection and enhancement of migration staging posts (e.g. along the Gulf of Finland flyway).

One LIFE-environment project, which carried out innovative research and pilot projects to define and develop ecological networks in Cheshire (United Kingdom) and Abruzzo and Emilia-Romagna (Italy), has been included as a case study in this study, and is therefore described in detail in Section 6.3 below.

Although the LIFE programme's overall impacts on connectivity cannot be quantified, the instrument has undoubtedly made important contributions to maintaining and increasing connectivity between habitats and species populations.

The LIFE programme has now been replaced 'LIFE+', which is carrying out similar biodiversity conservation actions (amongst others).

6.3 ASSESSMENT OF ECOLOGICAL NETWORK INITIATIVES AND IDENTIFICATION OF KEY FACTORS THAT SUPPORT OR HINDER SUCCESSFUL IMPLEMENTATION

6.3.1 Introduction and methodology

This part of the study examined in detail nine national or regional ecological network initiatives as case studies, with the aim of assessing their achievements and identifying factors that led to their successes or hindered them. The studies were selected from ecological network initiatives that have been identified in previous overviews and recent studies, such as those for DG Environment on guidance on implementation of Article 10 of the habitats Directive (Kettunen *et al* 2007) and the recent Green Infrastructure study[54]. The full list of reviewed initiatives is provided in this study's Inception Report and includes a number of transnational, national, regional and local corridor initiatives and ecological networks across a range of countries (reflecting different levels of urbanisation, agricultural intensification and period of EU membership).

From the identified corridor initiatives nine were selected for further more detailed case study analysis, in close consultation with the Commission Services. These reflect a range of approaches and degrees of successful implementation, but all include proposals for biodiversity corridors as part of the ecological network. Schemes were not considered for detailed analysis if they were relatively recent initiatives, or were closed or did not have a suitable contact for the provision of necessary information. The biodiversity corridor case studies selected for this study were:

- The Territorial System of Ecological Stability (TSES) in the Czech Republic.
- The Estonian Green Network.
- The Nature Frame in Lithuania.
- Biotoppverbund in Germany (a selected example from the Länder of Schleswig-Holstein).
- Landscape Ecological Planning in Finland.
- The National Ecological Network in the Netherlands.
- Networking for Biodiversity, Flanders.
- Cheshire regional ECOnet, UK.
- The Hungarian National Ecological Network.

The performance of each scheme was assessed primarily in terms of achievement of actions (e.g. land protection, or habitat restoration targets), as biodiversity impacts are largely unmonitored and therefore unknown. Each initiative was firstly assessed using information collated through a standard questionnaire. This was sent to the most appropriate contact person for each corridor initiative. The questionnaire ensured that a full range of background information was collected on the development of the initiative, its implementation approach and its progress (quantified as above). The questionnaire and responses are provided in Annex 4.1.

The questionnaire based analysis was followed up with a one-day workshop in Brussels on Thursday 2nd July 2009, to which an appropriate representative of each corridor initiative was invited (see Acknowledgments). The aim of this was to facilitate an in-depth and critical assessment of the corridor schemes. This proved valuable because problems and failures are rarely adequately documented in the publicly available literature.

[54] www.green-infrastructure-europe.org

Additional experts and representatives from key nature conservation organisations and other stakeholders attended (see Acknowledgements), including: BirdLife International, the European Centre for Nature Conservation, IUCN, WWF and the DG Environment Green Infrastructure study team.

The following section draws on the questionnaires and workshop findings as well as previous studies and published articles, and:

- describes the main approaches used to implement biodiversity corridors;
- assesses their progress; and
- summarises the key factors influencing their success.

6.3.2 Main approaches used to implement biodiversity corridors

Ecological network and corridor approaches in Europe

Current ecological network programmes in Europe are by no means consistent in the way in which they have been initiated, in their organisational form, in their instrumental choice or in the way they interact with spatial planning. Bennett (2009) uses three criteria to distinguish network programmes in relation to their interaction with spatial planning:

- the scale of the programme (international, national or sub-national);
- whether it is driven by a government or non-governmental actor (affecting its potential for incorporation into the spatial planning system); and
- whether the programme is legislatively binding or non-binding (setting the types of measures that can or must be taken by government authorities).

Using this framework, Bennett (2009) classifies ecological networks in Europe as follows:

1. International, multilateral or bilateral agreements on networks, e.g.:
    - Pan-European Ecological Network.
    - Bonn Convention agreements and memoranda of understanding.

2. National legislation that formally requires the development of ecological networks, e.g.:
    - Germany (to be implemented by the states).
    - Czech Republic and Slovakia (originally as Czechoslovakia).
    - Hungary.
    - Ukraine.
    - Moldova.

3. National policies that infer the development of ecological networks, e.g.:
    - Netherlands.
    - Switzerland.
    - Estonia.
    - Latvia.
    - Lithuania.
    - Romania.

3. Ecological network programmes initiated by lower government authorities:
    - Cheshire (Cheshire County Council, UK).
    - RENPA (Andalusia Autonomous Region, Spain).

4. Ecological networks initiated by NGOs or research institutions
  - European Greenbelt (international).
  - ECONET (Poland).
  - Nature Network (Denmark).
  - Planeco Planet (central Appenines, Italy).

Countries in the second category, (e.g. Germany and the Czech Republic), have established the basis for ecological networks within national legislation. Although legislation provides a 'hard' legal basis for the implementation of measures, in reality it does not provide a guide to the countries with effective and implemented ecological networks. This is then followed by legislative or policy documents that set out the strategic objectives of the network, for example the Slovak Act on Nature and Landscape Protection introduced a system called the 'Territorial System of Ecological Stability' (TSES), which aims to ensure 'maximum biodiversity, to provide ecological stability, and to support the productivity of the landscape' (Sabo *et al*, 1996). This introduced the concept of 'biocorridors' as one of three landscape elements essential to biodiversity conservation. In Lithuania, the Law on Protected Areas introduced the National Nature Frame that would include an ecological network. The planning process starts where the core areas and connective structures are identified.

Approaches to identifying networks are often based on combinations of structural and functional elements (see Section 6.2.2). In Germany, the Federal Agency of Nature Conservation has coordinated a project to identify nationally important areas based on both habitat characteristics and the needs of a series of focal species (i.e. those most in need of connectivity). In the Netherlands, maps were drawn up at national and provincial levels to connect areas of similar ecosystems (with certain species in mind) followed by a more detailed planning process to improve connectivity in agricultural landscapes. This stage included creating new core areas and habitat stepping stones, improving green-blue veining[55], using and strengthening existing habitat elements, with criteria and dimensions related to the needs of selected species (J. van Bodegraven, pers. comm.).

Within the UK a common approach has been developed amongst England, Northern Ireland, Scotland and Wales to produce a pan-UK ecological network based on functional connectivity as assessed by 'least-cost path analysis' (Adriaensen *et al*, 2003; Catchpole, 2006; Watts *et al*, 2005; all cited in Kettunen *et al*, 2007). However, there is little indication that is widely known or taken up by national and regional conservation agencies.

From an examination of the ecological network initiatives it appears that the main tools available to ensure the continued existence or restoration of corridors include:
- land purchase (or retained state ownership), swaps or leasing of land;
- strict legal protection under local, regional or national legislation;

[55] The term 'green-blue veining' is a one which has been long used in the Netherlands where ecology and landscape are closely related to and interwoven with patterns of small-scale agricultural and water management features (such as ditches, canals, lakes, brookes, marshes, etc.). These 'blue elements' in the landscape are important to support migration of species and conserve all kinds of habitat. Support from society for measures to improve connectivity is increased when combined with measures to improve water storage, water retention and water quality. In the Netherlands this often can create a win-win-situation. (J. van Bodegraven, pers. comm.).

- discretionary planning system based protection (e.g. inclusion of corridors in local plans, which should be taken into account in SEAs and EIAs and subsequent planning decisions);
- financial compensation in return for conservation measures (e.g. agri-environment schemes – see Section 7.4.9); and
- advisory or voluntary approaches with local stakeholders (e.g. promoted by LIFE+ Nature projects and NGOs).

The majority of the case studies used a combination of these approaches to a greater or lesser degree (see Table 6.4).

Table 6.4. Approaches used to implement corridors cited in the nine case studies

	Cheshire	Czech Republic	Estonia	Flanders	Finland	The Netherlands	Hungary	Lithuania	Schleswig-Holstein
Land purchase/state ownership	✓				✓	✓[2]	✓	✓	✓
Strict legal protection	✓	✓	✓			✓		✓	✓
Planning system based protection[1]		✓		✓			✓	✓	✓
Agri-environment schemes	✓		✓	✓		✓	✓	✓	✓
Advisory or voluntary (local stakeholders)	✓		✓			✓			
Other				✓[3]					✓[4]

Notes:

1. Inclusion of corridors in local, regional or national plans, which must be taken into account in impact assessments and planning decisions, but are not legally binding.
2. The approach of buying land in the Netherlands has been discontinued since 2004.
3. Refers to the restoration of connecting areas.
4. Declaration of areas with priority for nature protection by the state development authority (important for areas which are not yet protected by other law).

A number of countries have taken a multi-use approach to ecological networks, emphasising the need to balance the demands of people as well as biodiversity. Original plans for an ecological network in Estonia, for example, covered far broader goals than biodiversity conservation and could be considered sustainable development goals. These included facilitating the migration of species, buffering undesirable impacts, efficiently planning human settlements, reducing pollution, increasing recycling and providing opportunities for recreation. While the independence of Estonia brought severe economic pressure on the agricultural sector which threatened many valuable semi-natural habitats previously managed through traditional agricultural practices, it retains an ambitious set of aims, which includes balancing the requirements of land as a network for biodiversity as well as meeting the needs of society.

A number of the initiatives have considered the functioning of ecosystems when designating their network. In Schleswig-Holstein, legislation was developed to protect at least 15% of the land surface area as part of connectivity in order to preserve, and where necessary restore, typical ecosystems in the region. An important element of these are rivers and water courses to connect the areas of wildlife. Similarly in Hungary, priority habitats were designated mainly with a focus on habitats and ecosystems such as rivers and streams and their floodplains, wetlands, grasslands (including steppes), deciduous forests, bogs and marshes. In Finland, many of the corridors follow waterways which are important for connectivity.

Other networks are at an earlier stage of development. An ecosystem based network along the eastern bank of the River Meuse in the Netherlands has been planned and should eventually consist of approximately 1,975 ha of land, of which about 35% will be under stewardship agreements with local landowners. The province of Barcelona, on the other hand, provides one of the few examples of an ecological network that was developed and integrated with spatial planning regulations to determine where infrastructure developed within the region can take place. The SITxell system of the provincial administration of Barcelona currently protects up to 70% of land from development, identifies habitats for restoration and aims to make transport infrastructure more permeable. Some areas have been specially protected because of their key role for connectivity in the region (Kettunen *et al* 2007).

Many countries use a tiered approach to the scaling of their corridors, at national, regional and local level. The Dutch, for example, use a three tiered system:

- Arteries: 13 Robust Ecological Corridors managed at a national level.
- Veins: 25,000 ha of ecological corridors managed at a provincial level.
- Capillaries: 40,000 ha of typical landscape elements (including verges, roads, railways and canals) managed at a local or private level.

The legislation establishing the network also provides for the designation of 150,000 ha of interweaving and supporting areas with mixed functions. Schleswig-Holstein, Estonia and the Czech Republic similarly take a tiered approach.

Approaches to implementation

Table 6.4 above demonstrates the number of ways that Member States are ensuring that corridors are implemented and their important functions are protected. In Schleswig-Holstein, about 30,000 ha has been purchased in the past 30 years, about 2% of the land area of the state, with financial support from the federal government. River courses make up much of the linking corridors between the natural areas. Legal recognition of the remaining network does not prohibit development outright but requires the competent authority to make the case for overwhelming public interest. However, in reality, measures to maintain a good conservation status require more stringent intervention, usually on the basis of a contract with the landowner (e.g. through agri-environment payments.

Finland is particular in that the network is entirely on public land, run by a semi-state company that manages and sustainably harvests large sections of forest. Finland has also seen a very comprehensive engagement programme, which has enabled problems to be dealt with at a very early stage (See Box 6.2).

Box 6.2. Extensive stakeholder engagement in Finland

Finland undertook the most substantial stakeholder engagement of those included in this study. From 1995 to 2000 a total of 716 various interest group meetings were undertaken with around 1,275 interest groups including trade unions, NGOs, the forest industry, recreational users, hunting societies, village committees, research organisations, reindeer herders, Sámi people and local authorities. Consultation began at the beginning of each individual project (112 projects altogether) and approximately 13,000 people have been engaged in the process through public hearings, interest group meeting and open houses.

The Dutch system represents a quite different approach, due in no small part to very different circumstances. Since 1900, the Netherlands has lost approximately 75% of its area of natural habitats, leading to an associated significant drop in biodiversity (Lammers and van Zadelhoft, 1996). As a result, remaining natural areas are small and fragmented and waterbodies have high nutrient levels. In response, the federal government set a target of increasing coverage of natural areas from 8% to 18% by 2018 and set about reconnecting parts of the land through three types of ecological corridors (see above). The approach originally was for new areas to be bought by the state which has proved to be very expensive: currently over €0.4 billion is spent on nature conservation annually in the Netherlands from annual national funds, excluding spending by provincial authorities, NGOs and landowners. There has been some criticisms of this approach, including its scientific validity and cost-effectiveness in conservation terms (Box 6.3). Subsequently, land purchase has not been carried out over the last five years and responsibility has been devolved from national to regional levels.

6.3.3 Assessment of the progress of ecological corridors

Examination of the nine case studies from across the EU demonstrates that ecological network thinking is increasingly being used as a central approach to protecting biodiversity. However, there has been mixed progress, with most of the initiatives struggling to implement plans adequately. Although there are significant scientific challenges to creating an effective ecological corridor, it is often the practical and socio-political issues that constrain the implementation of ecological networks on the ground. In particular, securing adequate organisational capacity and human resources, funding, land ownership and stakeholder buy-in are often major challenges. This section examines evidence from the case studies on these issues and includes selected examples from the literature.

Box 6.3. Evolution of the National Ecological Network and corridor concepts in the Netherlands

The development of the National Ecological Network in the Netherlands has had the benefit of high levels of political support and funding, and has become a model for numerous network initiatives in Europe. However, in a recent review, van der Windt and Swart (2007) suggest conflicts arose between the proponents of scientific soundness of the network and those of social robustness, which reduced the role of scientists. The network was in fact instigated by the government as remediation and compensation for chronic eutrophication, acidification and fragmentation. The plan was initiated by governmental ecologists and was taken up rapidly by provincial authorities and private conservation groups. By 1997, 30% of the intended corridors had already been created but little or no attention had been paid to effective ecology (Bak and Reijn, 1997; cited in van der Windt and Swart, 2007). Thus, what was being promoted as an ecological exercise, originated from a desire to tackle water management issues as well as fragmentation and had been launched before any scientific evidence was available to support its potential ecological benefits.

Greater scientific qualification followed later. The Alterra Handbook for Robust Corridors (Broekmeyer & Steingröver 2001; cited in van der Windt and Swart, 2007) contained detailed information about the specifics of how to create particular corridors (e.g. corridors for the Otter *Lutra lutra* should be at least 50 m wide with a combination of water and vegetation). But the authors emphasised that corridors are not a panacea, but one strategy along with approaches such as improving habitat quality and enlarging nature reserves. In 2000, the government turned its attention away from small corridors with vague definitions to ‘robust corridors’, which could better link nature reserves and, importantly, combine ecological and social functions. Robust corridors also aim to support functions such as water management, recreation and cultural identity.

Expansion of the network

The most important achievement from a number of the initiatives has been the design of extensive networks and the incorporation of the networks into spatial plans. While this does not prohibit the destruction of sites within the networks, in many cases it ensures that special justification is required before development can occur in designated areas.

Designation of sites to be included in the networks has been extensive in many countries. In Lithuania, for example, 61% of total territory is under some form of protection as a result of its legal status established by two important acts. Approximately 19% of the Estonian territory is under some form of nature protection and the green networks covers 30-40% of the territory. In the Netherlands the network has expanded from 450,000 ha to 600,000 ha. The entire network, which aims to include 730,000 ha, has been 95% delineated on paper. The network has to be completed by 2018 and involves the integration of the network into national and provincial environmental and spatial strategy plans. In Schleswig-Holstein, it was estimated that approximately 75% of the corridors are under some form of nature conservation management (see Annex 4.1.4). The network in Schleswig-Holstein succeeded in altering Autobahn development proposals to avoid core areas of the ecological network, but it has had to cross other parts.

However, despite the expansion of the networks on paper, and improved protection of certain areas, the implementation of the networks on the ground (i.e. active management of sites, restoring habitat, regulating activities and so on) has typically been less successful. The problems with implementation have often arisen partly due to excessive detail and ambition at the design stage with insufficient consideration of the practicalities of implementation. This is demonstrated in Lithuania where the enormous size of the network demands huge financial, human and technical resources. This was compounded by a lack of specific objectives and prioritisation of certain zones inside the Nature Frame making it difficult for officials to prioritise existing resources. Overall, there is often a lack of communication by those who design the network with those at a local and regional level who are required to implement them, e.g. regarding what the network is and what will be required of them to make the network happen on the ground. This is vital as much of the implementation requires local officials to make informed decisions about where developments can be made and to train staff and construction workers on how to prevent damage to potential corridors such as streams, hedgerows and ditches etc. In the Czech Republic, over twice as much was spent on the design and mapping phase of the project than on implementation (see Annex 4.1.1). Thus, of the planned 50,000 core areas and 85,000 corridors, network measures have only been implemented in 200 sites and much of the network exists on paper only.

Progress of public consultation
The degree of consultation conducted has been mixed. Schleswig-Holstein and Cheshire point to successful local partnerships as a key to improvements made and Finland's widespread and comprehensive consultation drive appears to have limited conflicts during the implementation phase. However, in other areas the spatial planning process for the sites of the ecological network and for the corridor areas has been very slow due to long and numerous consultations with relevant administrations and stakeholder groups, despite the planning work on paper already prepared. Often this is due to a lack of extensive consultation at the early stages. In Flanders, the process of designation of the ecological network by scientists and government officials stated without consultation with farmers and this has resulted in a significant break down of trust between the two groups, which is severely hampering collaboration on nature conservation. The rebuilding of trust is now ongoing and is likely to take considerable effort and time .

Recorded ecological benefits
Assessing the success or failure of biodiversity corridors is difficult given the lack of data regarding the schemes. In many cases, ecological networks have no specific ecological aims or targets that are measurable, and there is often no benchmark against which progress can be measured. A serious issue is the lack of ecological monitoring to measure the impact of the networks. Some monitoring of ecological impacts does occur, for example in Schleswig-Holstein, but it is restricted to monitoring for Article 17 of the habitats Directives and to nature reserves and National Parks. This did reveal some benefits, including a 2% increases in the area of natural or semi-natural habitats. In Finland, as with other networks, it is assumed that there will be ecological impacts in the future but as of yet this change is not detectable.

Of the nine case studies, none carry out monitoring of the actual ecological impacts of biodiversity corridors. Consequently, it is not possible to establish if corridors have had any significant conservation benefits at all, let alone assess their cost-effectiveness.

A number of countries reported that pressures for development continue to increase fragmentation of habitats in many areas, and suggest that the networks have often not succeeded in improving ecological connectivity. The lack of implementation of the initiatives on the ground infers that it is unlikely that objectives to improve ecosystem resilience have been met. For example, in Cheshire, planned large scale habitat creation and restoration has not yet happened due to a lack of funding. In the Netherlands, despite progress in increasing the area under protection in the network, it seems very unlikely that favourable conditions will be attained by the target date of 2018 (see Annex 4.2 – Minutes from the workshop).

Trends in fragmentation
Fragmentation of the landscape in many areas continues to increase due to the construction of new roads and motorways. While the designation of the network has sometimes been successful in changing the course of motorways and other developments away from core areas, such protection is rarely, if ever, granted to ecological corridors. The permeability of the landscape remains an issue. Increasing competition with agriculture in certain areas continues to adversely affect the spatial connection between core areas. There remains a prevalent tension between nature conservationists, land-owners and users as a result of different interests concerning land use, which prevents constructive cooperation (for example, in Schleswig-Holstein and the Netherlands).

Co-ordination between regions
Constraints on the effectiveness of corridors include the differences in approaches between countries and in some cases between regions within a country. For example, the Belgian Regions of Flanders, Wallonia and Brussels all have different ecological network processes, making it difficult to compare ecological networks or to even embed networks at one level with those at a higher level. Some countries view their Natura 2000 network as analogous to an ecological network (e.g. Sweden) and others have developed separate ecological network processes (e.g. Germany). In some cases, there has been a fragmented approach to different parts of inter-regional corridors and a lack of cooperation between different stakeholders. In cases where there is no national framework for an ecological network, local initiatives can find themselves at odds with regional and national strategies which have prioritised economic growth as the prime objective and have not provided the space for the creation of ecological networks.

Provision of adequate funding
The results pointed to the shortage of funds and staff to implement the initiatives as planned as a significant issue restricting the implementation of the networks. As mentioned above, in many cases more funding has been directed to the planning stages than to implementation. In Lithuania, for instance, approximately 90% of funding towards the initiative has been spent on planning and only 10% on implementation. Concerns exist over the longevity of funding and the initiatives are vulnerable to changes in funding streams. The initiatives have struggled to make the money invested achieve changes that will endure once the funding dries up, casting doubt on the long term success of the projects.

There is a need to also make the funding that has been provided more effective. the Netherlands have cited significant constraints on budgets, despite being granted €0.4 billion per year (through national funds) to spend on the network, especially for the management of areas, acquisition and restructuring of agricultural lands and for the crossings of infrastructural barriers, which are by definition expensive policy options for conserving biodiversity. In addition, it is apparent that funding could be better targeted. A common complaint of LIFE funding was that it was only eligible for Natura 2000 sites[56] while much of the ecological networks are outside Natura areas, thus excluding large areas with the potential for supporting biodiversity.

---

[56] Or sites that could be designated as Natura sites after completion of the proposed conservation actions.

In some cases, the cost of protecting certain types of land restricts where habitat protection and restoration is possible. High quality agricultural land is expensive and as a result the land remaining for wildlife tends to be restricted to areas with less fertile soils (an issue cited by both Cheshire and Finland).

Restoration of corridors

Restoring and improving the quality of corridors has proved to be slow due to the difficulty in communicating the issues to landowners and stakeholders, and because of the high cost of maintaining the network. Resistance of local stakeholders can be caused by fear of the impacts of migrating or roaming animals (e.g. with respect to crops, disease vectors and road safety), fear of new constraints on farming practices and fear of declines in the net value of agricultural property. Often there remains confusion about ambitions, specific targets and the interaction between target-species and local interests.

6.3.4 Summary of key factors influencing success

From a consideration of the case studies and their common challenges (Table 6.5) and specific lessons (e.g. Box 6.4), several key themes have emerged as keys to the success in the implementation of ecological corridors. These are briefly outlined below.

Table 6.5. A summary of the constraints cited in the cases studies*

Constraints	Cheshire	Czech Republic	Estonia	Flanders	Finland	The Netherland	Hungary	Lithuania	Schleswig-Holstein
Over complication of the planning system for on the ground implementation		✓	✓					✓	
Lack of understanding at local level		✓						✓	
Tensions with local landowners						✓			✓
Differences in approaches within countries	✓			✓					
Funding constraints for implementation	✓	✓						✓	
High value land for other uses only	✓				✓				
Continuing fragmentation from external pressures						✓			✓
Agreements only voluntary	✓								
Lack of clear objectives from outset			✓						

* Note: these are constraints that emerged in the questionnaire responses from a single representative from each country and should not be taken as an exhaustive list of constraints for each network.

Box 6.3. Czech Republic "Territorial System of Ecological Stability" (TSES)

Background

The ecological network is based on the idea of climax ecology, i.e. that maintained ecosystems tend to reach a final stage of development. It was incorporated into law in the early 1990s.

Objectives

The ecological network's aims were to deliver "ecological stability" through:

- maintenance and restoration of the natural heritage;
- reinforcing ecosystem resilience in degraded landscapes and maintenance of intact areas; and
- delivering favourable impacts in surrounding, degraded parts of the landscape.

Approaches taken

There have been two principle approaches used in the TSES.

- The drawing up of highly technical and theoretical linear corridor maps. Corridors include "inter-regional" corridors (up to 100m wide) and "local corridors" (6-8m wide).
- Nature conservation laws to protect identified key ecological corridors, i.e. included in spatial plans at local, regional and national level, or if in protected areas.

Assessment of progress

Progress has been slow, despite very ambitious initial plans.

- There is an extensive network of core areas and corridors mapped centrally. However, of the planned 50,000 core areas and 85,000 corridors, actions have only been implemented on 200 sites. Much of the network remains on paper only.
- Although management rests with the state, municipalities and landowners, in effect, little management takes place as the purpose of the network is insufficiently clear. A key omission is the lack of monitoring of ecological impacts (it is neither envisaged nor implemented).

Key factors for success

From the Czech experience, a number of conclusions can be made on the factors required for success:

- Legal protection of areas under national legislation has been reasonably successful.
- Ecological requirements of specific species should be taken into account and measures in the field should be rigorously justified by scientific evidence. For example, a better alternative to a system of corridors may be a "patchwork" of variable habitats in the broader landscape and the management of small but ecologically important areas.
- Consideration of the implementation capacities before a plan is drawn up. In the Czech Republic, the capacity to implement the plan on the ground never existed, and therefore a more realistic approach should have been adopted.
- Those drawing up the plans should also be responsible for ensuring its practical success. In this case, more money was spent on developing maps than implementation and the planners had no responsibility to make the plans work on the ground.
- The need to engage those who will have to implement the plan, including informing local planners of what is expected of them and training them to help them achieve this.

Source: This study – see Czech Republic questionnaire (Annex 4.1.1) and workshop report in Annex 4.2).

Local stakeholder engagement and partnerships

All of the initiatives have highlighted the need for comprehensive engagement with local stakeholders right from the outset of the project. The stakeholders include all those who:

- have decision-making capacities regarding the land (such as local authorities);
- have an interest in how the land is managed (such as landowners);
- implement actions on the ground (such as field staff of local authorities, farmers, construction workers);
- use the land for resource extraction (such as forestry companies); and
- are interested in using the land for recreational uses.

Establishing an understanding amongst all of these stakeholders at an early stage is vital to preventing problems at a later stage of the project. The success of the initiatives depends on whether those who have direct control over the designated sites understand what is expected of them and for what purpose.

The Netherlands study highlighted the need for dedicated regional authorities with sufficient professional and creative professional mediators to draw and promote plans and to invest in relations with local stakeholders as a key factor to success. Time is needed to connect nature targets with other societal targets and to find solutions for local problems. If this is done, the there can be strong local incentives to implement ecological networks. One way of achieving this is through the development of local partnerships, where landowners and conservation interests work together towards mutually beneficial goals. Key to these partnerships is the changing of behaviour and attitudes towards greater acceptance of biodiversity considerations and thus building up practices that will continue after funding for schemes finish. Often this can be a slow process of collaboration in the spirit of sharing knowledge rather than dictating from one party to the other. In Schleswig-Holstein, "Local Alliances" (alliances of landowners, users, local nature protection organisations and authorities) have formed with connections to well financed agri-environment measures and land purchase schemes.

In a previous study of the practical implementation of ecological networks, Jones-Walters *et al* (2009) establish a clear set of guidelines to take plans from a design stage to local delivery through a series of consultation and participation. The study identified an eight step process of Preparation, Information, Analysis, Communication, Consultation, Participation, Conflict Management and Decision-making. Information and analysis form the basis of the plan development, considering socio-economic interests as well as the ecological information. This aids in defining the communication strategy by adapting the message and means to the different stakeholder groups identified in the analysis. Informed stakeholders are then in a better position to be consulted on a number of issues. These responses can be fed back into the information and analysis process and help define how best to involve stakeholders. Where necessary, conflict management techniques can be employed as part of the participatory process. This process can ensure that decision making is informed and consensual.

However, while early and comprehensive stakeholder engagement is vital to the success of the schemes, Jones-Walters *et al* (2009) find that a useful approach is to only engage the stakeholders with the key people that are needed, rather than attempt to seek a consensus on all decisions with all partners. A number of the case studies appear to support this conclusion, finding that extensive and drawn out consultation periods can slow implementation. Thus, careful stakeholder mapping at the beginning of a project, followed by careful and systematic consultation is a vital key to success.

Clear aims and vision

Clear aims have been identified by most of the initiatives as essential for managing the initiatives, communicating the network to other stakeholders and being able to measure their success. The absence of clear aims often leads to a lack of implementation as it is unclear what exactly is expected of those who are to implement the scheme. Some initiatives (such as the Netherlands and Cheshire) have stressed the importance of having a 'strong vision', which similarly is useful to communicate the initiatives and to achieve buy-in from important stakeholders. The plans should include clear quantified performance targets (directly linked to their objectives) that are objectively and systematically monitored over the long-term and reported to all stakeholders.

Establishing multi-functional use

An important factor to achieving local support for conservation measures is ensuring that people are not excluded from the benefits accrued from the sites. Allowing multi-uses of land for agriculture, resource extraction or recreation as well as biodiversity automatically allows a greater number of areas of land to be included, creates a more favourable impression of conservation, increases awareness of biodiversity issues and can deliver management of sites (for example through agri-environment schemes). In this way, conservationists may often be better able achieve their goals by showing how their work can be beneficial to others.

Sound scientific knowledge base

Measuring the impacts of ecological corridors is a necessity to ensure that the impacts of the corridor initiatives on biodiversity are understood and to determine how they can be improved. It is important to consider all options for increasing connectivity and select the most effective and efficient means of increasing connectivity. Networks should not focus exclusively on physically connecting habitats, but should also consider improving the size and quality of core habitats, the creation of new habitat patches as stepping stones and increasing the permeability of the landscape matrix. In certain cases, there may be more scientific support for the notion of a 'patchwork' of valuable habitats, including tiny micro-habitats.

It is important that ecological networks focus on the maintenance and enhancement of functionality, rather than just structural connectivity, where this is necessary to maintain or deliver favourable conservation status for both habitats and species. The requirements for increased connectivity measures should be ascertained through scientific studies that are based on the best available data. In particular, according to Kettunen *et al*., (2007) they should:

- avoid simplistic assumptions that habitat patches are not functionally connected if they are not structurally connected;
- take into account the differences between dispersal distances of key species groups and how these differ according to the landscape matrix surrounding patches; and
- identify, if feasible, functional networks with species populations that are too small to be viable, such that they require measures to increase their quality or connectivity.

There needs also to be careful consideration of the potential risks of increasing connectivity during the development of ecological networks. Proposals to connect sites of high nature conservation importance that have been isolated for long periods of time should be treated with particular caution as immigration may cause 'outbreeding suppression[57]' and lead to the loss of genetic variation among subpopulations.

[57] Outbreeding suppression relates to cases when progeny from crosses between individuals have lower fitness than those in the original populations. For example, selection in one population may produce a large body size

Maintenance of a good quality habitat and identification of key species and ecosystems in need

An important consideration is identifying priority habitats and species that need attention and ensuring their specific habitat and connectivity requirements are met. This point was emphasised by Finland, who maintained that the biggest factor affecting the survival of species was the quality of the habitat. A recommendation in this regard may be to give a high priority to reducing impacts on Natura 2000 sites by improving habitat conditions and reducing impacts from surrounding areas (e.g. upstream impacts in river catchments).

Network planners could look to identify areas of existing habitat that may be of high connectivity importance, irrespective of their direct biodiversity importance. For example parks, disused railways, canals and rivers in urban areas may hold few species or habitats of importance, but may provide important migration, dispersal or foraging routes.

Careful planning to take networks from design stage to implementation

Many of the networks failed to adequately convert good plans on paper to an effective network of corridors on the ground, often due to the lack of time and capacity at various levels. Therefore, the plan has to consider the implementation capacities of the country from the outset and establish a system which best fits the capacities of the country. This could be assisted by showing how the network could be seen as an asset in achieving other local and regional priorities (such as reduced flood risk, community cohesion, better access to the outdoors etc.). Establishing a clear delivery plan, including how to achieve local stakeholder buy-in (see above) and the training of local officials, is essential to ensuring plans are taken from the design phase to implementation.

Flexibility at a local level

Given the complexity of stakeholder engagement, the differences of local situations and the unpredictability of working with a range of stakeholders, ensuring that there is a degree of flexibility in the implementation of ecological networks is important. Implementation plans as described above will be different in each setting and managers may often have to manage several processes in parallel. Jones-Walters *et al* (2009) point to examples where successful initiatives have had to close and re-open under a different name to bypass immovable problems. Other successful initiatives arise from chance meetings, new opportunities and often “chaotic coming together of a number of favourable circumstances” (Jones-Walters *et al*, 2009) that could not have been planned for. In these circumstances, good leadership that is able to react to changing situations is important to capitalise on situations and opportunities as they arise. These sentiments are echoed in the case studies, which stress the importance of adapting to local circumstances.

Legal protection

Clear and effective legal protection appears to be a vital factor for the recognition of ecological networks. Legislation has proven quite effective at ensuring that networks have been incorporated into national, regional and local spatial plans, which then obliges competent authorities to consider the network in the management of their areas. A common approach has been to offer strict protection to core areas, while the remainder of the network (corridors and buffer zones) have been granted partial protection, requiring a developer to prove overwhelming public benefit to justify development in these zones. However, often this

in one population and a small population size in another. Cross-breeding between the two may produce an intermediate body size which may not be adaptive in either population.

degree of legal protection alone has not been able to reverse the trend of increasing fragmentation (see Schleswig-Holstein questionnaire, Annex 4.1.4) as a result of increasing transport infrastructure and urban development. This suggests that stronger legal protection is required and there needs to be greater understanding and recognition of the economic benefits associated with nature which should be incorporated into high level strategic planning.

Sufficient and innovative funding for conservation measures
All of the initiatives refer to adequate funding for design, implementation and funding as a crucial part of success for ecological networks and corridors. However, the amount of funding alone is not sufficient to guarantee success. It is important that spending is directed at initiatives that are of prime importance and is channelled through initiatives that build community support and ensure longevity. In the Netherlands, despite €0.4 billion per annum being spent at a national level, the initiative has some way to go to meet its target of 18% of the total area incorporated into the network and is unlikely to restore the network to favourable status, due to continuing pressures of fragmentation, unfavourable environmental conditions and resistance from landowners and other local stakeholders. Therefore, while funding implementation is a crucial factor in the success of the ecological networks, they are unlikely to be successful if measures to tackle the underlying causes of fragmentation and the lack of trust by local stakeholders are not adequately implemented.

Funding mechanisms could be better utilised to improve the durability of ecological network schemes and to ensure they provide sustainable benefits by the time initial funding finishes. To achieve this, there should be greater focus on capacity building and improving local stakeholders and local authorities' understanding of the ecological networks so that implementation becomes mainstreamed. In this respect Cheshire and Schleswig-Holstein point to delivery of grants and agri-environment schemes (managed through successful local partnerships, see above) as an important factor to success.

Mainstreaming of ecological considerations in overall government policy
A number of case studies highlighted that despite substantial governmental spending on some networks, their success continues to be constrained by ongoing fragmentation as a result of large infrastructure projects and other pressures. This highlights the fact that conservation policies tend to be secondary considerations to economic priorities, which fail to recognise intrinsic and ecosystem benefits associated with the maintenance of biodiversity. Therefore, discussion about the future of ecological networks and corridors needs to be considered when economic priorities are been set. Without a high-level commitment to tackling the underlying drivers of fragmentation, policies to promote ecological networks will be undermined.

International and inter-regional co-operation
Efforts are needed to intensify co-ordination and knowledge sharing between neighbouring national and regional ecological networks, for example, on what has and has not worked in various ecological network initiatives. There also needs to be greater capacity and understanding built into local and national planning institutions so that conservation considerations are mainstreamed into planning processes. This can be achieved by greater co-operation and knowledge sharing between conservationists and the planning community (e.g. through joint workshops, and closer working relations).

7 CHAPTER 7: DRIVERS AND POLICIES THAT INFLUENCE INTENSIFACTION / MARGINALISATION AND LOSS OF PERMANENT GRASSLAND

7.1 INTRODUCTION

This chapter addresses the following two components of Tasks 4 and 5 respectively of the Technical Specification.
On the basis of the information gathered under Task 1, the contractor shall:

- *assess the role of drivers that cause intensification/marginalisation, current (EU) legislation with a significant impact and the current instruments used by Member States to avoid or limit intensification/marginalisation (including land abandonment);*
- *assess the role of drivers for the conversion of permanent grasslands to other uses, of current (EU) legislation favouring or hindering it and of the current instruments used by Member States to avoid or limit this conversion.*

These tasks have been combined into this single chapter because the drivers and policies influencing intensification / marginalisation and the loss of permanent grassland are closely linked. In particular there are many overlaps between relevant policy instruments. For related reasons, the discussion of the impacts of intensification / marginalisation and the loss of permanent grassland have been combined in Chapter 8.

The discussion of drivers in this chapter builds on the introduction to general drivers of land use change that was provided in Chapter 2.

7.2 Review of drivers of intensification/marginalisation

7.2.1 Defining intensification and marginalisation

Intensification has taken place in most types of farming systems in Europe for several decades, and is usually understood as a process of increasing the use of agricultural inputs (e.g. fertilisers, pesticides, feed and mechanisation) for the purpose of increasing productivity per unit of land, livestock or labour. It is often accompanied by changes to farm structures and to patterns of cropping and stocking, generally with a trend towards increasing simplification and scale. Intensification is not easily measured, and the proxy indicator of trends in total purchased inputs (such as fertilisers, pesticides, and feedstuff) is often used, but this provides no information about input trends or secondary changes within different production systems.

Marginalisation is a process driven by a combination of social, economic, political and environmental factors, by which certain areas of farmland cease to be viable under existing land use and socio-economic structures. It is a dynamic concept, related directly to the conditions at the moment of analysis and depending on a multitude of factors, including the geographical situation and the age, financial resources and character of the farmer concerned (Pinto-Correia and Sørensen, 1995). Marginalisation takes a variety of forms and occurs at different scales, ranging from the individual patch of land to sizeable regions (Baldock *et al*, 1996). Depending on individual circumstances and opportunities available, economic marginalisation may lead to many very different responses from farmers. These are summarised in Box 7.1 and include changes in the type and intensity of production (to reduce costs or increase market income), different forms of abandonment, land transfers and restructuring (which may lead to intensification) or a change of land use out of agriculture altogether.

Box 7.1 Farmers' responses to drivers of marginalisation
The different responses of farmers to the economic viability of their current farming system becoming marginal depends on a complex mix of factors at the time, but will have a series of consequences for the land-use pattern, landscape and natural environment of a region, and hence the provision of land services. Possible responses at farm level include:

- attempting to improve farm income by intensifying production and increasing output per hectare, especially where investment aid is available (for example, the production-oriented grants in most EU Member States during the 1960s and 1970s were a significant driver of intensification, and current EAFRD Axis 1 investment and restructuring support could have the same effect in EU-10 Member States).

Where increased productivity is not an option, other choices aimed at maintaining economic viability include:

- a change from one agricultural land use to another, e.g. from crops to permanent grassland, typically involving the simplification of a mixed farming system into livestock production only;
- changes within farming systems e.g. reduced input use and/or stocking densities, reduced maintenance of infrastructure etc., often known as 'extensification' in English;
- a 'contraction' of the farming system, usually involving an intensification of production on the better land and the running down or abandonment of poorer, less accessible parcels;
- restructuring of holdings as some farmers leave the land and others take it over in order to increase their farm size (often known as 'extensification' in French);
- complete or partial abandonment, or cessation of productive faming while complying with cross-compliance standards in order to obtain CAP income support payments;
- a change of land use out of agriculture, for example to forestry or urban building.

(after Brouwer *et al*, 1997)

7.2.2 Context and characteristics of drivers of agricultural change

The drivers of intensification and marginalisation interact with each other, sometimes in complex and dynamic ways and over varying timescales, and the response of farmers is very context specific. Similar combinations of drivers can produce quite different responses, depending on the farming system, the farm structure (including the availability of additional factors of production – land, labour and capital), the biophysical conditions (soil, slope, altitude, climate) and social circumstances. These factors may lead to significant changes in the balance of land uses, especially between agriculture, forestry and the built environment (as considered in Task 2).

This task will focus on a number of key drivers that are likely to have the most significant impacts on land use intensification in the EU over the next 25 years to 2030, including:

- agricultural commodity markets;
- markets and policies for renewable energy;
- farm structures and land tenure;
- climate change; and
- technology.

Agricultural commodity markets
The world population is projected to rise to 9.1 billion in 2050 from a current 6.7 billion, and the FAO estimates that a 70% increase in farm production will be required over the next 40 years, coming mostly from yield growth and improved cropping intensity rather than from

farming more land[58]. Although the population in the EU and other developed regions of the world is not expected to increase as sharply, EU annual per capita consumption of meat is projected to increase from 85.1 kg/head in 2008 to 87.6 kg/head in 2015 (DG Agriculture, 2009). The growing global demand for meat and dairy products increases demand for soya and cereal based animal feed, and although most of the additional production will come from developing countries, EU farmers sell commodities in global markets and are responsive to price fluctuations. Whilst agricultural commodity prices have declined from their recent historic high (particularly for cereals), there is some agreement among the key institutions that, in the coming ten years, the prices for all farm commodities except beef and pig meat - even when adjusted for inflation - are unlikely to fall back to their average levels before the 2007-08 peaks (CEC, 2008; OECD-FAO, 2009). By 2018 average crop prices are projected to be 10-20% higher in real terms relative to 1997-2006, while prices for vegetable oils are expected to be 30% higher. Figure 7.1 illustrates this, comparing both the 'spike' in 2007-08 commodity prices and the OECD predicted prices for 2018 with average prices for the ten years 1997-2006. Despite the increasing demand for biofuels, one of the main factors in rising crop prices is production costs, which are particularly sensitive to crude oil prices, also projected to rise significantly.

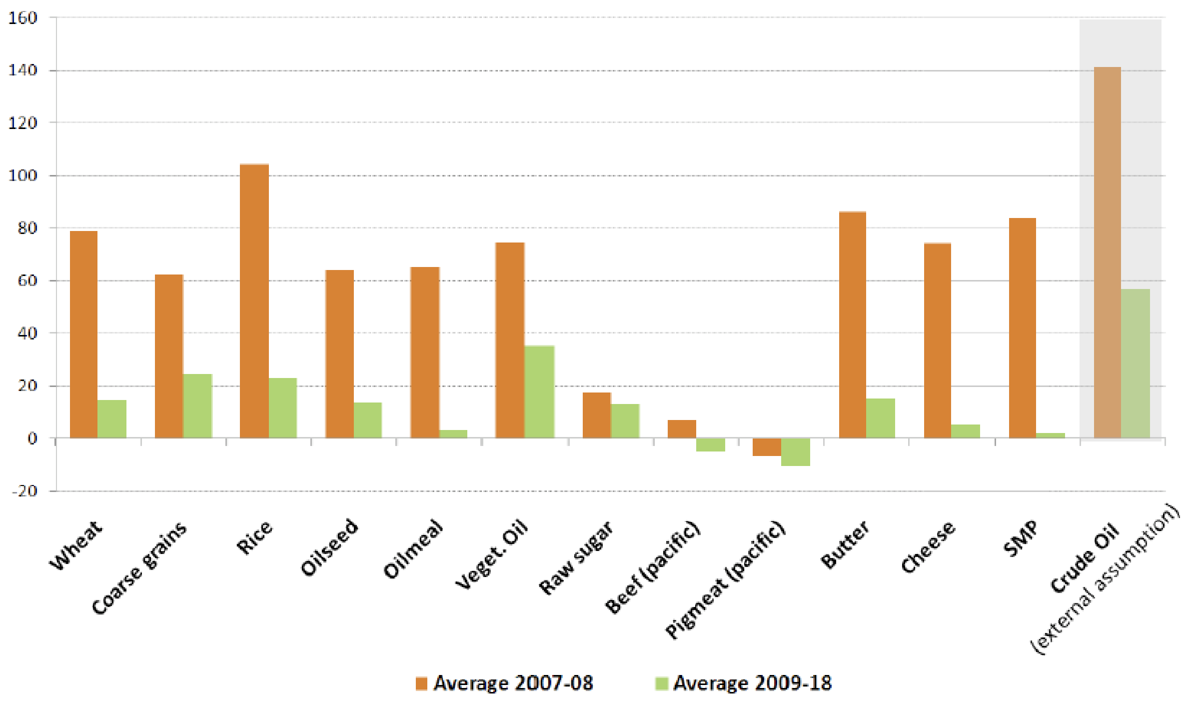


Figure 7.1 Percentage change in agricultural commodity prices in 2007-08 and predicted prices in 2018, relative to 1997-2006 average prices (source: OECD, 2009)

Agricultural commodity production other than wheat and coarse grains is expected to shift increasingly towards the world's developing regions, especially for meat and dairy products. Wheat will remain predominantly a food commodity, but the share of vegetable oil used for biodiesel is expected to increase worldwide from 9% in 2006-08 to 20% in 2018, and the increase in Europe is predicted to be much higher, as shown in Figure 7.2 below (OECD-FAO

58 FAO Director-General Jacques Diouf opening statement of the Forum on *How to Feed the World in 2050*, held 12-13 October 2009 in Rome

op cit), although with stable oilseed production projected over the next seven years, the EU will continue to remain a large net importer of oilseeds over the medium term (DGAgri, 2009).

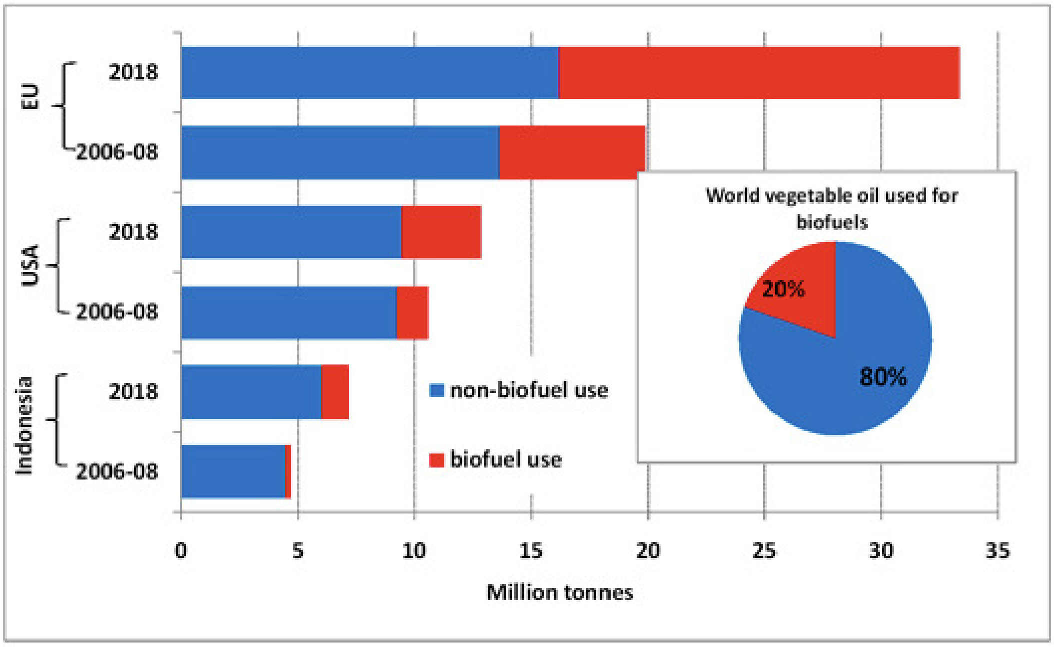


Figure 7.2 Projected use of vegetable oil in the production of biodiesel (source: OECD, 2009)

EU cereals production, after the peak of 2008/09 with more than 310 million tonnes, is projected to decline slightly over the next couple of years before growing over the medium term and reach just above 300 million tonnes, by 2015. Some of this increase has come from the more than 3 million hectares of former set-aside land, much of it already returned to production.

Although growth in agricultural productivity in the EU slowed over 2000 - 2006 relative to the 1990s, as in other developed economies, some further increases in crop yields per hectare and outputs per animal, are expected in response to higher prices driving technological change. Over the next decade rises in agricultural productivity will be greatest in the EU-12 Member States, with rapid transfer of new and existing technologies (Cooper *et al*, 2009). For example, farmers in the EU-12 Member States, who were unable to afford fertilisers and pesticides on any scale before accession to the EU, may increase usage of these inputs as they become more affordable in the context of full participation in the CAP[59]. Over the next ten years, consumption of plant nutrients (N+P+K) in the EU is forecast to increase by 6% for cereals and 26% for oilseeds, in contrast to an expected decrease of 7% for fodder crops and 9% for grassland, due to the trend toward extensification in the meat sector (EFMA, 2009). There are significant regional differences in these predicted of changes. In EU-15, over the period 2008-18, there will be general reduction in all plant nutrient consumption, in contrast to a general increase in EU-12 (except Slovenia). This is partly due to the current low phosphorus and potassium application rates in the majority of the EU-12 countries, but also the result of a significant rise in nitrogen consumption in the EU12, which will outstrip the

---

59 As a result of the CAP, the single market and higher market prices, farmers' income in the EU-12 is now 47% higher than before accession (source: http://ec.europa.eu/budget/budget_detail/next_year_en.htm December 2009)

projected decrease in EU-15 consumption, leading to an overall increase in N consumption of 3.8% for EU-27. The differences are illustrated in Figure 7.3

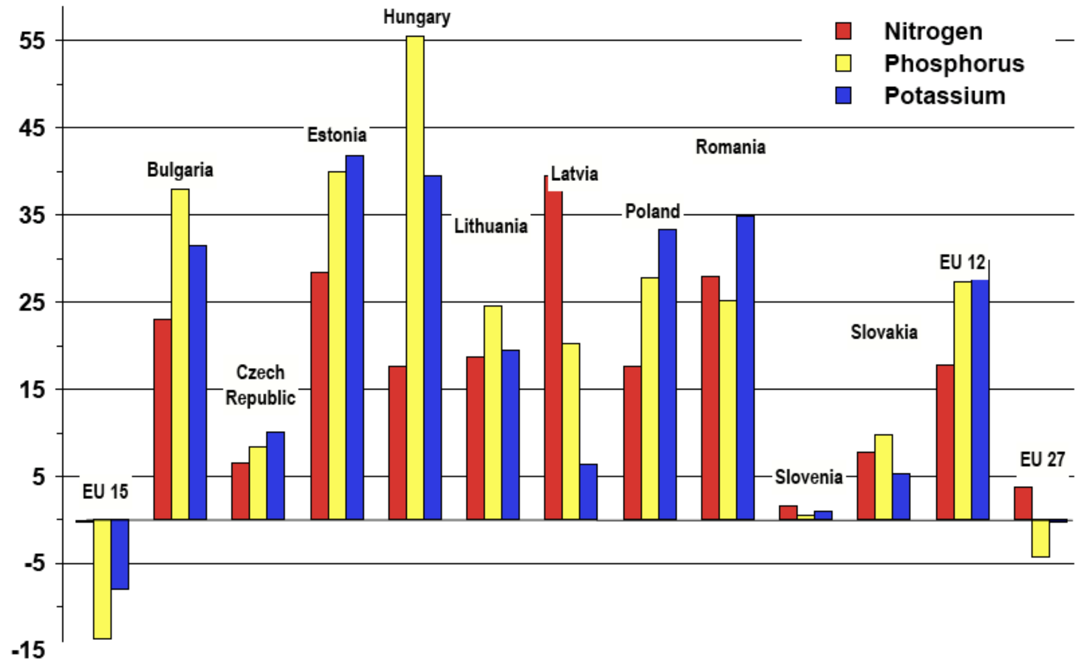


Figure 7.3 Forecast percentage change in fertiliser use 2008-2018 (source: EFMA, 2009)

The implication of these trends is likely to be the intensification of arable production in parts of EU-12 and consolidation of existing patterns of specialisation and concentration of production in EU-15, particularly for existing arable farmers located in the most productive areas, such as the Paris Basin, the Po Valley, Italy and eastern England.

Fluctuations in cereal prices affect livestock prices too, particularly for farming systems that depend on cereal-based feed for all or part of the year. As increased feed prices drive up consumer prices of meat, the demand for beef and lamb will decline in favour of cheaper poultry meat. There is predicted to be a continuing decrease in beef production to 7.9 million tonnes in 2015, a decline of 4.3% from 2007 (DG Agriculture, 2009). Competition from external markets, such as Argentina and Brazil, further dampens the prospects for the EU's beef sector. The outlook for the sheep and goat farming sectors is equally unpromising, in line with past long-term trends and the impact of decoupling of ewe premiums in the major producing countries; production is expected to be less than 1 million tonnes by 2015, a decline of 9.6% from 2007 (DG Agriculture, 2009). On better quality land this may lead to the displacement of livestock production by cash crops, but this may not be an option on poorer land, further undermining the viability of marginal beef, sheep and goat systems, and increasing the threat of land abandonment particularly in the new Member States, where there were significant declines in grazing livestock numbers (largely cattle) between 1990 and 2000, whilst the share of pig production increased (EEA, 2005a). A predicted EU-27 increase in milk production of 2.3% above 2007 levels by 2015 masks a decline of 4.2% in EU-12, driven by a steady decrease in subsistence production (DGAgri, 2009).

This analysis suggests that current market conditions will serve to underline the vulnerability and inherent fragility of low-intensity grazing livestock systems in many parts of the EU and especially small, semi-subsistence farms in EU-12. This can be expected to generally have negative influence on the biodiversity quality of permanent pasture, and on habitat connectivity.

In the forestry sector significant land use change as a result of market forces seem unlikely, given the current marginal value of timber in the EU. However, forest expansion may occur opportunistically as a result of the abandonment of marginal farmland, or as a result of EAFRD funded schemes for environmentally beneficial afforestation of agricultural land. Such measures may also support the creation of new native woodland as biodiversity corridors or as buffer zones between intensively managed farmland and designated Natura 2000 sites.

Markets and policies for renewable energy

The bioenergy sector, particularly biofuels, has created a new market outlet for cereals, sugar and oilseeds. It is a rapidly developing market that emerged as a result of concerns over energy security and unsustainable levels of greenhouse gas emissions, and is now underpinned by related policy interventions. The US, Brazil, Thailand, India and China have all set mandatory targets for the use of biofuels in liquid transport fuels (World Bank, 2008), and the EU is pursuing ambitious targets for 2020[60]. These targets drive an increase in the global demand for biofuel feedstocks, and in the EU more vegetable oil (much of it imported) will be used for the production of biodiesel, but domestic consumption of EU-grown cereals is also projected to keep growing over the medium term, mainly driven by the rapid growth in bioethanol use, which is expected to more than double over the next six years (albeit from a very low base) and reach 20 million tonnes by 2015 (OECD, 2009 and DG Agriculture, 2009). There is some concern that grazing land may be converted to grow energy crops, or to grow conventional arable crops if energy crops displace these from the current arable land. The Renewable Energy Directive 2009/28/EC (RED) attempts to limit the negative consequences of expanded European demand for bioliquids and biofuels by proposing a series of sustainability criteria, including that biofuels and bioliquids '*shall not be made from raw material obtained from land with high biodiversity value*', defined as forests, nature reserves and '*highly biodiverse*' grasslands. The clarification of what this means, particularly for non-natural grasslands, could have a significant impact on the extent to which grasslands rich in biodiversity can be protected from destruction for the purpose of establishing energy crops. If energy feedstocks fail to meet sustainability criteria they will not count towards RED target or be eligible for EU subsidies and therefore will not be financially viable. However the projected increase in oilseed crops for biofuel and consequent displacement of other arable crops could still lead to indirect pressure on grasslands in the more fertile areas.

Farm structures, land tenure and social changes

The structural scale of farms affects the ability to use certain machinery and technologies, labour availability, and the opportunities to maximise returns per hectare by changes to stocking and cropping. Smaller farms have several attributes which may, in principle, result in their adopting less intensive management techniques. These include constraints on economies

60 On 17 December 2008 the European Parliament agreed on a Directive to ensure that to ensure renewable energy makes up at least 20 % of the EU's total energy consumption by 2020, with renewable energy accounting for at least 10 % of the EU's total fuel consumption in all forms of transport.

of scale achievable, limited access to capital for many small farms and the disproportionate representation of more traditional part-time and organic producers. Even where intensity of production on the holding is no lower than average, a landscape populated by small farms is likely to offer a greater variety in the crops grown, management systems and features, because of the larger number of decision takers and their varying perspectives, situations and abilities (Cooper *et al*, 2009).

The Scenar 2020 study (European Commission, 2006c) concluded that the relative competitive advantage in certain commodity markets will develop unevenly across the EU; for example, growth in crop production will be slightly higher in the EU-10 than in EU-15, but growth of livestock production will be almost twice as high in the EU-15 than in EU-10. These regional responses to commodity markets will inflect the general trend of a decrease in the number of farm units and an increase in their average size[61]. An important feature of EU agriculture is the production of agricultural commodities on family farms operated by part-time farmers who also engage in other activities. This differs among Member States from 40% in Belgium, Ireland, Luxembourg and the Netherlands to about 80% in Greece, Spain, Italy and Portugal (European Commission, 2006c).

It is predicted that by 2020 out-migration from peripheral areas (particularly on the eastern EU frontier and in the north-west corner of the Iberian peninsula) will cause a labour deficit which, compounded by difficulty of access to markets, will encourage rationalisation of farm structures and accelerate of the shedding of labour in the agricultural sector; another possible outcome is land abandonment. In several areas of new Member States there are deep social and economic problems affecting traditional farming communities, including high levels of rural unemployment, loss of agricultural markets, poor working conditions in agriculture and lack of investment. Although older farmers may have accepted generally low living standards and their place in a strong rural culture, the next generation frequently seeks occupations offering greater financial rewards and shorter working hours, often in towns and cities.

A change in ownership of farms, particularly a generational change, may often be accompanied by changes to land management or farm structures. As the new Member States take advantage of EU membership and a growing economy, young people are more likely to move to towns and cities, threatening the survival of many small rural communities. The rapid increase in the opportunity costs of labour was the one of factors behind mechanisation and intensification of low input agricultural systems in Europe after the Second World War, although recent policy developments have reduced incentives for further intensification (Strijker, 2005). In certain intensification contexts, restructuring may increase the pressure:

- to remove landscape features;
- to convert grasslands to arable use; or
- lead to a cessation in management of features and abandonment as time is diverted to other activities.

Landscape simplification may also occur in the context of economic marginalisation whereby features are lost due to lack of management, with implications for biodiversity corridors.

Economically marginal farmland is often of low market value, particularly if it is not eligible for CAP payments. This may make it attractive to developers seeking land for infrastructure,

---

[61] A 25% decline in the number of farms between 2003 and 2020 is differentiated at around -2% p.a. in EU- 15 and -4% p.a. in EU-10

housing or tourist developments, as has happened in Romania and along the coasts of Estonia and Croatia. Farmers may hold unused land in the hope of a future sale, managing it only to the minimum standard required by GAEC cross-compliance, or perhaps not managing it at all. Some farmers may find it more profitable to cease low intensity livestock farming and convert their grassland to other uses, including EAFRD supported afforestation of agricultural land for environmental purposes.

Climate change

As described in Chapter 2, climate change is likely to have an increasingly important influence on agriculture in the EU. However, the likely impacts are complex, uncertain and spatially differentiated, driven by the interaction of many factors in different bio-geographic situations - warmer temperatures, the effects of increased CO_2 concentrations on crop growth and variability in weather patterns.

Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but to decrease at temperatures above this[62]. Climate change is expected to lead to a yield increase for most crops in most parts of Europe over the coming decades. The magnitude of this effect is still uncertain but cereal yields could be 1-3 tonnes/ha greater than at present. However, other factors may reduce yields or limit the ability of farmers to achieve their potential. For example, water supply is a critical factor is and there is considerable uncertainty and variations in projections of regional precipitation. As happened during the heat wave in 2003, a lack of precipitation could convert the positive effect of climate change (stimulated plant growth) into a negative effect (decrease in yield due to water stress). This threatens particularly the southern and eastern parts of Europe (European Commission, 2006c). Increased cereal yields might lead to intensification pressures in some parts of the EU, while water stress, flooding and the impacts of extreme events might lead to marginalisation elsewhere. The impacts on grassland and livestock farming are likely to differ significantly between southern and northern Europe, as shown in Table 7.1 below.

Table 7.1. Impacts on grasslands of incremental temperature changes in local temperature (after IPPC, 2007)

Local temperature change	Sub-sector	Region	Impact trends
+0-2°C	Pastures and livestock	Temperate	Alleviation of cold limitation increasing productivity Increased heat stress for livestock
		Semi-arid and Mediterranean	No increase in net primary productivity
+3°C	Pastures and livestock	Temperate	Neutral to small positive effect (depending on GMT)
		Temperate	Negative on swine and confined cattle
		Semi-arid and Mediterranean	Productivity decline Reduced ewe weight and pasture growth More animal heat stress

62 The IPPC (2007) projects slight increases in crop productivity at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, but at lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C).

7.3 REVIEW OF DRIVERS OF LOSS OF PERMANENT GRASSLAND

7.3.1 Introduction

For clarity, as proposed in the technical proposal to this study, the issue of permanent grassland has been recast as by focusing on *the loss of permanent grassland*, which *may arise from the intensification and marginalisation of agricultural land use*.

Defining 'permanent grassland'

There are many definitions of permanent grassland, used for different purposes, and here we consider three, to illustrate the problems in obtaining accurate information about this land service:

- Permanent pasture as defined in the context of Pillar 1 CAP support;
- Semi-natural grassland; and
- High Nature Value (HNV) grasslands.

The definition of *permanent pasture* used for the purposes of agricultural policy (e.g. in GAEC standards for farmers and Member States' obligations to maintain permanent pasture under Regulation 793/2009) is very broad. It includes all farmland used for grass or other herbaceous forage that has not been included in the arable rotation for 5 years or more, capturing a very wide range of grazed land from biodiversity-rich HNV grasslands of Natura 2000 quality at one extreme, through other semi-natural grasslands, to cultivated grasslands (which may be less than 5 years old, if ploughed up and immediately reseeded as grassland). In the most intensive permanent pastures re-seeding with selectively bred cultivars of grass and other fodder species, and the use of mineral fertilisers and herbicides allows farmers to achieve high yields, but usually with little associated biodiversity value.

Semi-natural grassland essentially has developed as a consequence of pastoral agriculture being imposed on cleared woodland or drained marshland, or when natural climax grasslands have been modified by human activity but still retain a predominance of native species and remain relatively 'unimproved' in agricultural terms (Hopkins, 2009). Semi-natural grasslands may be associated with scrub, woodland, hay meadows, steppe or a combination of different types. This is a broader classification than 'High Nature Value' (HNV) grassland, but more specific than "permanent grassland" which includes agriculturally improved land.

High Nature Value (HNV) grassland is the most biologically valuable semi-natural grassland, typically an integral part of low intensity, low input farming systems, where semi-natural vegetation is utilised by livestock. High levels of structural diversity and the presence of other semi-natural features may be characteristic of many HNV grassland systems.

Defining 'loss'

Loss of permanent grassland may be temporary or permanent, and can be considered as loss of a specific habitat in situ, or as loss of part of a total resource, at any scale from individual farm to regional or national. Rotational, cultivated grassland is easily replaced within a year by reseeding, in the same or a different location. Long-established species-rich grasslands and other semi-natural habitats used for extensive grazing, important for their biodiversity, take decades to recover if cultivated. The ecological recovery of grasslands may take even longer following long-term overgrazing or agriculture improvements such as increased fertiliser use, herbicide treatments or drainage. Such grasslands are likely to have an impoverished flora and recovery may require proactive restoration measures to regain the original species composition.

7.3.2 Impact of drivers of intensification and marginalisation

Almost all the drivers of intensification and marginalisation reviewed in the previous section will have an impact on permanent grassland management because its use is so closely associated with livestock farming.

Farmers are still adjusting to the introduction of decoupled payments and it is too soon to evaluate the wider impacts on livestock systems, which are likely to differ from one area to another. Some farmers will see these as a source of income without the need to keep livestock, while others will have to maintain livestock numbers to secure the remaining coupled element of their direct payments, or recoupled Art.68 payments.

Biofuels

Apart from the indirect pressures on fertile grasslands from the possible displacement of arable food crops described above, it is possible that increased cultivation of short-rotation coppice and short rotation forestry as an energy crops could threaten a wider range of grasslands.

Afforestation

Some Member States have set ambitious targets for afforestation of farmland, offering farmers an element of income support for up to 15 years, in addition to planting and initial maintenance payments. Marginal grassland outside designated Natura 2000 areas may be targeted, especially where there are few prospects of improving agricultural incomes. The afforestation schemes must have environmental objectives, which can include the extension of forest resources as a contribution to climate change mitigation (provided that this will not harm biodiversity or cause other environmental damage). The protection of HNV grasslands from permanent loss to tree planting depends on the forestry authorities identifying grasslands important for biodiversity and refusing applications for these sites. More specific protection is provided for designated Natura 2000 grasslands in that afforestation must be consistent with the management objectives of the site.

Social factors

A significant area of HNV grassland in Eastern Europe is now owned by people who live elsewhere, as a result of the land restitution process following national independence. The new owners may be urban dwellers with no experience of, or particular interest in farming. Some of this land is rented by active farmers, but where no local farmers are able or willing to take it on the land may be managed just to meet the minimum standards of GAEC maintenance required for CAP payments, preventing complete abandonment.

Abandonment of grasslands

Brouwer *et al* (1997) identified two types of region that they considered to be susceptible for marginalisation, one characterised by extensive agriculture, where the stocking density of grazing livestock was very low (0.6 LU per hectare of forage crops), and the other by more intensively managed small-scale farms (average size 5 hectares), many of them growing permanent crops. This analysis pre-dated the EU-12 accession, which brought into the EU new Member States with significant areas of very small farms (many of them semi-subsistence) and extensively managed farmland. Figure 7.4 illustrates how much variation there was across the EU in 2005 in the proportion of total farmland that is forage land with low livestock densities, an indicator of extensive livestock farming. In the Baltic countries, Portugal, Sweden and Austria more than 40% of the farmed land has livestock densities less than 1LU per forage hectare, in contrast to Denmark, Ireland, the Netherlands and Belgium which, although important livestock farming areas, appear to have no extensively managed forage land.

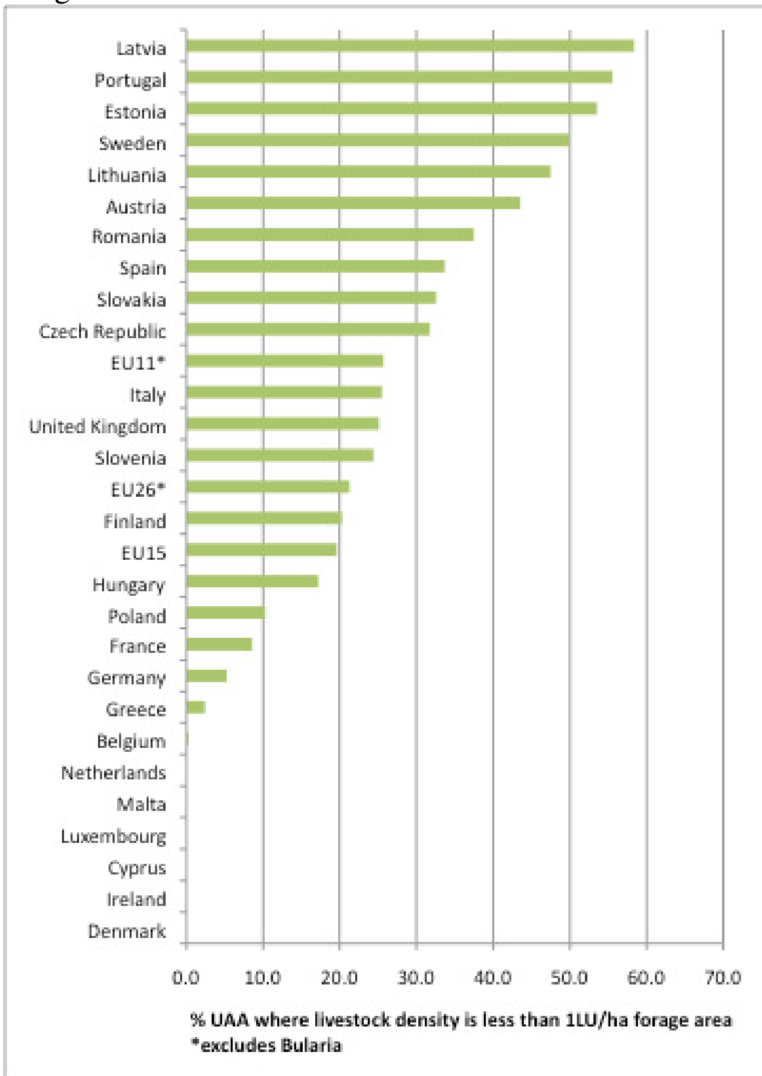


Figure 7.4 Percentage of UAA with livestock density <1LU/ha forage area in 2005 (own chart based on summary table 3.4.3.2 (areas of extensive agriculture) in EU, 2008)

Statistics on the area occupied by the different categories of permanent grassland are limited by the lack of precise definitions and different approaches followed in different countries. Pötsch and Krautzer (2009) suggest a total of 56 million hectares of various types of grasslands in EU-27, which is more than a third of the agricultural area, and estimate that the total grassland area in the EU declined by nearly 13% from 1990 to 2003. The EEA (2004a) estimated that 15-25% of the European countryside supported farmland of "high nature value" (mostly grassland) based on the EU15 countries. A more recent review by Emanuelsson (2008), quoted in Hopkins (2009), looked at regional differences and noted serious losses of semi-natural grassland in north-western Europe (Norway, Benelux, Denmark) and problems elsewhere due to the lack of grazing systems for maintaining semi-natural grassland (notably in parts of Germany, UK and Sweden). The situation in eastern and central Europe is mixed, with Romania probably having the greatest area of well-managed semi-natural grassland in Europe, but elsewhere drivers such as contractions in the agricultural sector and uncertainties about land ownership have resulted in large areas of semi-natural grassland now becoming unmanaged. In southern Europe the situation is also mixed. In alpine regions semi-natural grassland is often associated with tourism, and in many places it has a traditional link to niche food products (e.g. speciality cheeses) characterized by livestock feeding of forage (hay and grazing) of mountain pastures and meadows. Today, semi-natural grassland is mainly to be found in areas of low growth potential such as mountain pastures, drought-prone shallow soils, coastal salt marsh, heathlands etc., though there are some exceptions. Examples include lowland peaty areas and also situations where, for reasons of policy or land ownership, potentially productive grassland sites have survived with semi-natural grassland under traditional low-input management (Hopkins, 2009).

The dramatic drop in livestock numbers which accompanied the collapse of the Soviet system seems to have contributed to the semi-abandonment of large areas of semi-natural grazing land in central and eastern Europe, creating conditions where relatively small economic or social changes could tip the balance towards complete abandonment and permanent loss of these HNV areas. During the 1990s, millions of hectares of farmland in most of the new Member States were abandoned as a result of the transition process. Data on abandonment of HNV farmland is difficult to obtain, but it is clear that the scale of land abandonment varied according to a range of local conditions, and covered different types of farmland, although much of it is grassland - for example in Estonia 60% of the high and medium value grasslands were abandoned, a far higher proportion than for agricultural land generally. In the Baltic countries and Poland land abandonment is concentrated in regions where the productive capacity of soil is low on peaty or poor moraine soils. In central Europe, land abandonment is particularly concentrated on poor sandy soils in hilly regions and on wet soils in river valleys, and in south-eastern Europe is also observed in mountainous areas where traditional pasturing has ceased.

Agricultural land abandonment can be permanent or transitional and may take different forms, including actual abandonment where the land is not used at all by the owner or occupier; and semi abandonment or hidden abandonment, where there is still some form of management, which might be simply to keep it available for future use or to claim a subsidy. Very extensive or intermittent farming operations may also fall into this 'hidden' category, for example on some subsistence farms, where extensive management is generally associated with very low or zero market returns but can be of considerable conservation value[63]. Abandonment of semi-natural grasslands, particularly species-rich swards, generally has a negative impact on biodiversity, and also results in a structural change from an open to a closed landscape, leading eventually to recolonisation by trees and shrubs in most of Europe.

7.4 POLICIES THAT INFLUENCE INTENSIFICATION / MARGINALISATION AND PERMANENT GRASSLAND LOSS

7.4.1 Introduction

The CAP has been the most important influence on agriculture land uses in the EU and therefore on the degree of and location of intensification/marginalisation and the retention/loss of permanent grasslands. The most relevant CAP policy instruments are therefore described in detail below, together with their links to intensification/marginalisation and permanent grassland loss.

[63] Land Abandonment, Biodiversity and the CAP: land abandonment and biodiversity, in relation to the 1st and 2nd Pillars of the EU's common agricultural policy; outcome of an international seminar in Sigulda, Latvia, 7-8 October 2004.

Some water policy instruments also have an important influence on land management, albeit indirectly (and mostly through CAP instruments) and a brief review of the Water Framework Directive and Nitrates Directives are therefore provided at the end of Section 7.4.

Recommendations for CAP and water policy revisions and, where necessary new instruments to maintain and enhance the provision of land services is provided in Chapter 9.

7.4.2 Introduction to EU agricultural policy

The CAP has been a central element of European policy since the Treaty of Rome in 1957. The original focus was on supporting agriculture to provide stable food supplies, and this was achieved by a range of market measures including import tariffs, export subsidies, intervention purchasing, private storage aid, quotas and direct payments to farmers. Combined with far-reaching technological advances, the CAP was hugely successful in increasing agricultural production, which in turn led to problems of over production, increasing costs, incompatibility with international trade rules and concerns over environmental impacts. To deal with these problems the CAP has been subjected to several major reforms and an almost continuous process of adjustment for the past 50 years.

One of the most significant reforms, intended to create a more competitive, market responsive agricultural sector and align rural development expenditure with EU priorities, occurred in 2003-05 and coincided with the enlargement of the EU from 15 to 27 Member States. The basic structure of the CAP, which is likely to remain in place until at least 2013, is often characterised as two 'Pillars', with around three quarters of the budget in Pillar 1 where it is mainly used for direct payments to farmers. The remainder of the budget forms the European Agricultural Fund for Rural Development (EAFRD) to fund Pillar 2, used by Member States to support seven-year rural development programmes. The CAP budget for 2009 is €55.8 billion (41% of the EU budget).

The following assessment of agricultural policies does not deal with the market-based CAP policies (e.g. intervention buying, storage aids, export subsidies and import tariffs), which are not relevant to the focus of this study (and were largely unchanged by the 2003 reforms), but concentrates on the key elements of the CAP summarised in Box 7.2 below, which have significant impacts at farm level across the EU.

The key features of 2003-05 CAP reform were the decoupling of Pillar 1 direct support payments (which had previously been linked to the number of livestock or area of crops on a farm); new cross-compliance requirements for farmers; and the introduction of compulsory modulation. In 2009 the so-called 'Health Check' of the CAP broadened and deepened some of these reforms which, together with the agreed CAP budget, will remain in place until 2013, when the next significant CAP reform is expected, driven by pressures to reduce the CAP budget and to focus public funding more closely on the public benefits of agriculture

Box 7.2 The structure of the Common Agricultural Policy (CAP) today

Pillar 1[64] is used mainly for direct support payments to farmers under the Single Area Payment Scheme (SAPS) or the Single Payment Scheme (SPS), with associated cross-compliance requirements.

Pillar 2[65] is the European Agricultural Fund for Rural Development (EAFRD), with a budget of €13.7 billion in 2009, used to co-fund Member States' Rural Development Programmes, under four objectives or 'axes', each with Strategic Guidelines and a menu of measures from which Member States may choose those most appropriate for their needs, and design detailed support schemes for farmers and rural communities.

- Axis 1: improving the competitiveness of the agricultural and forestry sector;
- Axis 2: improving the environment and the countryside;
- Axis 3: the quality of life in rural areas and diversification of the rural economy;
- Axis 4: the Leader approach (area based local development plans).

Axis 2 expenditure is the element of the CAP budget explicitly identified as a source of finance for farm-level delivery of EU environmental priorities. The Council Strategic Guideline for Axis 2 specifies that:
'To protect and enhance the EU's natural resources and landscapes in rural areas, the resources devoted to axis 2 should contribute to three EU-level priority areas: biodiversity and the preservation and development of high nature value farming and forestry systems and traditional agricultural landscapes; water; and climate change. The measures available under axis 2 should be used to integrate these environmental objectives and contribute to the implementation of the agricultural and forestry Natura 2000 network, to the Göteborg commitment to reverse biodiversity decline by 2010, to the objectives laid down in Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (1), and to the Kyoto Protocol targets for climate change mitigation'[66]. The key Axis 2 actions identified under these Guidelines were refocused in 2009, indicating that *'agri-environment measures and forestry measures can be used in particular to enhance biodiversity by conserving species-rich vegetation types and protecting and maintaining grassland and extensive forms of agricultural production. Specific actions under axis 2, such as agri-environment measures or afforestation, can also help to improve the capacity to better manage the available water resources in terms of quantity and protect them in terms of quality. Furthermore, certain agri-environmental and forestry actions contribute to curbing emissions of nitrous oxide (N2O) and methane (CH4) and help to promote carbon sequestration'*.[67]

The overall balance of CAP funds between Pillar 1 and Pillar 2 is roughly 3:1 for the whole EU but this masks very significant differences between Member States, and in general the balance is more even in most of the EU-12 New Member States (and Austria) than in the 'old'

64 Regulation (EC) No 73/2009

65 Regulation (EC) No 1698/2005 as amended.

66 Community Strategic Guideline for Rural Development (programming period 2007 to 2013) Council Decision of 20 February 2006 (2006/144/EC).

67 Council Decision of 19 January 2009 amending Decision 2006/144/EC on the Community strategic guidelines for rural development (programming period 2007 to 2013) (2009/61/EC).

Member States. Figure 7.5 illustrates these differences in terms of receipts per hectare in 2013, by which time Pillar 1 direct payments will have been fully phased in for EU-12.

The current, unequal distribution of funding between the two CAP Pillars in EU-15 countries is slowly being rebalanced using a process of compulsory modulation through which a proportion of Pillar 1 direct payments to farmers each year are re-allocated to Pillar 2. From 2010 Member States can only use this extra rural development funding specifically for the 'new challenges' of biodiversity, climate change, renewable energies, water management and dairy restructuring. The rate of compulsory modulation started at 3% in 2005 and will rise to 10% by 2012 (with exemptions for small farms and higher rates for very large farms). The UK and Portugal are continuing to use additional voluntary modulation, with a total modulation rate of 19% in England for the period 2009-2012 (used to fund agri-environment and other measures).

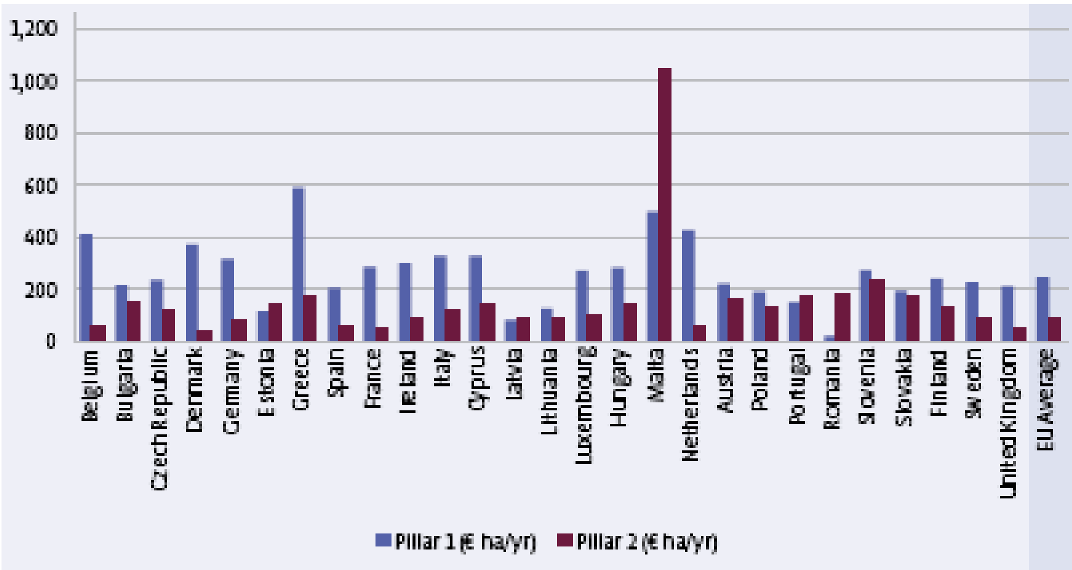


Figure 7.5 Average annual Pillar 1 and Pillar 2 receipts, €/ha of UAA (based on 2013 budget allocations, before additional voluntary modulation transfers in the UK (Natural England (2009) after European Commission (2009)))

7.4.3 CAP Pillar 1 direct payments (SPS and SAPS)

The basic rationale underlying Pillar 1 of the CAP can be traced back more than 50 years to the Treaty of Rome, at a time when agriculture in the six Member States was strongly affected by national intervention mechanisms that were incompatible with the free movement of goods. To allow agricultural produce to move freely within the Common Market, whilst maintaining intervention in the agriculture sector, some national intervention mechanisms had to be transferred to Community level. Although the original social and economic objectives of the CAP have remained unchanged since 1958[68] the policy tools have been regularly adapted

[68] Article 33 (39) of the EC Treaty sets out the internal objectives of the CAP:

- to increase agricultural productivity by promoting technical progress and ensuring the optimum use of the factors of production, in particular labour;
- to ensure a fair standard of living for farmers;
- to stabilise markets;
- to assure the availability of supplies;

for a variety of reasons (e.g. to counter over-production, to adapt to world trade rules and to accommodate new Treaty objectives such as economic and social cohesion and environmental protection). Prior to the 2003 CAP reform and the accession of twelve new Member States, farmers in EU-15 countries received Pillar 1 direct payments per hectare of crops and set-aside or per head of beef cattle, sheep and goats. This had a distorting effect on both individual farmers' stocking and cropping decisions and on overall production.

Decoupling of Pillar 1 payments

The purpose of decoupling of Pillar 1 payments in the 2003 reform was to make EU farmers more competitive and market orientated, while maintaining income stability. It also provided a simpler system of direct payments for the new Member States. The environmental significance of decoupling is in the shift from supporting *farm production* (of crops and livestock) to supporting *farmers' incomes.* Farmers can choose not to grow crops or keep stock at all and still receive decoupled payments, provided they observe cross-compliance requirements. In the EU-12 New Member States direct support from Pillar 1 (mostly under the Single Area Payment Scheme) has been paid on a flat rate per hectare basis since accession, with the opportunity to differentiate payments between arable land and grassland. The EU-15 Member States have the more complex Single Payment Scheme, introduced in stages since 2005, in which some or all of farmers' existing direct support payments have been 'decoupled' from crop or livestock production, and converted to payments per hectare of farmland. How these payments are calculated depends on the version of SPS adopted, but across most of the EU-15 decoupled payment rates per hectare vary from farm to farm, because they are based on an individual farm's historic payments before decoupling, with the highest rates per hectare on the most intensively managed farms (because they had received higher payments per farm under the previous 'coupled' system). England is phasing in a different model of decoupled payments, and by 2012 all farms within each of three zones[69] will have the same SPS rates per hectare, allowing a more even distribution of support, although the farms with the highest proportion of permanent semi-natural grazing land will receive the lowest rates per hectare.

Farmers risk losing part of their CAP payments if they fail to observe cross-compliance requirements aimed at promoting more sustainable agriculture. These are in two parts - Statutory Management Requirements (SMR) linked to EU legislation, and standards for maintaining land in Good Agricultural and Environmental Condition (GAEC)[70], defined at Member State level. Cross-compliance now applies both to direct support payments and agricultural land management payments in Pillar 2, and the standards have to be observed on the whole farm, not just on the parcels eligible for payments. SMR and GAEC cross-compliance are discussed separately below.

Link to intensification/marginalisation and maintenance/ use of permanent grassland

The decoupling of direct payments from production reduced incentives to maintain current patterns of production that had previously been linked to support payments. Decoupled payments allow farmers more flexibility to respond to market signals and adapt their farming

- to ensure reasonable prices for consumers.

69 The lowest rate is for moorland SDA, then non-moorland SDA, with the highest rate in the rest of England outside the SDA.

70 Articles 5 and 6 and Annexes II and III of Regulation (EC) No 73/2009

systems, and cropping and stocking patterns, including the option not to farm at all, provided they observe cross-compliance standards. The impact of this on intensification and marginalisation and on permanent grassland will vary from farm to farm and over time, depending on a complex mix of factors including the profitability of different enterprises, farm structure, availability of capital, the availability and opportunity cost of labour, the impact of cross-compliance and the preferences of individual farmers.

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

The intensive arable sector in EU-15 was already strongly market–orientated before decoupling and although decoupled Pillar 1 income support may cushion the impact of price variability on the farm business, and possibly allow farmers to make more 'risky' cropping decisions, markets are likely to be the main driver of cropping decisions. On more productive land, farmers' greater responsiveness to the market is likely to lead to further intensification, and more rapid changes in cropping patterns and possibly the cropped area, with land being converted from grassland to arable, for example in response to high world cereal prices or the emerging biofuels market. This may affect biodiversity corridors and possibly lead to the loss of permanent grassland, although that depends on the scope and effectiveness of regulatory controls preventing conversion.

The livestock sector is likely to see significant changes as a result of decoupling, especially in the marginal, extensively managed grazing systems on permanent grasslands and semi-natural habitats where farm incomes are heavily dependent on CAP payments, and decoupling breaks the link between number of livestock and household income. In many of these areas livestock numbers are likely to decline as a result of decoupling, and both beef and sheep production will move to more productive land. In the dairy sector decoupling makes it easier for marginal dairy farmers to move into beef production, or out of livestock altogether without losing their direct payments. The predicted impact of decoupling in England is illustrated in Box 7.3 below.

Box 7.3 Predicted impacts of decoupled SPS payments in England

- Sheep are expected to become more common on lowland areas and less common in the uplands;
- Beef cattle to become less numerous overall (but with marked decreases in uplands); some increases in dairy areas; losses from least productive parts of existing lowland semi-natural grazed habitats such as heath lands (unless sustained through environmental management);
- Dairy to continue the trends towards fewer but larger farms concentrated in lowland areas with accompanying increases in maize production;
- In most productive arable areas larger scale, block cropping of wheat and rape and simplified rotation systems (in which fallow plays a significant role) are likely to become more dominant. (CSL/CCRU, 2006)

There will be some benefits from decoupling for the biodiversity quality of permanent grassland and other grazed semi-natural habitats where coupled livestock payments had encouraged over stocking, for example in parts of the UK and Ireland. Headage payments, for sheep in particular, had led to widespread environmental degradation, particularly in valuable upland habitats (Brown *et al*, 2001) and the reduced grazing pressure will allow these habitats to recover. But in other parts of the EU there is concern that numbers of grazing livestock, particularly cattle, will be too low to maintain important habitats because these farming systems are uneconomic. In high nature value grassland habitats of parts of southern and eastern Europe, already suffering major problems of abandonment and a dramatic decline in livestock numbers following the socio-political changes of the past 20 years, decoupled payments are helping to maintain important grassland habitats, although these may now be mown (to meet cross-compliance requirements) rather than grazed.

7.4.4 Cross-compliance - Statutory Management Requirements (SMR)

Farmers receiving CAP payments risk losing some or all of their CAP payments if they fail to comply with 19 Statutory Management Requirements (SMRs) based on pre-existing EU Directives and Regulations covering public, animal and plant health, animal welfare and the environment[71]. SMR cross-compliance now applies to seventeen Member States using SPS direct payments and is being phased in for the other ten that are using SAPS (during 2009-11 for most of them but not until 2012-14 for Bulgaria and Romania).

Link to intensification/marginalisation and maintenance/ use of permanent grassland

The SMR compliance standards at farm level should be directly linked to relevant obligations in the regulations protecting Natura 2000 habitats and species on farmland, with implications for biodiversity corridors, permanent grassland and other farmland habitats which are designated Natura sites (or used by Natura species). SMR standards linked to the Nitrates Directive include restrictions on the application of fertilisers (which may lead indirectly to the creation of permanent grassland) and other measures to improve the biological quality of ponds, ditches and other water bodies, which may help to protect biodiversity corridors.

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

Where permanent grassland is within a designated Natura 2000 site it should be protected from both loss and damage, whether from intensification or other pressures, and also from the negative effects of marginalisation, because Member States have a duty to maintain habitats for wild birds in SPAs, and to establish 'favourable conservation status' for habitats in SACs. In practice Member States appear to have had some difficulties in defining specific farmers' obligations under the Birds and Habitats Directives, especially in relation to habitat protection and management, and where Natura 2000 sites have not yet been designated, no action can be required of farmers in relation to cross compliance. Only 11 of the 17 Member States were judged to have applied comprehensive farmers' obligations for these two SMRs (Alliance Environnement, 2007; ECA, 2008). Grazed Natura 2000 habitats, almost all of them permanent grassland, should be protected from *intensification* by the legal restrictions, which typically require prior approval for activities which might damage the habitat (as in Germany, Sweden and the UK, see Box 7.4), but these restrictions can vary from site to site, and farm level cross-compliance checks have been criticised as inadequate (ECA, 2008). SMR cross-compliance is unlikely to prevent *marginalisation* of Natura 2000 land unless it is accompanied by agri-environment or similar payments for positive action by farmers (e.g. to maintain specific grazing levels). It has been suggested that SMR cross-compliance places a disproportionate burden on farmers managing HNV extensive livestock farms (Boccaccio *et al*, 2009), and that this and other factors may present significant barriers to accessing CAP support, particularly for semi-subsistence HNV farms managing important permanent grassland areas in some of the new Member States (Jones, 2009; Keenleyside and Oppermann, 2009). In contrast, large specialised intensive arable farms do not need to consider the twelve SMRs concerned with livestock, and are more likely to already be compliant with the relevant regulations.

---

[71] Including elements of the Birds Directive (79/409/EEC), the Habitats Directive (92/43/EEC) and the Nitrates Directive (91/676/EEC).

Box 7.4 Examples of SMR farm-level requirements for Natura 2000 sites designated under the Birds and Habitats Directives

Sweden - permission must be obtained to undertake any activities that may have a significant impact on the environment within a protected area.

Spain - fencing of habitats, stubble burning and road construction are prohibited, and there are prescribed conservation measures for some Natura 2000 areas.

Germany - permission must be obtained to undertake any activities that may have a significant impact on the environment within a protected area, and in some Länder 'protected area regulations' or individual arrangements place additional requirements on farmers – e.g. prohibition on ploughing grassland or making changes to water levels; requirements to retain landscape features.

UK - every Natura 2000 site is also designated as a Site of Special Scientific Interest where land management is regulated by national laws requiring land managers to seek consent for potentially damaging activities (specified for each site) and to comply with any management notices.

In Nitrate Vulnerable Zones (NVZs) compliance with the Nitrates Directive should discourage farmers (especially livestock farmers) from further intensification because of the requirements for nutrient balances, adequate manure storage and the limit of 170kg N/ha/year from livestock manure (although there are some derogations from this, of up to 250kg/ha/year). Figure 7.6 shows the location of designated and potential NVZs in the EU-25. Even if farmers in NVZs continue existing intensive management they may have to change farming practices and invest in manure storage facilities, manure applicators, and manure disposal. Brouwer and Hellegers (1996) concluded that major adjustments are required on certain farms in certain regions, and the Nitrates Directive will therefore have significant regional variations in its impact, and in a study of seven Member States Kuik (2006) found the costs per hectare of implementing the Nitrate Directive varied from €6 to €236, caused at least in part by differences in industry structure, livestock intensity, historical rates of fertiliser application, and the vulnerability of soils to nitrate leaching. In the Netherlands, the annual costs associated with the administration of the farm-gate balance were estimated at €1,500 per farm and many farmers also paid high levies for N and P surpluses (RIVM, 2002; cited in Oenema, 2004). Where compliance with NVZ action programmes requires permanent green cover and/or prohibits all use of fertilisers (e.g. near watercourses) it is possible that this may lead to the permanent conversion of arable land to grassland, with a potential impact on the total area of permanent pasture (although it may be mown rather than grazed). In the intensively farmed areas of NW Europe the effect of reducing the existing intensity of farming may lead to marginalisation pressures on farm businesses (e.g. small dairy farms) if they cannot absorb the costs, or to marginalisation of certain areas within farms. There are additional concerns about the impact of the Nitrates Directive when it is introduced in the other ten Member States, which have both intensive farms and large numbers of small livestock units. On the one hand there is scepticism that countries may formally transpose EU legal requirements but fail to follow these through into substantive changes in norms and practices (Karaczun, 2005); on the other hand it is likely that the scale of the investment required (for example in manure storage) could marginalise some small extensive livestock farms, possibly leading to intensification (if they are amalgamated into larger units) or to loss of biologically rich permanent grassland if their grazing land is abandoned or converted to arable.

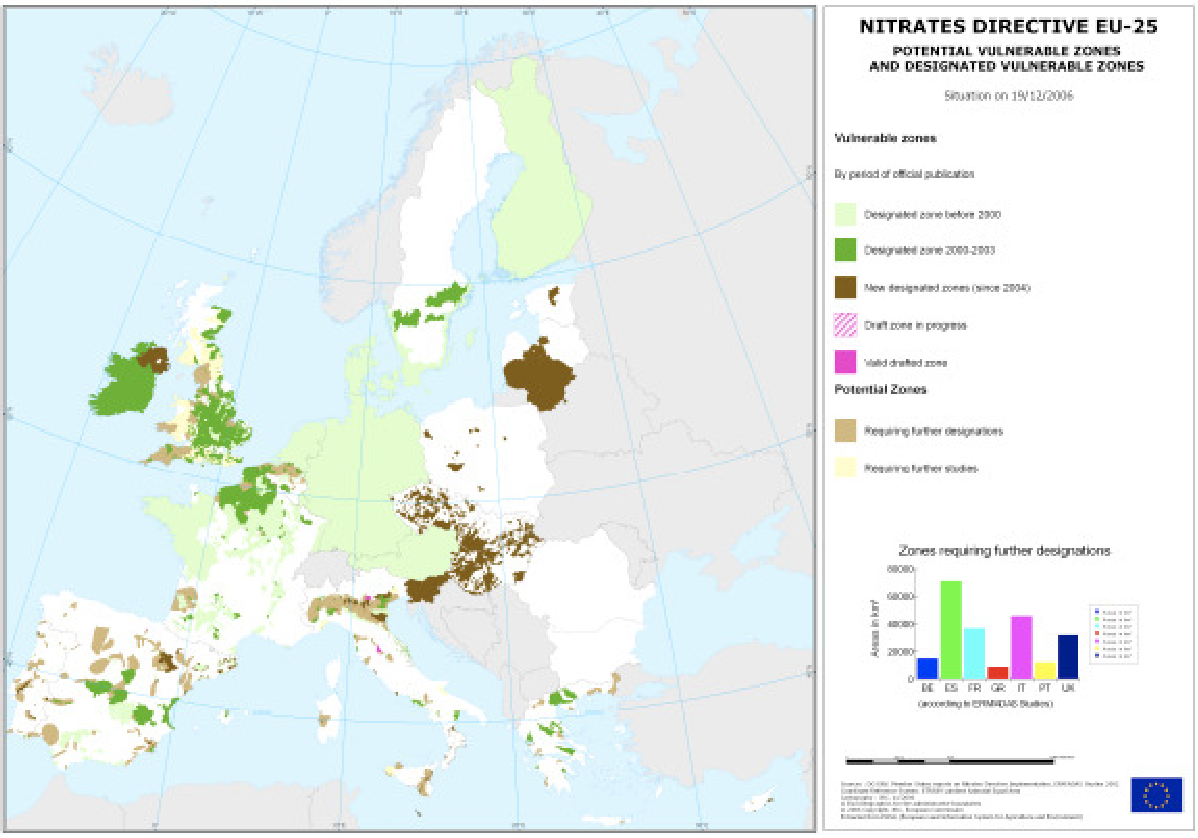


Figure 7.6 Nitrate Vulnerable Zones designated in EU-25 (2006) and area requiring designation according to Commission assessment (source: European Commission (2007) Annexes to SEC (2007) 339)

Effectiveness of SMR cross-compliance

It is very difficult to separate out any *additional* effect of SMR cross-compliance on farmers' behaviour, because this legislation applies at farm level irrespective of whether or not CAP payments are claimed, but for claimants there is the potential loss of CAP payments in addition to any legal penalties. It is likely that farmers' awareness of their obligations has increased as a result of advisory material and enforcement of administrative requirements, such as those for tagging and recording movements of livestock. Whether overall compliance with regulations has also increased is unclear, and inspection rates are low, at only 1% (although 75% of the compliance inspections must be based on risk assessment). On the basis of audit checks in seven Member States[72] the European Court of Auditors (ECA, 2008) concluded that some countries had only partially implemented cross compliance, and that the legal framework for cross compliance was too complex, particularly for some SMR requirements. There is also some evidence that the most frequently penalised non-compliance is with SMR standards such as cattle identification, that are much easier to inspect than the site-specific requirements of the Habitats and Species and Birds Directives.

[72] Finland, France, Greece, the Netherlands, Poland, Portugal and Slovenia

7.4.5 Cross-compliance - Good Agricultural and Environmental Condition (GAEC)

Description

The stated purpose of this part of cross-compliance is '*to ensure that all agricultural land, especially land which is no longer used for production purposes, is maintained in good agricultural and environmental condition*'. Member States must define verifiable farm-level requirements for GAEC based on the framework shown in Table 7.2 below, taking into account the specific characteristics of the areas concerned, including soil and climatic conditions, existing farming systems, land use, crop rotation, farming practices and farm structures.

The GAEC framework was extended as part of the 2009 Health Check of the CAP, with the addition of new standards for: buffer strips along watercourses (to be implemented by 2012); for water abstraction; and for the establishment and/or retention of habitats, offering Member States an opportunity to recapture some of the environmental benefits of set-aside (both to be implemented in 2010). Other changes include a more detailed specification of landscape features, and distinction made between compulsory and optional standards.

Table 7.2. Framework of issues and standards for GAEC cross-compliance (standards shown in *italics* were added in 2009) (source: Annex III of Regulation EC 73/2009)

Issue	Compulsory standards	Optional standards
Soil erosion: Protect soil through appropriate measures	- Minimum soil cover	- Retain terraces
	- Minimum land management reflecting site-specific conditions	
Soil organic matter: Maintain soil organic matter levels through appropriate practices	- Arable stubble management	- Standards for crop rotations
Soil structure: Maintain soil structure through appropriate measures		- Appropriate machinery use
Minimum level of maintenance: Ensure a minimum level of maintenance and avoid the deterioration of habitats	- Retention of landscape features, including, where appropriate, *hedges, ponds, ditches trees in line, in group or isolated and field margins*	- Minimum livestock stocking rates or/and appropriate regimes
		- Establishment and/or retention of habitats
	- Avoiding the encroachment of unwanted vegetation on agricultural land	- Prohibition of the grubbing up of olive trees
	- Protection of permanent pastures	- Maintenance of olive groves and vines in good vegetative condition
Protection and management of water: *Protect water against pollution and run-off, and manage the use of water*	*- Establishment of buffer strips along water courses*	
	- Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures	

Member States have had considerable freedom to choose how to define and implement GAEC standards, although this will be reduced somewhat from 2010, with the new distinction between compulsory and optional standards. Some Member States have made particular efforts to design and target GAEC obligations to achieve real environmental benefit, for example in France where farmers must provide 5m wide buffer strips along watercourses (see Box 7.5). However, in other cases weaknesses are perceived in some defined obligations, for example in Austria where mowing to remove unwanted vegetation is permitted during the bird breeding season, and a derogation allows terraces to be removed for reparcelling projects, and in Italy where stubble burning is permitted in Natura 2000 sites (Boccaccio *et al*, 2009). In many cases existing national regulations have been used as GAEC standards – this is the case for more than half the GAEC standards in the UK.

Link to biodiversity corridors, intensification/marginalisation and maintenance/ use of permanent grassland

Several GAEC standards are directly relevant to the provision of land services, including compulsory standards for:

- the retention of landscape features, including hedges, ponds, ditches, and trees growing in lines, groups, isolated or in field margins; retention of terraces; prohibition on grubbing up olive trees and maintenance of olive groves and vines in good condition; (many of these features form biodiversity corridors);
- the protection of permanent pasture;
- avoiding the encroachment of unwanted vegetation on agricultural land (both linked to both intensification/marginalisation and the protection of permanent pasture); and
- (from 2012) the establishment of buffer strips along watercourses (which could help to reduce water pollution by silty nutrient-rich run-off and thus improve the biological quality of wetland biodiversity corridors, provide new linear grassland corridors and increase the area of permanent grassland in arable farming regions).

Optional standards related to the provision of land services include:

- minimum stocking rates or appropriate regimes (linked to both intensification/marginalisation and the management of permanent pasture); and
- (from 2010) establishment or retention of habitats is a potential means of creating or retaining biodiversity corridors and permanent grassland, especially in areas of intensive agriculture.

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

Landscape features of farmland often provide biodiversity corridors, and almost half of all Member States have GAEC farmers' obligations that protect a range of landscape features including unproductive natural habitats on farms and man-made structures (Alliance Environnement, 2007). Some Member States have targeted the retention of specific features such as stone walls, hedgerows, small woods and terraces, for example in Germany and the UK where GAEC standards correspond to the actual diversity of farmland features present. In other countries common features have been omitted, as in France where the rich diversity of farmland hedgerows, trees and stone walls are not protected by GAEC. Some countries have based GAEC standards on pre-existing national regulations, but in other Member States the requirements are more general, as in Spain where the national law establishing GAEC refers to the 'maintenance of the structure of the terrain', although it only explicitly mentions field margins. Nine Member States have farmers' obligations relating to the retention of terraces[73],

[73] Austria, Cyprus, Czech Republic, Germany, Greece, Spain, Italy, Luxemburg and Romania

although only in Romania and Spain are terraces also to be maintained. In a few other cases some form of management has been specified providing a slightly higher baseline level of protection, as in the UK where there are restrictions on the timing of hedge cutting, to protect bird species during the main breeding season (Farmer *et al*, 2008).

The GAEC mechanism has already been used by several Member States to create new grass buffer strips on farmland as illustrated in Box 7.5. The authors of a French case study estimate that approximately 423,000 ha of grassy buffer strips have been created next to watercourses since the introduction of the national GAEC standard for 'environmental cover' (Pointereau and Coulon, 2008). Grass strips alongside watercourses may have an effect on water pollution by reducing the amount of spray and fertiliser drift reaching watercourses and by intercepting silty run-off, but these strips need to be reasonably wide if they are to achieve significant benefits. There may also be biodiversity benefits from buffer strips, for example for some invertebrates and the birds that feed on them, but there is little evidence currently available (benefits for plants are likely to be lower due to the relatively fertile conditions).

Box 7.5 Examples of GAEC cross-compliance used to create or improve biodiversity corridors

Austria
No tillage operations next to watercourses, or 10m adjacent to stagnant water bodies and 5m next to other watercourses.

England
A strip of land must be left uncultivated adjacent to hedgerows and watercourses. The strip should measure two metres from the centre of a hedge and a minimum of one metre from the top of the ditch bank. The strip must not be cultivated nor have fertilisers, herbicides or pesticides applied to it. The standard targets two key habitats (watercourses and hedges) and does not apply to small fields (defined as being of two hectares or less) or to newly planted hedgerows less then five years old.

Finland
There must be a 60cm wide, untilled verge between fields and major ditches and/or watercourses, where no fertiliser or pesticide application is allowed.

France
3% of the area declared in order to obtain CAP subsidies must be sown with an environmental cover. This strip should have a minimum width of 5m, a maximum width of 10m and a minimum surface area of $5m^2$. Strips alongside watercourses should be prioritised, although if this is insufficient to reach the 3% requirement, strips alongside linear features should also be targeted. The sowing of an environmental cover with species authorised by each department is obligatory between 1 May and 31 August. Fertilisers and pesticides cannot be applied to the strip. Small producers (defined as those with a cultivated area less than that needed to produce 92 tonnes of cereal) are exempt. Exemptions also apply when no watercourses are present on the holding.

(Case Study Reports; IEEP, 2008a; Alliance Environnement, 2007) in Farmer *et al* (2008)

Several Member States have GAEC requirements to maintain pasture by grazing or appropriate mowing regimes – for example, Spain and Greece have set national minimum stocking levels (with regional variations) and appropriate mowing regimes. In France, stocking density criteria are set locally, while in Ireland stocking levels are set only in targeted areas including commonages. In Luxembourg, abandonment of agricultural land is prohibited. As shown in Box 7.6, the UK has farmers' obligations to avoid overgrazing and unsuitable supplementary feeding but no stocking densities are specified.

Box 7.6 GAEC standards for grazed semi-natural habitats in the UK (England)

The aim of the GAEC over-grazing requirements[74] is to protect important grazed habitats that contain natural or semi-natural vegetation, including heathland and moorland, unimproved grassland, grazed woodland or forest, and sand dunes. No stocking densities are set, because optimal stocking rates vary with the location, type and current state of the habitat. Farmers must not:

- graze so many livestock that the growth, quality or diversity of natural or semi-natural vegetation is adversely affected; or
- provide supplementary feed for livestock in a way that adversely affects the quality or diversity of natural and semi-natural vegetation through trampling or poaching of land by livestock, or by ruts caused by vehicles used to transport feed.

Detailed guidance on best practice is provided in the farmers' handbook[75].

Member States have introduced a range of specific GAEC standards to protect permanent pasture at farm level (in addition to the obligation on Member States to ensure that a certain proportion of their UAA is permanent pasture - see below and Annex 1). In the Czech Republic, Germany, Greece, Spain and Italy ploughing up of permanent pasture requires prior authorization, in the Netherlands farmers must declare the area of permanent pasture, and in the UK, there are measures to protect ecologically valuable natural and semi-natural permanent pasture by requiring GAEC cross-compliance with Environmental Impact Assessment Regulations. Even where Member States have no specific standards for permanent pasture, other standards such as those for grazing or mowing, and avoiding the encroachment of unwanted vegetation, may also contribute to the protection of permanent pasture (Alliance Environnement, 2007).

Limitations of GAEC cross-compliance standards

GAEC is primarily a broad-brush mechanism to ensure observance of minimum standards. Together with SMR cross-compliance (and minimum requirements stemming from some national regulations on fertiliser and plant protection products which are a pre-requisite for agri-environment contracts). GAEC forms the baseline for Pillar 2 environmental land management payments, which means that farmers cannot receive agri-environment funding for anything required by GAEC standards. Because both national legislation and GAEC standards vary significantly from country to country, reflecting regional priorities, it is possible that some Member States in one part of Europe will pay farmers under agri-environment schemes for environmental management that is part of the GAEC baseline elsewhere or vice versa. For example annual mowing of traditional hay meadows is a GAEC requirement in Sweden, where land use is more strictly regulated, but in the UK conservation management of hay meadows is an agri-environment option. This simply reflects the regional variation in baseline standards across Europe, but the ECA did criticise some Member States for not applying their own GAEC standards as the baseline for agri-environment payments.

Where GAEC standards are not based on legislation already in force, compliance can be an additional cost to the farm business, and setting standards that are too onerous could be counter-productive, if farmers balance the costs of compliance against the risk of detection and financial penalties, particularly where decoupled payment rates per hectare are low. Research has shown that Member States are generally reluctant to include GAEC standards

[74] Defra (2008) Single Payment Scheme The Guide to Cross Compliance in England – Version 1

[75] Defra (2008) Management of Habitats and Landscape Features: Guidance for Cross Compliance in England – Version 1

that require management (rather than simply obliging farmers to simply not remove a feature) or may result in a loss of income, such as protective buffer strips in England and France which reduce the total field area that can be farmed (Jongeneel *et al.*, 2008).

7.4.6 Member State obligations to maintain a proportion of land under permanent pasture

Description

In addition to the GAEC framework[76] which Member States use when defining verifiable farm-level standards, there is a separate, quantitative mechanism to maintain a proportion of farmland under permanent pasture. Member States must ensure that the proportion of permanent pasture within the total utilised agricultural area is kept at a level equivalent to at least 90% of the proportion in 2003-2005[77]. When introduced as part of the 2003 reform, the justification reflected concerns about the effect of decoupling on farmers' cropping decisions, stating that '*since permanent pasture has a positive environmental effect, it is appropriate to adopt measures to encourage the maintenance of existing permanent pasture to avoid a massive conversion into arable land.*'[78].

Permanent pasture in this context is defined as '*land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in the crop rotation of the holding for five years or longer….*' and 'grasses or other herbaceous forage' is defined as '*all herbaceous plants traditionally found in natural pastures or normally included in mixtures of seeds for pastures or meadows in the Member State (whether or not used for grazing animals)*[79]. However the rule does not apply to permanent pasture to be afforested, if the afforestation is '*compatible with the environment*'.

Rules for maintaining pasture at a given ratio have no precedent in national legislation, although there are rules governing the conversion of permanent pasture in a number of Member States, for example, in Austria and Belgium (Flanders) where national nature conservation law may restrict the conversion of permanent pasture.

Almost all Member States apply this rule regionally or nationally, with 'trigger levels' for precautionary action. When the ratio of permanent pasture to total agricultural area is decreasing farmers receiving direct payments have to apply for prior authorisation to convert permanent pasture. Austria applies this authorisation procedure as soon as any decrease is observed, other Member States have a range of different trigger levels (for details please see Annex 1). When a 10% decline is likely, Member States must require farmers to reconvert the permanent pasture they converted into other uses back into permanent pasture, or establish an amount of other land under permanent pasture. A few Member States require re-conversion before a 10% decline is reached e.g. at 8% in Slovenia, 7.5% in Belgium (Wallonia) and 5% in Latvia (Alliance Environnement, 2007).

---

[76] See Article 6.1 and Annex III of Regulation 73/2009

[77] Article 6.2 of Council Regulation (EC) No 73/2009, and Article 3.2 of Council Regulation (EC) No 796/2004 as amended. The baseline year varies between Member States.

[78] Paragraph (4) in the recitals at the beginning of Council Regulation (EC) No 1782/2003

[79] Article 2 of Regulation 796/2004 (as subsequently amended)

Link to intensification/marginalisation and maintenance/ use of permanent grassland

This policy enables Member States and the Commission to track the conversion of permanent pasture and, provided most grassland farmers apply for SPS or SAPS, to limit losses to no more 10% of the national or regional total area of permanent grassland, but because loss to environmental afforestation does not count in this calculation actual losses could be higher. Furthermore, because there is no location-specific impact at farm level (at least until there have been regional or national losses), there could potentially be very significant local conversion over a short period of time on suitable soils e.g. in some lowland dairying areas.

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

While this should prevent large scale losses of permanent pasture it is important to note that the 10% limit does not ensure the protection of precisely the same parcels that comprised 90% of the land that had permanent grassland present in 2003-05, because conversions (in both directions) can produce a 'revolving door' effect, although in more marginal cropping areas this will be limited by the capability of the land. This quantitative rule is aimed at avoiding massive conversion of grassland and uses a broad, agronomic definition of permanent pasture, ranging from heavily fertilised sown grass leys of low biodiversity value to species-rich permanent hay meadows and grazed heathlands. Unless Member States choose to apply additional location or habitat specific requirements (as in the UK where separate GAEC requirements apply to pastures more than 15 years old, see Box 7.7), the protective effect for biodiversity from the quantitative rule is not guaranteed, and valuable semi-natural habitats outside designated conservation areas may not be protected. Although the effectiveness of this quantitative rule may be limited for permanent pastures of high environmental value, Member States have the possibility of providing additional protection for these pastures if they so choose, for example by defining the compulsory farm-level GAEC standard on protection of permanent pasture in a way that makes a qualtitative distinction between different types of permanent grassland; by prioritising agri-environment measures**;** or by using other measures such as nature conservation legislation (as in Austria, Germany, Italy and the UK)..

Box 7.7 Using EIA regulations to protect HNV permanent pasture

The GAEC standards in England include compliance with a process of Environmental Impact Assessment[80], which provides farm-level protection for significant areas of permanent pasture.

A farmer planning to increase agricultural productivity on 2 hectares or more of uncultivated land or semi-natural area (for example by clearing vegetation, ploughing, draining, spreading fertiliser or lime, or reseeding) must apply to the national nature conservation agency for a 'screening decision', and then if required to do so, apply for formal consent to carry out the work. The types of land covered by the regulations include land that has not been cultivated (physically or chemically) in the last 15 years; and semi-natural habitats such as grasslands, heathland, scrub marshes, fens, peat bogs and open water. The 2-hectare 'threshold' also applies where several small projects, with a combined area of 2 hectares or more, are planned on a single holding[81].

---

[80] As required by the Environmental Impact Assessment (Agriculture) (England) (No. 2) Regulations 2006, which are part of existing national legislation.

[81] Source: http://www.naturalengland.org.uk/ourwork/regulation/eia/default.aspx and RPA/Defra (2007) *Single Payment Scheme - Management of Habitats and Landscape Features:* Guidance for Cross Compliance in England PB 12903

7.4.7 Sectoral Pillar 1 payments - Article 68 and other relevant measures

Description

In the initial stages of implementing the 2003 CAP reform it was possible for some EU-15 farmers, mainly in the arable, olive oil and livestock sectors, to retain a proportion of 'coupled' Pillar 1 payments alongside their SPS decoupled income support (the EU-12 new Member States used national funds in a similar way). By 2012 all remaining coupled payments will have been phased out, except those for suckler cows, sheep and goats.

The 2003 CAP reform offered those Member States using SPS[82] a different, more targeted way of 'recoupling' Pillar 1 payments, in which they could top-slice 10% of the Pillar 1 funds within a sector to provide additional support for '*specific types of farming which are important for the protection or enhancement of the environment or for improving the quality and marketing of agricultural products*'[83]. In the 2009 Health Check reform these recoupling options were broadened to include animal welfare, buffering the phasing-out of milk quotas, and risk management (insurance premiums and compensation for animal or plant diseases). There is also new scope for redistributing this recoupled part of the budget between farming sectors[84].

Set-aside has already been phased out, to be followed by milk quotas (permits for farmers to sell milk), which will be phased out by 2015. The effect of both will be to allow further rationalisation, specialisation and intensification in the arable and milk sectors.

Link to intensification/marginalisation and maintenance/ use of permanent grassland

Recoupled payments are a potentially useful way of providing extra support for economically vulnerable types of livestock farming, including mountain dairy farms, where the grazing systems maintain semi-natural habitats. This could help to prevent intensification and marginalisation particularly in the uplands, and support grazed habitats including permanent grassland.

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

This potentially useful measure does not seem to have been sufficiently used or adequately targeted on environmental objectives. Only half the EU-15 Member States[85] used the 2003 recoupling option, Article 69, and all of these included support for the beef sector, with support for the arable and sugar sectors supported by four Member States each. Other sectors for which national envelopes have been used include the sheep, dairy, tobacco, olive oil and cotton sectors, with Italy also having introduced a national envelope for energy crops in 2007. In the absence of formal reporting requirements comprehensive information was difficult to obtain, but a survey of these Member States indicated that the use of recoupling did not appear to have achieved significant environmental benefits, partly because Member States set such broad eligibility criteria that the majority of producers receive these funds, irrespective of the nature of their management systems or environmental performance. The exception

[82] the EU-15 plus Malta and Slovenia

[83] Article 69 of Council Regulation (EC) No 1782/2003

[84] Article 68 of Council Regulation (EC) No 73/2009

[85] Finland, Greece, Italy, Portugal, Slovenia, Spain, Sweden and Scotland (UK)

appears to be Finland, where it is felt that environmental benefits have been achieved in both extensive grazing and extensive arable systems. Here recoupling included support for suckler cow systems, in order to enhance product quality and to maintain extensive grazing for environmental reasons, and for winter cereal crops on at least 10% of arable land, for the environmental benefits of autumn/winter plant cover (Hart and Eaton, 2008).

The measure's new flexibility, together with the lack of reporting or monitoring and evaluation requirements, means that in future Member States could choose to support projects with neutral, or even negative, environmental consequences e.g. intensification of the dairy sector. Annex 2 shows how some of the Member States plan to use Art. 68 payments in 2010.

7.4.8 CAP Pillar 2

Strategic aims and funding of Pillar 2

The European Fund for Rural Development (EAFRD), which forms Pillar 2 and has approximately a quarter share of the total CAP budget until 2013, offers Member States a flexible suite of measures from which to build their seven-year Rural Development Programmes (RDPs). EU level guidance is provided on the three strategic aims of EAFRD support - improving the competitiveness of agriculture and forestry sector (Axis 1); improving the environment and the countryside (Axis 2); and improving quality of life in rural areas and diversification of the rural economy (Axis 3); and on the Leader approach (Axis 4) which supports community-led local development strategies combining measures from the other Axes and involving a broad range of rural actors.

RDP expenditure is co-financed by the Member States, who are required to spend a minimum proportion of their EAFRD allocation on each of the objectives – 25% in the case of measures to improve the environment and countryside. There is only one compulsory measure, for agri-environment support, which Member States must offer across the whole of their territory[86]., but otherwise Member States have a great deal of freedom to design RDPs and allocate expenditure to suit their needs, using appropriate EAFRD measures (see Table 7.3). The extra €5 billion rural development funding[87] available from 2010 for the 2007-13 programme period must be used to address the 'crucial new challenges for European agriculture' of climate change, renewable energies, water management, biodiversity and dairy restructuring. With all the revised RDPs approved early in 2010, Member States appear to be giving highest priority to biodiversity, which has been allocated 31% of the additional funding, followed by water management with 27%, dairy restructuring and climate change, each allocated around 14%.

EAFRD funding used for improving the environment and the countryside is expected to '*contribute to three EU-level priority areas: biodiversity and the preservation and development of high nature value farming and forestry systems and traditional agricultural landscapes; water; and climate change*'[88]. The effectiveness of this and other RDP

---

86 Council Regulation (EC) 1698/2005 as amended

87 Generated from the higher rate of compulsory modulation following the CAP Health Check and the EU Economic Recovery Package

88 Community Strategic Guideline for Rural Development (programming period 2007 to 2013) Council Decision of 20 February 2006 (2006/144/EC)

expenditure will be evaluated using a common monitoring and evaluation framework. The strategic aims for the other two priorities make no reference to the environment, and although some of the associated measures have the potential to support marginal livestock farming systems on permanent pastures, and help to prevent marginalisation, there is no obligation for Member States to use them in this way. The following analysis therefore focuses on the key EAFRD measures alleviating the negative impacts of intensification and marginalisation, of which the most important are the agri-environment, Natura 2000 and LFA (natural handicap) measures.

Table 7.3. The range of EAFRD funded rural development measures available for Member States 2007-13

Axis 1 Improving the competitiveness of the agriculture and forestry sector		
Human potential	vocational training and information actions, including diffusion of scientific knowledge and innovative practices for persons engaged in the agricultural, food and forestry sectors;	111
	setting up of young farmers;	112
	early retirement of farmers and farm workers;	113
	use of advisory services by farmers and forest holders;	114
	setting up of farm management, farm relief and farm advisory services, as well as forestry advisory services;	115
Restructuring, physical potential and innovation	Modernization of agricultural holdings;	121
	improving the economic value of the forests;	122
	adding value to agricultural and forestry products;	123
	cooperation for development of new products, processes and technologies in the agricultural and food sector and in the forestry sector;	124
	improving and developing infrastructure related to the development and adaptation of agriculture and forestry;	125
	restoring agricultural production potential damaged by natural disasters and introducing appropriate prevention actions;	126
Quality of agricultural products	helping farmers to adapt to demanding standards based on Community legislation;	131
	supporting farmers who participate in food quality schemes;	132
	supporting producer groups for information and promotion activities for products under food quality schemes;	133
Transitional measures	supporting semi-subsistence farms undergoing restructuring;	141
	supporting the setting up of producer groups;	142
	supporting agricultural holdings undergoing restructuring, including diversification to activities outside agriculture, due to a reform of a common market organisation	
Axis 2 Improving the environment and countryside		
Sustainable use of agricultural land	natural handicap payments to farmers in mountain areas;	211
	payments to farmers in areas with handicaps, other than mountain areas;	212
	Natura 2000 payments and payments linked to Directive 2000/60/EC;	213
	agri-environment payments;	214
	animal welfare payments;	215
	support for non-productive investments;	216
Sustainable use of forestry land	first afforestation of agricultural land;	221
	first establishment of agroforestry systems on agricultural land;	222
	first afforestation of non-agricultural land;	223
	Natura 2000 payments;	224
	forest-environment payments;	225
	restoring forestry potential and introducing prevention actions;	226
	support for non-productive investments;	227
Axis 3 Quality of life in rural areas and diversification of the rural economy		
Diversify the rural	diversification into non-agricultural activities;	311

economy	support for the creation and development of micro-enterprises;	312
	encouragement of tourism activities;	313
Improve quality of life	basic services for the economy and rural population;	321
	village renewal and development;	322
	conservation and upgrading of the rural heritage;	323
Training and information	training and information for economic actors operating in the fields covered by Axis 3;	331
Skills and animation	skills acquisition and animation with a view to preparing and implementing a local development strategy;	341
Axis 4 Leader		
The Leader approach uses area based local development strategies, local public-private partnerships, bottom up decision-making, multi-sectoral design and implementation, innovative approaches, cooperative projects, networking of local partnerships	implementing local development strategies;	
	competitiveness;	411
	environment/land management;	412
	quality of life/diversification;	413
	implementing transnational and inter-territorial cooperation projects;	421
	running the local action group, acquiring skills and animating the territory	431

7.4.9 Agri-environment and non-productive investment measures

Description

The agri-environment measure is the oldest and one of the most important land management mechanisms developed under the CAP, and is unusual among CAP Pillar 2 policy instruments in that its use is obligatory, yet a very high level of subsidiarity is encouraged in the design, targeting, delivery and pricing of schemes. This freedom of choice is essential, because achieving the intended environmental objectives depends on matching the incentives offered to farmers to many different local factors, which can vary enormously even within one region.

For the 2007-13 period there are 94 RDPs across the EU-27, all offering farmers the option of 5 or 7-year contracts for specific environmental management activities, in return for annual payments based on costs incurred and profits foregone. In total, about €68 billion of public money is allocated for 2007-2013 across 13 measures under Axis 2, accounting for approximately 46% of all public expenditure under the EAFRD. This is a substantial budget, and provides by far the largest source of funding for nature conservation related land management in the EU, representing 16% of the total CAP budget for 2007-2013. There are significant differences between regions in the relative priority given to agri-environment expenditure within RDPs, and within Axis 2 budgets as shown in Figures 7.7 and 7.8, and Table 7.4.

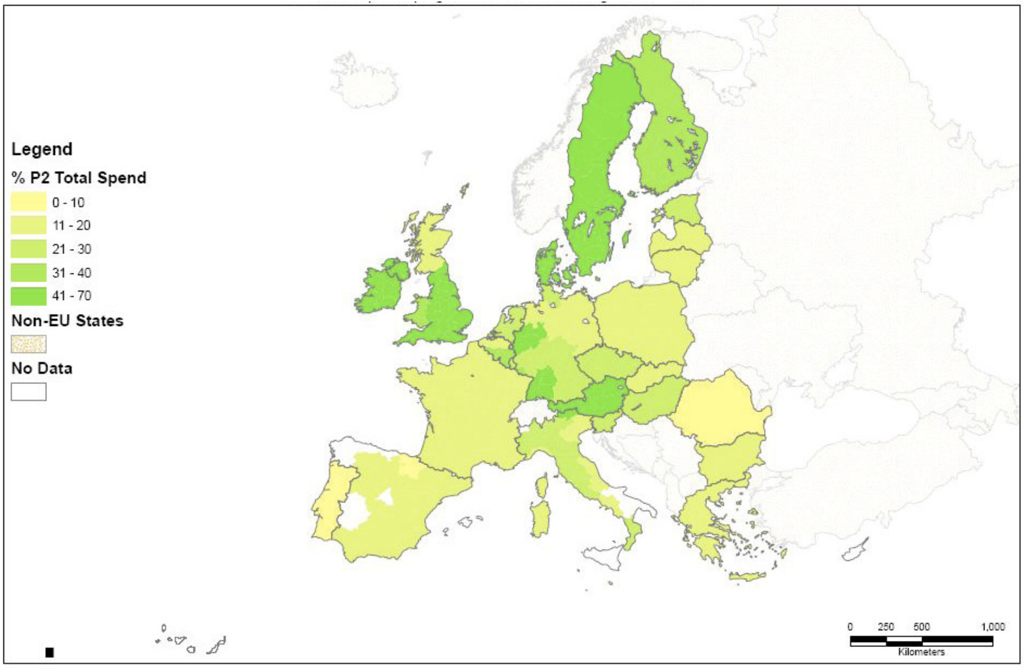


Figure 7.7 Agri-environment expenditure as a percentage of allocated Pillar 2 total expenditure (EAFRD and co-financing), by RDP (IEEP, 2008)

Agri-environment schemes tend to differ in three key ways, often reflecting societal preferences, institutional arrangements and financial and political pressures: the level of expenditure dedicated to the measure; the environmental objectives of the schemes, and the ways in which they are targeted (for example geographically delimited or open to all farmers across the territory). Agri-environment payments can be used to support appropriate grazing measures designed for specific habitats, and thus both protect biodiversity and contribute to the economic viability of potentially marginal farms, but their impact depends not just on measures and budget available locally but also on the farmers' ability to meet GAEC cross-compliance standards, provide the required grazing animals and have management control of the grazing land for five years. This can be a problem where land is rented on short leases or graziers with their own flocks use other farmers' land or common land for seasonal grazing[89].

[89] Seasonal grazing is important for maintaining HNV mountain grasslands throughout Europe, and other grasslands in Romania, Bulgaria, Turkey, Spain and France.

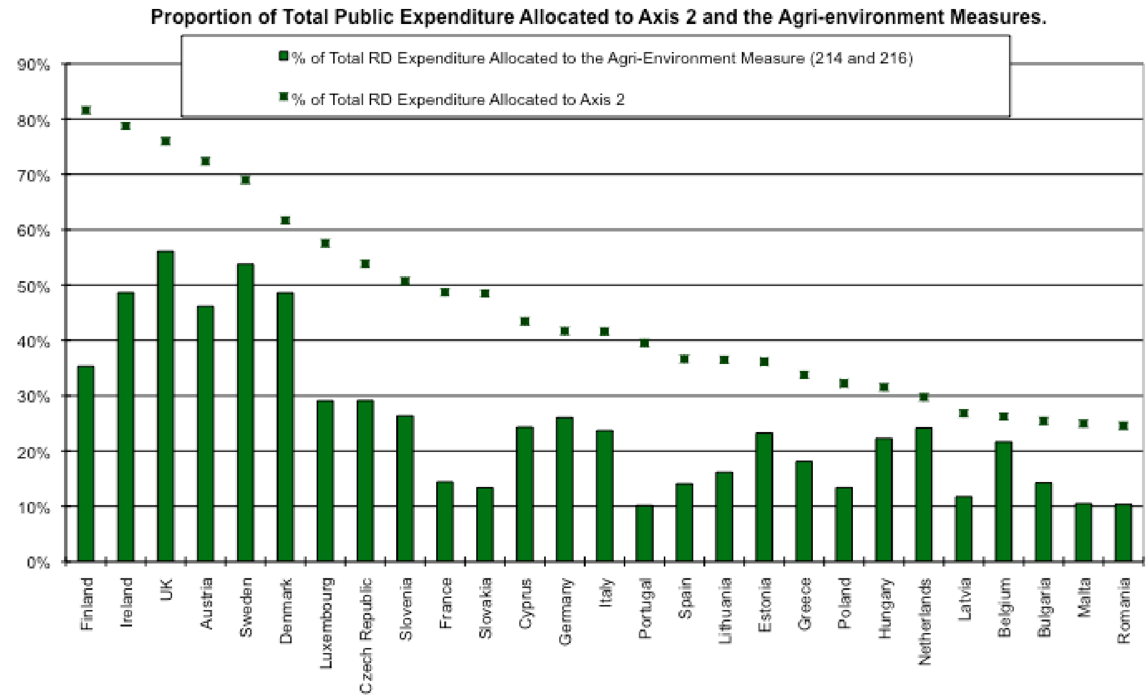


Figure 7.8 Proportion of total public expenditure allocated to Axis 2 and to the measures for agri-environment (214) and non-productive investment (216) in 2007-13 RDPs

Table 7.4. Breakdown of expenditure on Axis 2 measures in 2007-13 RDPs

Code	Measure	Total Public Expenditure (€)	Number of RDPs in which measure used*	RDPs which give high priority to this measure**
214	Agri-environment payments	34,538,105,581	84	UK and Sweden allocate >50% TPE
212	Payments to farmers in areas with handicaps, other than mountain areas	11,058,699,316	72	Scotland, Ireland, Bayern, Hessen and Luxembourg allocate >20% TPE
211	Natural handicap payments to farmers in mountain areas	10,597,787,326	55	Corsica and Valle d'Aoste allocate >38% TPE
221	First afforestation of agricultural land	3,517,725,764	63	Castilla La Mancha and Lombardia allocate >10% TPE
226	Restoring forestry potential	2,507,493,971	55	Castilla la Mancha, Asturias and Andalucia allocate >10% TPE
227	Non-productive investments (forests)	1,300,473,983	67	La Rioja, Andalucia & Navarra allocate >5% TPE
216	Non-productive investments (agriculture)	900,032,481	47	Wales, England & Puglia allocate >5% TPE
213	Natura 2000 payments and WFD payments	786,867,600	26	Ireland allocates 9% TPE
215	Animal welfare payments	639,445,278	20	Sardinia allocates 17% TPE
223	First afforestation of non-agricultural land	590,512,047	37	Scotland & Galicia allocate >5% TPE
225	Forest environment payments	434,315,058	29	Scotland and Baden Wuerttemburg allocate >2% TPE
224	Natura 2000 payments (forests)	155,683,538	17	Estonia and North Rhein Westphalia allocate >2% TPE
222	First establishment of agroforestry systems	29,146,557	15	Marche allocates the greatest proportion (0.5% TPE)
Total		67,056,288,499		

Source: IEEP own calculations.

Note: * based on an examination of 84 programmes. ** expressed in terms of% of TPE. TPE refers to total public expenditure i.e. EAFRD + amounts raised through compulsory modulation + national co-financing

Agri-environment schemes are complemented by the non-productive investment measure[90] which provides one-off funding for work essential at the start of an agri-environment contract – for example removing invasive scrub from abandoned grassland or restoring the infrastructure of water meadows. Specific agri-environment actions tend to focus on limiting the negative environmental impacts of modern farming, or on maintaining, enhancing restoring or creating of new habitats and cultural landscapes. Table 7.5 illustrates some of the ways they have been used.

Table 7.5. Examples of the diversity of agri-environment actions

Type of agri-environment scheme	Examples
Reduced inputs of fertilisers and pesticides	crop nutrient plans for the whole farm; more accurate nitrogen fertilisation of arable crops; 6 metre grass buffer strips along watercourses; integrated pesticide management.
Organic farming	organic beef and dairy farming; organic production of essential oils and medicinal herbs, fruit and olives; organic honey production.
Livestock extensification	reduced stocking rates and shorter grazing season on moorland; restrictions on grazing and mowing dates to allow grassland species to set seed.
Arable land	conversion from arable crops to permanent grassland or woodland; crop rotation.
In-field arable management	prevention of wind and water erosion; skylark plots within crops; uncropped conservation strips.
Wildlife habitats and species	hay meadows, wood pastures, reed beds; wet grassland for bird breeding and feeding areas; wildflower meadows for bees and butterflies.
Farmland landscapes	stone walls; cultivation terraces; hedgerows, earth banks and lines of trees; fishponds; strip cultivation.
Water use and management	non-irrigated arable crops; water meadows and wetland creation.
Genetic diversity	local breeds of cattle, sheep, goats and horses; local varieties of cereal and vegetable crops.

Link to intensification/marginalisation and maintenance/ use of permanent grassland

Agri-environment is the leading CAP measure capable of targeting:

- the maintenance, restoration and creation of biodiversity corridors on farmland;
- the management and restoration of permanent pastures that are of value for their botanical diversity, or because they are important habitats for other taxa (e.g. butterflies or over-wintering wildfowl); and
- support for the environmental management of High Nature Value Farming systems and traditional agricultural landscapes, to combat risks of marginalization and abandonment.

[90] Article 41 of Regulation (EC) 1698/2005

Impact on intensification/marginalisation and maintenance/ use of permanent grassland

When examining impacts on biodiversity, it is necessary to consider how and why agri-environment measures are being implemented. For example, although Finland allocates a high proportion of its RDP expenditure to agri-environment measures, these are primarily used to meet water and soil protection objectives rather than habitat conservation. In Portugal, biodiversity objectives are the focus of a range of schemes tailored to the needs of particular areas, including Natura 2000 sites, but elsewhere in the country agri-environment support is solely focused on organic farming. By contrast, England and Hungary, for example, place a much stronger emphasis on biodiversity conservation.

Overall, it appears that when they are appropriately designed, targeted and implemented, agri-environment schemes can provide substantial benefits for biodiversity corridors, management of permanent grassland and other HNV farming practices. It also seems that ‘narrow and deep’ approaches with more targeted (and possibly more demanding) maintenance and management options provide more certain benefits than ‘broad and shallow’ measures that offer relatively simple, low-cost management over a very wide area. The transaction costs, particularly for the delivery agencies, of highly targeted ‘narrow and deep’ schemes are often much higher than those for ‘broad and shallow’ schemes, because the former usually require site-specific contracts negotiated by specialist advisers. Factors associated with successful agri-environment schemes include partnerships between government agencies, NGOs and landowners, targeted implementation that ‘fits’ well with existing farm practices and delivers conservation results, appropriate payment rates, availability of advisers with specific conservation knowledge, and an ability to target resources at relatively small areas (Tucker *et al*, 2009). Monitoring and evaluation of rural development programmes is being improved, but, on the basis of previous monitoring, known factors associated with poor biodiversity outcomes include small-scale, inappropriate placement and generalised national habitat management measures unsuited to local conditions.

Examples of innovative agri-environment schemes used in the 2007-13 RDPs to prevent intensification/marginalisation of important grazed habitats and to improve the extent and quality of permanent grassland are shown in Box 7.8 below. Agri-environment payments can be designed to support suitable grazing measures and thus contribute to the viability of potentially marginal farms, but their impact depends not just on measures and budget available locally but also on the farmers’ ability to meet GAEC cross-compliance standards, provide the required grazing animals and have management control of the grazing land for five years. This can be a problem where land is rented on short leases or graziers with their own flocks use other farmers’ land or common land for seasonal grazing[91], but some Member States have addressed this as the examples from Romania and the UK (Wales) show.

[91] Seasonal grazing is important for maintaining HNV mountain grasslands throughout Europe, and other grasslands in Romania, Bulgaria, Turkey, Spain and France.

Box 7.8 Examples of agri-environment schemes contributing to land services in 2007-13 RDPs

Supporting basic grassland management

In France, farms with at least 75% of grassland are eligible for an "extensive grassland premium" of 76€/ha, which limits fertiliser use, grassland conversion and renewal. In Italy (Veneto) measures for the maintenance of grassland are aimed predominantly at mountain areas and Nitrate Vulnerable Zones (NVZ), with requirements to limit fertiliser and pesticide use and avoid disturbance during bird nesting times. In the Czech Republic national measures for the basic management of meadows/pastures offer premia of ~75/112 €/ha in return for limits on fertilisers, herbicides grazing and grassland restoration and mulching, plus restrictions on mowing dates. In Sweden, basic grassland management measures are offered for all permanent grassland (the application of fertiliser and pesticides is forbidden on permanent grassland in Sweden).

Mountain pastoralism in Bulgaria

Bulgaria and Romania have the largest contiguous area of HNV farmland in the EU, much of it now threatened by abandonment or intensification. Bulgaria's RDP targets HNV farming systems, with schemes designed with the help of ecologists. A scheme for the restoration and maintenance of species rich grasslands promotes traditional mowing methods (by hand or slow machines) and has special measures for forest meadows. A pilot agri-environment scheme in to support mountain pastoralism in areas threatened by land abandonment encourages farmers to use traditional patterns of seasonal grazing where shepherds look after local breeds in high mountain pastures in the summer months, using Karakachan dogs to protect the grazing livestock from wolves or bears.

Common grazing land in Wales (UK)

Bringing common land into an agri-environment schemes is often difficult but in Wales (UK) the 16 commoners grazing sheep on 800 hectares of a heathland Natura 2000 site have a 5 year agri-environment contract to increase cattle grazing levels during the spring and summer, with the aim of suppressing bracken and grazing the coarse vegetation which has dominated the wet Natura 2000 heathland. Sheep numbers will be limited in winter, to prevent over-grazing of semi-natural habitats, and non-productive investment will be used to clear bracken and scrub for habitat restoration.

Preventing grassland intensification, for the benefit of protected species in the Czech Republic

Corncrake (*Crex crex*) populations declined in Western Europe with intensification of grassland management, because mowing for silage early in the season destroys the nests, and later the chicks can be lost if they try to escape from mechanical mowers by hiding in the long grass at the centre of the field. In the Czech Republic a special agri-environment scheme to improve the long-term conservation status of this EU priority species is available on suitable corncrake breeding areas, mainly grasslands that can be mown. The grassland must be managed without using fertilizer or manure, and mown late in the season by a single mower, from the centre outwards, or from one side to the other to allow the chicks to escape.

Grassland restoration for biodiversity in the UK (England)

In the UK (England) the higher-level agri-environment scheme explicitly address the maintenance, restoration or creation of species-rich, semi-natural grassland. Premia are approximately 150€/ha for maintenance/restoration of grassland for target features (e.g. bumblebees, field birds), 230€/ha for maintenance or restoration of species rich, semi-natural grassland and up to 390€/ha for maintenance/restoration of wet grassland for breeding waders. Premia for the creation of such grassland from arable, ley grassland or abandoned land are slightly higher, and some of these measures can be combined with supplements (of about 90€/ha), e.g. for haymaking or raised water levels. For several of these combinations the resulting premia may exceed 400€/ha.

7.4.10 Natura 2000 compensation payments

Farmers of land in designated Natura 2000 sites may be able to claim compensation for the legal restrictions resulting from the designation, but probably at least two thirds of HNV farmland in the EU will not be designated as Natura 2000 and, even in the Member States that have made excellent progress with designation, Natura 2000 payments cannot be made to farmers until the relevant national legislation is in place[92]. It is also unclear if Natura management plans will be drafted tightly enough to face unexpected challenges such as new pressures on grassland from an increased demand for arable land. This measure, which also includes compensation for compliance with farm-level requirements of the Water Framework Directive, has been used in 25 RDPs, most extensively in Germany (Saxony-Anhalt, Brandenburg, Schleswig-Holstein and North Rhine Westphalia), Ireland and Spain (Asturias) where it accounts for between five and fourteen percent of Axis 2 expenditure.

7.4.11 Natural handicap (LFA) areas

Description

More than half of the farmland in the EU has been classified by Member States as Less Favoured Areas (LFA) that suffer from handicaps which threaten the continuation of agricultural land use. LFA compensation payments (now called natural handicap payments) have been available to farmers for more than 30 years, originally linked to numbers of livestock or area of crops, but now paid on a per hectare basis, and using a significant proportion of RDP funding in some Member States. Following criticism of differences in interpretation of the LFA designation criteria and failures to target support (ECA, 2003), the European Commission has proposed new, biophysical criteria for defining 'natural handicaps' with the intention of putting a revised classification system in place by 2014. Although often viewed by farmers as a long-standing form of CAP income support, natural handicap payments are an optional EAFRD measure, and are being phased out of some RDPs and replaced by more targeted agri-environment schemes, in response to the need for more closely specified payments targeted at the provision of environmental public goods.[93]

---

[92] DG Agri has pointed out two key principles to keep in mind:

- support to farmers/foresters under Articles 38 and 46 can only be paid once the specific changes in farm practice linked to designation under Natura are mandatory requirements (under national legislation) at the farm holding/forest level;
- the land which receives Natura payments must be located in a Natura area. While there is some flexibility to pay Natura support before final designation of sites, the list of sites must be sufficiently advanced/stable that there could be no question that particular sites would not be included in the final list. (Source: DGAgri reply dated 18.7.2006 to queries from WWF Bulgaria).

[93] For example, in parts of the UK(England and Wales)

Link to biodiversity corridors, intensification/marginalisation and maintenance/ use of permanent grassland

LFA payments can contribute to supporting the incomes of marginal livestock farms grazing permanent grasslands and other habitats.

Impact on biodiversity corridors, intensification/marginalisation and maintenance/ use of permanent grassland

LFA payments remain the second most frequently used measure in the 2007-13 RDPs, accounting for more than €21 billion public expenditure across 72 regions or Member States. An EU study found that LFA payments had made a significant contribution to farm family income, particularly in mountain areas, and that the focus on livestock farms has helped to address the key environmental issue of continued grazing on farms where profitability tends to be low (Cooper *et al*, 2006). This may counteract pressures of marginalisation, and help to maintain the use of permanent grasslands, but other authors see the failure to target HNV farming systems as a weakness (Boccaccio, 2009).

7.5 OTHER POLICY OPTIONS FOR HABITAT CREATION AND MANAGEMENT ON FARMLAND

Some observers have drawn attention to the use in other countries of Environmental Priority Areas (EPAs) for habitat creation and management within the framework of cross compliance, notably in Switzerland. Swiss farmers enjoy relatively higher levels of support than their EU counterparts (almost 60% of gross farm receipts compared to less than 30% for the average EU27 farmer[94]), and cross-compliance requirements are more demanding than those in the EU, as illustrated in Box 7.9.

An EPA approach to cross-compliance in the EU would represent a significant development of the current GAEC framework where the new standard for "habitat creation and/or retention' is optional, and so far unused by most Member States. The implications for farm costs would vary from one farm type to another, and from farm to farm within each type. For example a very intensive arable farm might have to reduce the area used for cropping, while an extensive livestock farm might have no difficulty meeting the habitat requirement, but would face a possible reduction in the total area eligible for agri-environment support; in both cases there is a potential impact on farm income. On the other hand overall administration costs of EPAs could be significantly less than for agri-environment schemes. EPAs could be regarded as an encroachment onto agri-environment territory, but this distinction is already somewhat blurred, for example in the UK where the entry level scheme in Wales, Tir Cynnal, already requires farmers to maintain 5% of the farm as habitat land and in England the entry level scheme requires farmers to achieve a minimum 'points' threshold by selecting from a range of options, some of which are area-based.

[94] Producer Support Estimates for 2006-08 taken from OECD (2009). The Producer Support Estimate (PSE) is an indicator of the annual monetary value of gross transfers from consumers and taxpayers to support agricultural producers, measured at farm gate level, arising from policy measures, regardless of their nature, objectives or impacts on farm production or income.

Box 7.9 Ecological Compensation Areas in Switzerland

In Switzerland, the Ökologischer Leistungnachweis ÖLN is a precondition for the receipt of direct and ecological support payments. It is subject to compliance with relevant environmental legislation.
The ÖLN includes the following requirements for farmers:

- Compliance with animal welfare legislation;
- Stable nutrient balance with a maximum margin of 10% for N and P;
- Adequate share of ecological compensation area (7% of the Utilised Agricultural Area; 3.5% in the case of special crops such as vegetables, fruits or vines);
- Regular crop rotation (breaks between cultivation of the same crops or at least 4 different crops with maximum shares for single crops);
- Soil protection requirements for winter cover. In addition soil erosion may not occur regularly, otherwise suitable measures have to be taken or a soil protection plan applied;
- Targeted use of plant protection products.

In many cases, the requirements of the ÖLN are higher than those in the EU, and a central element of the ÖLN is to maintain, create and increase the ecological value of landscape elements. Farmers have to prove the existence of a certain percentage of ecological compensation area at the farm level (e.g. extensively managed grassland, setaside land and field strips, hedges or field woods, small water bodies, stone walls, traditional orchards, and natural tracks) and requirements exist for the maintenance and management for these features. If necessary, these areas have to be created or leased additionally. Of the 120,000 hectares under ECAs (12% of the total agricultural area in Switzerland), three quarters are extensively managed hay meadows, while a much smaller proportion are wildflower strips, a characteristic ECA type for arable regions. Voluntary agri-environment payments are used to complement the obligatory management within ECAs (Cooper *et al*, 2009).

A more radical option to increase farm-level habitat creation and management is so-called ‘orange ticket’ cross-compliance, where farmers would be required to enter an agri-environment contract in order to qualify for Pillar 1 payments. This clearly has significant implications for both transaction costs and agri-environment payments. ‘Orange ticket’ cross compliance apparently has at least once precedent in the EU, in 1998 in Ireland where overgrazing by sheep was threatening Natura 2000 habitats. Farmers received ewe premium only if they took part in the Irish agri-environment scheme (Rural Environmental Protection Scheme) or an alternative national scheme, which included a farm plan specifying the number of animals permitted on the farm and eligible for payment in the areas vulnerable to overgrazing (Kristensen, L and Primdahl J., 2004).

7.5.1 The influence of water policies on land management

While water policies do not directly dictate land management practices, they influence the development of some agricultural policies and the implementation of measures that have implications on pollution, e.g. from the intensive use of fertiliser or the conversion of grassland to arable land. The two water policy instruments with strongest implications for land management are the Water Framework Directive and the Nitrates Directive. These are therefore outlined below, and a more detailed assessment of their influences on water retention and quality services provided in Chapter 9.

Water Framework Directive

The Water Framework Directive (2000/60/EC) establishes a framework for the protection of fresh water, estuaries, coastal waters and groundwater in the Community. It aims to protect and enhance the status of aquatic ecosystems and the terrestrial and wetlands directly dependent on aquatic ecosystems and promote sustainable water use based on long-term protection of water resources. It aims for all aquatic systems to reach 'good ecological status' by 2015 or (or within two subsequent six year periods). Member States are required to undertake extensive analysis of biological, chemical and hydromorphological (i.e. a combination of hydrology and physical structure) characteristics to determine how far the ecology has been affected by human activity and use these characteristics should form the basis for the water management objectives to deliver good ecological status of the waters.

The Directive includes a number of principles dealing with the management of waters, stating that decisions should be taken as close as possible to the locations where water is affected or used with programmes of measures adjusted to regional and local conditions. It also emphasises the polluter-pays principle and requires Member States to undertake an economic analysis of the water use and allows for economic instruments within the programme of measures. Within a river basin where use of water may have transboundary effects, the requirements for the achievement of the environmental objectives established under the Directive, and in particular all programmes of measures, should be coordinated for the whole of the river basin district.

A key part of the Directive is the requirement for Member States to develop catchment-based River Basin Management Plans. In the plans, Member States have to specify a monitoring programme for a general assessment of water status and develop a series of mitigation measures for specific threats to any water body where status is not 'good'. The aims are to be carried out by

- establishing river basin districts with integrated management;
- identifying point and diffuse sources of pollution;
- meeting the requirements of protected areas;
- undertaking economic analyses of water use; and
- developing a programme of measures to achieve objectives in each river basin district.

Once plans are published (they were due to be completed by December 2009) it should be clearer what Member States intend to do to achieve good ecological status of their waters and what the corresponding implications are for land management. It is already clear that diffuse pollution will be a major concern for water quality. While the discharges from point sources have decreased over the past 30 years, the loss from diffuse sources has generally remained at the same level (EEA, 2005a). The point source reductions have been largest for phosphorous, mainly as a result of the improved purification of urban waste water. The relative impact of diffuse sources, particularly agriculture have since become more important. Therefore it is likely that these water quality measures will have an impact on the major uses of land, and should result in certain changes in practices. These measures could include the times of the year that ploughing can occur, whether slopes can be cultivated, what type of fertiliser can be applied and at what times of the year.

Nitrates Directive

The Nitrates Directive (91/676/EEC) seeks to reduce or prevent the pollution of water caused by the application and storage of inorganic fertilizer and manure on farmland. It is intended both to safeguard drinking water supplies (by limiting the concentration of nitrates to 50 mg/l in groundwaters and to the limits defined in the Drinking Water Directive for surface waters) and to prevent wider ecological damage to aquatic systems in the form of the eutrophication.

Member States are required to identify waters (which includes marine, coastal, estuary, surface and ground waters) actually or potentially affected by pollution from nitrates, and which are or may become eutrophic, known as 'nitrate vulnerable zones.' These require specific action programmes to control nitrate pollution associated with these waters and must include measures prescribed in Annex III of the Directive and those prescribed (in accordance with Article 4) in the codes of good agricultural practice developed by the Member States.

The codes of good agricultural practice should include certain provisions, including:

1. advice on land use management, including the use of crop rotation systems and the proportion of land area devoted to permanent crops relative to annual tillage crops;
2. the maintenance of a minimum quantity of vegetation cover during periods that could remove nitrogen from the soil and pollute waters (i.e. during rainy periods);
3. the conditions for land application of fertiliser on unsuitable land (near water courses, on steep slopes and or water-logged, frozen or snow-covered land); and
4. the procedures for land application such as the rate of spreading, that will maintain nutrient losses to waters at an acceptable level.

Similarly, the programmes for nitrate vulnerable zones must include the conditions under which land application of fertilisers must be limited, including instructions relating to;

1. soil condition, type and slope;
2. climatic conditions, rainfall and irrigation;
3. land use and agricultural practices (such as crop rotation practices) to be based on a balance between foreseeable nitrogen requirements of the crops and the nitrogen supply to the crops from the soil and from fertilisers.

Member States are required to review nitrate vulnerable zone designation every four years following a reporting cycle. By 2003, seven of the EU-15 had established the entire territory as a nitrate vulnerable zone and other countries increased their designation of nitrate vulnerable zones, such as the United Kingdom (from 2.4 to 32.8%) and Italy (from 2 to 6%). In total, 44% of the EU-15 was designated as a nitrate vulnerable zone as of the end of 2003. Of the EU-10 new Member States, three adopted a 'whole territory approach' while the remaining seven countries have designated between 2.5% (in Poland) to 48% (in Hungary). Results show that further designation will be required to fully implement the legislation in the EU-15, while results are pending on the adequacy of designation in the EU-10 (COM(2007)120).

Implementation of programmes has been slow, but by 2003, all of the EU-15 (bar Ireland, which followed in 2006) had established one or more programmes of actions on their territory. However, many still show several areas of non-conformity, including:

- the absence of minimum distance for fertiliser application near water bodies (or too narrow width of unfertilised buffer strips);
- a lack of restrictions on fertiliser application when soil conditions are unsuitable; and
- insufficient length or limited applicability of the measures on restricted periods for fertiliser application.

Monitoring from the period 2000-2003 shows that 30% of groundwater sites at EU-15 level were improving, 34% stable and 36% were deteriorating with respect to the previous reporting period. For surface waters, 55% of sites showed improving trends, 30% were stable and 14% of sites were deteriorating. Within these figures, certain differences between countries are discernible. The United Kingdom, Belgium and France all showed deteriorating trends in over 30% of groundwater sites (without improving trends elsewhere) as well as accounting for much of the deteriorating surface water sites (along with Portugal and Luxembourg). Italy, Greece and Belgium (Flanders) provided too little information to discern trends in ground water quality.

While the Commission suggests that it will take several years before improvements in water quality will be seen as a result of new measures (COM(2007)120), it is likely that the Directive will positively benefit quality and ecology of aquatic systems through reduced nutrient pressure. While it does not refer explicitly to terrestrial ecology, the full implementation of the Directive will also promote changes to land use management practices with reduced pressures on land ecosystems. The reduction of application of fertiliser and more restricted ploughing, for example, is likely to slow soil disturbance and erosion. The scope in the Code of Good Agricultural Practice for determining land use management through crop rotation and minimum plant land coverage provide the opportunity for Member States to specify conditions that can improve conditions for biodiversity by encouraging the increase of permeability of the landscape.

7.6 DRIVERS AND POLICIES - DISCUSSION AND CONCLUSIONS

There can have been few periods in the history of European agriculture has been so diverse and also undergoing such a lengthy process of adapting to significant policy changes at farm, European and global levels. The diversity is expressed in both biogeographical terms, with different climates, soils, crops, farming systems and environmental issues from Northern Sweden to the Mediterranean, and in terms of agricultural and social structures from very small semi-subsistence farms in parts of Romania and Bulgaria to arable farms of several thousand hectares in the UK. Pillar 1 payments are still being decoupled in EU-15, while not yet fully phased in for most of EU-12, and the Health Check revisions are about to be phased in across EU-27. Farmers are increasingly exposed to sometimes volatile global markets and the effects of climate change. The period until 2013 will be one of consolidation and adjustment, as farmers adapt to the effects of decoupling, and rural development plans use the additional funding from compulsory modulation to address the ‘new challenges’. In addition to biodiversity these include challenges not necessarily linked to environmental land management such as climate change, renewable energies and water management priorities, which could absorb significant proportions of RDP budgets. In EU-15 there will be probably be some simplification of Pillar 1 support towards regional payment rates, while in EU-12 the Pillar 1 payment rates will continue to rise until phasing in is completed in 2012. Another major reform of the CAP is expected in 2013, possibly driven by the twin objectives of concentrating spending where it most adds value in the delivery of public goods, and reducing the overall share of the EU budget devoted to agriculture. Measures to encourage EU agriculture to reduce greenhouse gas emissions and to protect water resources are likely to be high priorities.

Given this background of change and diversity it is not surprising that the impact of the drivers and policies described above on future land use and land services will be equally diverse. Responses to a particular combination of drivers are very context-dependent and may lead to intensification in one place and to structural or land use change in another, or to loss of permanent pasture on some farms but improved biodiversity management of semi-natural grazing areas on another. These locational and structural differences in impacts make it difficult to draw EU wide conclusions, and have implications for both the design and implementation of policies for the provision of land services. Nevertheless it is possible to draw some conclusions:

- Increasing exposure to global markets will sustain the trend towards specialisation and economies of scale in most sectors, with production moving towards the most competitive parts of Europe; the scope for further intensification in EU-15 is rather limited, while technological developments such as precision farming and improved manure management for housed livestock here may lead to some reduction in negative environmental impacts (e.g. on water quality). In contrast, there is considerable scope for further intensification in parts of EU-12, where rising levels of inputs such as arable crop nutrients could have negative impacts on biodiversity and diffuse pollution, although the implementation of baseline standards in the livestock sector could bring benefits (e.g. controls on manure storage under the Nitrates Directive).

- Arable production will increase, as a result of improved productivity and some increase in the area (although the CAP rules on grassland conversion should limit total net loss of grassland). Marginal arable land may move in and out of production/fallow in response to price fluctuations and, in response to climate change, some arable production may move within Europe, as yields improve in northern latitudes and water resources becomes more of a problem in the south. The permanent crops sector will also see a shift to larger units and a further decline in small, low-intensity units cropping older trees, with negative consequences for biodiversity.

- The livestock sector will suffer from declining profitability in the beef, sheep and goat sectors, driven by lower prices, and will see major restructuring of the dairy sector to fewer, larger units of production by the time quotas are removed in 2015. There is likely to be increasing polarisation of all the grazing livestock sectors, with the intensively managed farms using more permanent housing of livestock (including cattle) in larger units, while low-intensity grazing systems using beef, sheep and goats, together with mountain (and semi-subsistence) dairy systems become even less viable, with significant declines in the numbers of livestock, particularly in EU-12. In many cases the result will be a decline in grazing management across many semi-natural habitats, with partial or complete abandonment in some cases. Elsewhere, especially in some parts of EU-12, significant restructuring will take place with small low-intensity farms combined into larger units, landscape features removed and grassland management intensified. Some grazing land may be converted to arable, afforested or used for development. These trends will be tempered to a certain extent by the effect of income support from Pillar 1, and targeted support from Pillar 2, particularly LFA and agri-environment management payments, and also Art.68 sectoral payments in some Member States. It is likely that many of these environmentally important grazing systems will not survive, and those that do will require significant long-term public funding.

- A strengthened legislative baseline, particularly with the implementation of the Water Framework Directive, should help to constrain some of the negative environmental impacts of arable farming and could lead to the establishment of some new areas of permanent grassland (e.g. buffer strips) within arable areas. The Pillar 1 requirements on conversion of permanent grassland should limit total losses at Member State level but unless coupled with other measures will afford little protection for biologically important habitats.

- The cost of Pillar 2 environmental support for both voluntary (agri-environment) and compensatory (LFA, Natura 2000) measures will rise, as a result of the profitability of the arable sector on the one hand and the increased risk of structural change or abandonment of small, low-intensity livestock and permanent cropping farms on the other.

- The leverage exerted by GAEC cross-compliance requirements above the regulatory baseline will gradually weaken on economically viable farms that do not use Pillar 2 support, as Pillar 1 payment rates per hectare reduce in the short term through modulation and in the longer term by possible reductions in the CAP budget. In future some of these farmers may simply choose to forego Pillar 1 income support, particularly in years when market prices are strong.

The policy responses needed to address these impacts are discussed in Chapter 10.

8 ASSESSMENT OF IMPACTS OF INTENSIFICATION / MARGINALISATION AND LOSS OF PERMANENT GRASSLAND ON LAND SERVICES

Leon Braat, Alterra and Graham Tucker, IEEP

8.1 INTRODUCTION

This chapter addresses two components of Tasks 4 and 5 as outlined in the specification description as follows:

On the basis of the information gathered under Task 1, the contractor shall:

- *assess the likely impacts of (trends in) intensification/marginalisation of land (including land abandonment) on the land services; to the extent it is feasible, this assessment should be quantitative.*
- *assess the likely impacts of (trends in) ploughing up permanent grassland on the land services; to the extent it is feasible, this assessment should be quantitative.*

These tasks have been combined in this chapter as they are closely related. The Task 4 and 5 components related to the drivers of intensification / marginalisation and the loss of permanent grassland are covered in Chapter 2 (in introductory terms) and in detail in Chapter 7.

As noted in the study's Inception Report it was intended that these tasks would translate the projected changes in intensification and marginalisation from the previous modelling outputs, into map overlays (as carried out with respect to soil sealing - see Chapter 4). These would then be used to assess impacts on indicators of land services, which would be mapped and summarised according to appropriate political and geographical scales. The expected outputs were overviews of impacts in terms of the land services, due to the changes in intensification and marginalisation, expressed in maps and statistics of the selected land service indicators. Similar quantitative analyses were planned for the assessment of impacts of the loss of permanent grassland.

However, in collecting the material expected to be necessary to produce the intended assessment, it became clear that the processes which are covered in Task 4, *intensification versus marginalization, and in the extreme case abandonment, of agricultural land use*, are not only quite different in "nature" from the processes under the heading of *soil sealing*, but have been researched, documented and classified, quantified and mapped in quite different ways. Essentially "the soil sealing issue" has been approached in studies as a change in "land cover", with widely adopted clear categories and transitions between categories, spatial analysis and land use accounting and mapping. In contrast the changes in agriculture referred to as intensification/marginalisation and the loss of permanent grassland are treated as changes in "land use" with widely differing statistical and mapping approaches and no clear and uniform categories and transitions, different and changing definitions, and a predominantly economic set of indicators and proxy variables (see Box 8.1 for further discussion).

Box 8.1. Constraints on the quantification of projected impacts of intensification / marginalisation and the loss of permanent grassland on land services

Food production

The suitability of soils for arable cropping and permanent grassland was used in Chapter 4 as an indicator of the performance of the land service food production. The soil suitability for arable cropping and permanent grassland was calculated from the revised soil suitability criteria used in the Crop Growth Monitoring System (CGMS) of the MARS Crop Yield Forecasting System (see Chapter 4). The analysis was carried out by overlaying the soil suitability maps with maps of the land cover flows for the period 1990-2000, and for the period 2000-2030. The land becoming unavailable for arable cropping or permanent grassland due to these conversions is depicted as a percentage of total area for NUTS3 units in the European Union. This type of overlay analysis is not possible for the intensification and marginalization issue, as the information on these changes is not available in a readily usable format, and data from different time periods cannot be easily compared. As noted in discussions in this project, the scope of the project does not allow farm level data to be processed for Europe.

Water retention

Impacts of intensification which goes along with compaction (as compared to current situations and marginalization, and abandonment) are similar to some extent with impacts of soil sealing on water retention as discussed in Chapter 4 (Stoate *et al*, 2009). They include the reduction of water infiltration and increased runoff volumes and peak flows. The processes associated with marginalization and abandonment would conversely, at different rates per soil type lead to increases in water infiltration and decreased run off volumes and peak flows. Again, however, the land use information and the working scale available in the project does not enable a spatial representation of these processes. To indicate the *change of performance of the land use service "water retention"* as a result of changes agricultural land use, we looked at the possibility of using Effective Soil Water Storage Capacity in the first 100 cm of the soil (SWSC_eff_2 in mm), as was done in the soil sealing Task 2 analyses (see Chapter 4). In *unsealed* soil profiles, e.g. in agricultural land, infiltration of water in an unsaturated soil profile under precipitation will result in a wetting profile with low soil water suctions at the surface, which implies that most of the effective soil water storage capacity is available in the topsoil. Intensification which goes along with compaction, will result in reduced infiltration, implying that a smaller part of the effective soil water storage is used for water retention. This occurs in an estimated 33 million hectares of agricultural land in the EU with yield losses of 5-35% (Anon., 2006).

Soil condition

Impacts of soil sealing on soil organic carbon stocks were estimated in Chapter 4 as part of Task 2, using analysis for soil sealing with the MITERRA-Europe model. In MITERRA-Europe the Tier 1 approach was implemented to assess changes in soil organic carbon stocks due to land use changes or changes in land management. The IPCC protocol distinguishes six types of land use: forest land, cropland, grassland, wetlands, settlements and other land. In the Task 2 analysis we extended these land use types with perennials and abandoned land. Change in SOC stocks can be estimated for mineral soils with land-use conversion using the initial (pre-conversion) SOC stock and SOC stock after conversion. So the basic mechanism and model to quantify and map the changes for Europe are available. However, the geographically explicit and localised and quantified changes in area per land use class is still lacking, so an EU wide assessment, by necessity was based on interpretations at higher geographical scales, such as NUTS regions.

Biodiversity

The MSA indicator, as used in the GLOBIO3 model (Alkemade *et al*, 2006), was developed to quantify the impacts of land use changes and associated pressures on biodiversity. It is therefore also used in this study to assess the impact of soil sealing on biodiversity (see Section 4..4.2 and for a detailed account of the methods, Annex 2.6). The MSA index is a measure of the intactness of ecosystems and their natural species communities, and does not take into account other aspects of biodiversity, such as impacts on rare or otherwise threatened species.

However, this globally applicable indicator is not well suited to assessing the biodiversity impacts of land use changes in the EU. Thus is because in the EU, a large proportion of habitats and species of conservation importance are reliant on farming systems, albeit low intensity HNV systems. The assumptions in the MSA indicator on the biodiversity value of farmland and the benefits of abandonment are therefore almost certainly overly simplistic in an EU context.

It would be more appropriate to assess the likely impacts of abandonment through a European specific analysis of key species of EU conservation importance based an assessment of their specific habitat requirements, such as carried out by Butler *et al,* (2007). Such new and detailed analysis is beyond the scope of this project, but would provide valuable information that would aid the development and targeting of policy measures (see Section 10.3) to support farming where this is beneficial for biodiversity.

The consequence is that the assessment of the impacts of the trends and future of intensification versus marginalisation (and in the extreme case abandonment) and the loss of permanent grassland, can not follow the same approach as the one used for soil sealing impacts. An adapted approach is therefore used here, which combines descriptions of impacts on the land services, together with a comparison of relatively highly aggregated maps of trends and future geographic distributions of these processes. Before presenting results of this comparative approach, a description is given of the general types of land use change and associated pressures that result from intensification / marginalisation and the loss of permanent grassland.

8.1.1 Types of impacts associated with agricultural land use changes

The historic and expected changes in the structure and composition of the agricultural sector in Europe, as described in Chapter 7, in terms of intensification/marginalisation have led, and are expected to continue to lead to changes in land use patterns and practices, including the loss of permanent grasslands. In this section we outline these changes. Impacts are discussed in Section 8.2.

Intensification

Two major classes of consequences of the intensification processes (see for definition Section 7.2.1) can be distinguished in the field, but not always in the land use accounts and maps:

Changes in structure of farms and farm regions with associated changes in patterns of cropping and stocking.

- Increasing simplification and scale

Simplification may refer to types of crops and stocks in a region, or on a farm, moving from mixed farms and mixed farming patterns to mono-cultures and feed-lot ranching. This has happened across Europe, and led to a decrease in the diversity of rural landscapes (Pedroli *et al*, 2007), and at the scale of individual lots, to removal of landscape features such as hedges, woodland and ditches (e.g. Manhoudt and De Snoo, 2003), or at least to a cessation in management of the landscape features.

- Conversion of grasslands to arable use

A special case is the large scale conversion of (permanent) grassland to arable use (which may include grasslands, but these are temporary grasslands as part of a crop rotation). This typically results in higher agricultural productivity, but with a loss of associated historic landscape features, and grassland biodiversity. There are also major changes to soil structure as a result of the disturbance from ploughing and other cultivations and compaction from heavy machinery (Uphoff *et al*, 2006).

- Abandonment

As effort and investment time is diverted to the productive activities, some areas that are deemed to have less potential for agricultural production (or for which intensification would be considered not to be cost-effective) may be abandoned. In some cases this may be partly to help restore biodiversity (e.g. through natural regeneration or proactive habitat restoration measures).

Changes in the intensity of use of inputs in the agricultural production processes (crops and livestock)

These typically include:

- increased frequency of use and/or quantities of fertiliser and pesticides (sometimes resulting in simpler crop rotations or simpler rotations, which reduces crop diversity in the landscape);
- more frequent cultivations (e.g. cultivation and reseeding of temporary grasslands) and other agricultural operations (e.g. hedge cutting and ditch clearance); and
- hydrological management (e.g. field irrigation and drainage).

Application of fertiliser and pesticides changes the physico-chemical environment in the soils, and can directly and indirectly affect ecological processes and species within fields, and beyond as a result of drift and transport in water courses. Increased drainage changes the physical structure and hydrology first and the chemical composition secondly (due to increased aeration of the soils).

Marginalisation

The following processes are considered to be potentially part of the marginalisation issue (see Section 7.2.1 for definition):

Changes within farming systems

- reduced input use (less fertiliser, pesticides, maintenance work);
- reduced stocking densities;
- reduced maintenance of infrastructure; and
- a 'contraction' of the farming system, usually involving:
  - intensification on the more productive land, and
  - reduced inputs or abandonment of poorer, less accessible parcels of land.

In all these cases, food production is expected to decrease, at least at the farm level. In the contraction case intensification in some areas may balance out abandonment in others, but such circumstances are unlikely occur often.

Change into other forms of "agricultural" use

The following types of conversions are most prominent:

- conversion of crops to permanent grassland, typically involving the simplification of a mixed farming system into livestock production only;
- afforestation of agricultural land; and
- conversion of agricultural to grow energy crops.

In the first case, food production is continued, but in a less intensive form. Afforestation and energy crops imply loss of the cessation of food production as the primary land use (though some products such as honey may be produced).

The change from agricultural land to land use types such as infrastructure, industrial areas, or residential areas and tourist developments can be typically classified as forms of soil sealing. The consequences for the land services are extensively described in Section 4.3. If the other land use is reverting agricultural fields to "nature", then the processed / impacts listed under abandonment can be taken as typical.

Abandonment

The last case of change in the agricultural sector is the extreme form of marginalisation called abandonment. As discussed in Section 7.3.2, there are a variety of forms of agricultural abandonment. It can be permanent or transitional and may range from actual abandonment where the land is not used at all by the owner or occupier; to semi abandonment or hidden abandonment, where there is still some form of management, which might be simply to keep it available for future use or to claim a subsidy. Very extensive or intermittent farming operations may also fall into this 'hidden' category. Extensively grazed grasslands, especially those in mountainous regions and/or on poor soils are most likely to be subject to abandonment.

When farms are fully closed under permanent abandonment and all work on the land is stopped, then natural ecological processes of invasion, colonisation and succession takes over, in which case the following consequences are typical:

- invasion and colonisation of land and existing, but abandoned buildings and infrastructure;
- natural succession, e.g. pioneer vegetations (on abandoned cropland) and a re-growth of shrubs, scrub and eventually woodland vegetation; and
- in some cases, soil erosion may occur at first if traditional terracing or other water and soil preserving practices are abandoned. Flooding may occur if flood defence structures fall into disrepair.

However, in some cases active measures are undertaken (though not necessarily immediately) to convert the land to other uses, such as forestry and/or to restore habitats for nature conservation purposes.

8.2 IMPACTS OF INTENSIFICATION / MARGINALISATION

8.2.1 Location of changes

Consideration of the likely future impacts of intensification/ marginalisation and the loss of permanent grasslands needs to take into account the projected locations of such land use changes. This context affects the magnitude of impacts, and in some cases whether it is beneficial or detrimental to the land service in question. This section therefore briefly reviews the key findings of this study in terms of projected trends in land use change in the EU.

As a result of current trends in land use drivers (as discussed in Chapter 7) it is expected that the main areas of future intensification in the EU up to 2030 are most likely to be in the EU-12 Member States (Cooper *et al*, 2009). This study's model projections based on the B1 reference scenario also indicate that the most likely areas for agricultural expansion are in the new Member States, especially the Baltic States (see Table 3.6 and Figure 8.1). This contrasts with more recent periods where intensification indictors suggest that the main areas of intensification were in Ireland, Spain, the former GDR, Hungary, the Baltic States and parts of North Western Europe (see Figure 3.7 for 1990-2000). However, the data for the Hungary, the former GDR and Baltic States may be misleading and probably relate to relatively small increases in the second part of the 1990's following a major decline in agricultural inputs and extensive abandonment of agriculture, which occurred as a result of the political changes in the region and a crash in state support.

The current expectations for intensification in the new Members States arise because there is considerably more scope for investment, restructuring and technological improvements in the agriculture sector in the region. For example, the use of fertiliser in Bulgaria, Hungary, Poland and Romania, declined dramatically in central and eastern Europe around 1990, and has only slightly recovered since (Faostat, 2008, cited in Stoate *et al,* 2009). There are large areas of HNV farmland in these countries, but it appears unlikely that they will be at risk of intensification according to the analysis in Section 3.4.2. Instead, as described below, these areas are much more likely to be at risk of abandonment.

Losses of permanent grassland are projected to be widespread across the EU, with significant declines in all Member States other than (Cyprus, Denmark, Finland, Malta, and the Netherlands). Particularly large declines are expected in Portugal (69% loss), Greece (46% decline), Spain (43% decline) and Estonia (30% decline).

The analysis in Chapter 7 indicates that the areas which are most susceptible to marginalisation are regions with extensive farming and those where small-scale farming is prevalent. Regions dominated by extensive farming include many areas in Spain and Portugal and regions with a pre-dominance of small-scale farm holdings can be found in parts of many of the EU-12 Member States. Furthermore, this study's projections for land use change suggests that, under the B1 scenario, there will be widespread abandonment, particularly in Spain and Portugal, parts of Finland and Sweden, highland areas of France, Italy, central Europe, Romania, Bulgaria and the UK, and parts of Greece (see Figure 8.1). However, it is important to note that the green colours do not indicate that all agricultural activities in these locations are likely to be abandoned. In reality finer-scale patterns of change will be more diverse.

It seems reasonably certain that HNV farmland areas will be particularly affected by land abandonment, according to the detailed analysis carried out in this study. The projected land use changes indicate that 9.0% of the non irrigated arable land may become (semi-) natural vegetation area, and 10.87% may turn into recently abandoned arable land (Table 3.8). The projected abandonment trend for pasture is even greater with 20.4 percent developing into recently abandoned pasture, and 7.7 percent into (semi-) natural vegetation areas. The loss of HNV pasture areas in the Mediterranean countries (Greece, Spain, Portugal and Italy) is particularly significant. Of existing semi-natural vegetation areas, 17.3% is expected to develop into forest.

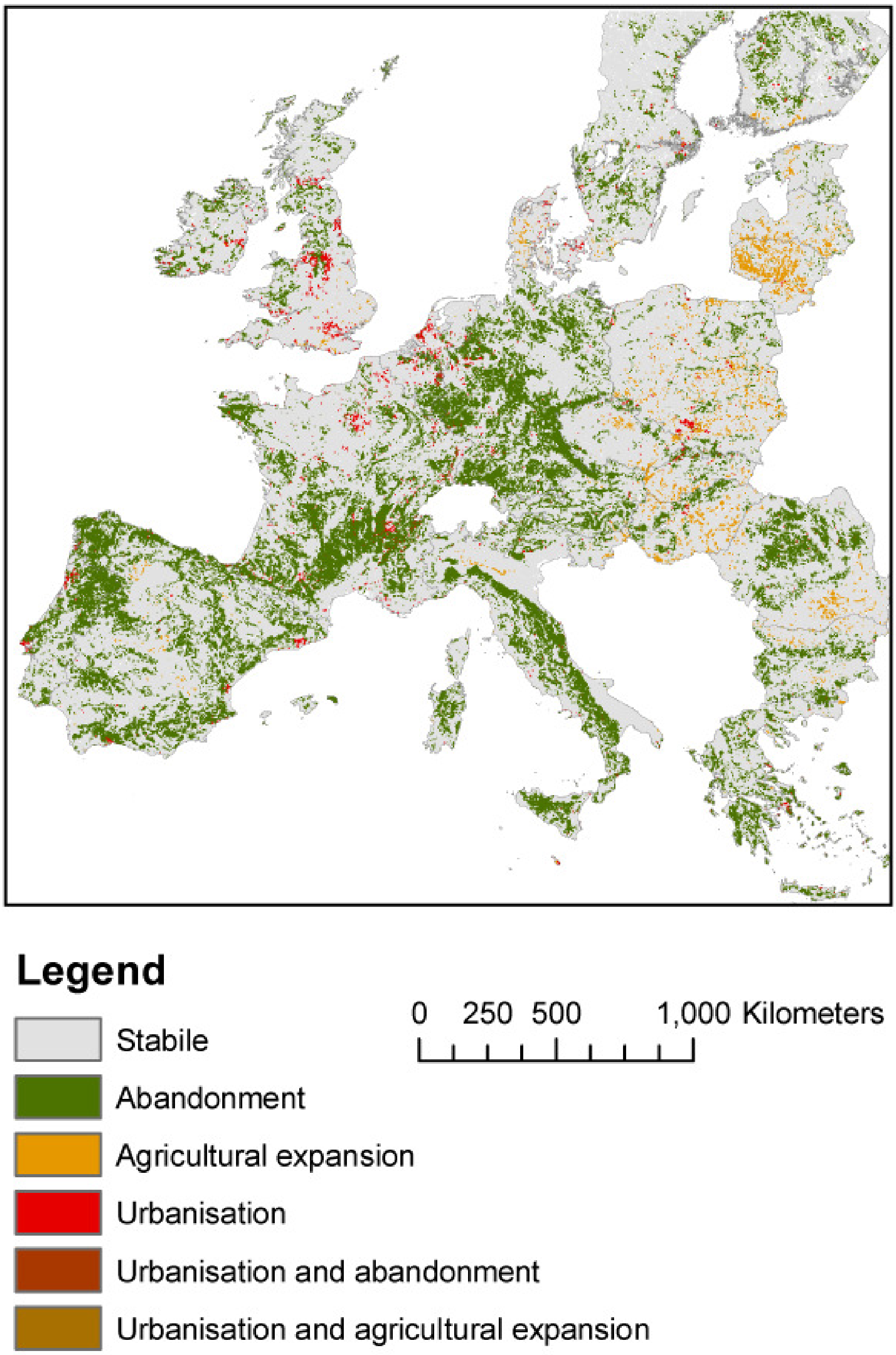


Figure 8.1. Generalised dominant land use / cover change for 2000-2030. Source: this study's modelled projections based on the B1 reference scenario. Reproduced from Chapter 3 – see section 3.4.2 for details.

It is, however, important to note there is less confidence over the reliability of the projections for abandonment in parts of central Europe (such as Germany), the UK and Ireland, this is because the normal drivers of abandonment are less apparent in these areas.

Despite the increase in some semi-natural habitats resulting from some abandonment the combined changes in land use are projected to lead to an overall decline of 14% in the area of semi-natural habitats (which as discussed below are of high biodiversity importance). According to the model projections (Table 3.6) the most significant declines in semi-natural habitat (in both relative and absolute terms) are expected in eastern Europe, with substantial declines in the Baltic States, Bulgaria, the Czech Republic, Poland, Slovakia and Slovenia.

8.2.2 Magnitude of the impacts

Table 8.1 summarises the major changes caused by intensification/ marginalisation and the loss of permanent grassland in general terms.

Food production

It is clear from the discussion of the agriculture commodity markets in Section 7.2.2 that the global and EU demand for cereals, meat, dairy products and other agricultural products will remain strong. Recent scientific studies also indicate that the availability of additional suitable land for agriculture in the world is restricted. These factors together with the growing demand for biofuels (which will further increase the competition for land) and increasing impacts of climate change are expected to maintain relatively high agricultural commodity prices. These drivers might be expected to support an increase in food production in the EU through agricultural expansion and intensification. However, as discussed in Chapter 7, agricultural commodity production, other than wheat and coarse grains, is expected to shift increasingly towards the world's developing regions, especially for meat and dairy products.

Consequently, the results of this study strongly suggest that the agricultural area in the EU will decline (until at least 2030), with a projected loss of 13% of both arable land and grassland according to the B1 scenario. Most of this decline will come about as a result of the abandonment of marginal areas of agriculture. This projection for grasslands, appears to be highly plausible and would be a continuation of the observed decline over the last few decades (see Table 4.2). However, it should be noted that the projections for arable loss are larger than projected in other studies, and may be questionable. For example, the EURuralis study (www.eururalis.nl) observed a smaller growth of crop production and the production of animals from 2000 till 2030 in the EU (up to 50 millions of tonnes of crop and 50 Mhead of farm animals in the B1 scenario) due to lower demographic and economic growth.

Table 8.1 The impacts of agricultural intensification and marginalisation and loss of permanent grassland on the land services food production, biodiversity, water retention and soil organic matter. Source: accounts in Sections 8.2 and 8.3, and Chapters 2-7, Stoate *et al*, 2009.

	Intensification (higher inputs per ha)	Marginalisation (lower inputs per ha)	Loss of permanent grassland
Food production	Normally increases in yield, but yields reduction may occur as a result of soil erosion and compaction.	Decrease of yields, and change of products (e.g. from cereals to extensive dairy / meat production), to loss of all commercial food products (though sometimes with replacement by other commodities, e.g. timber, energy crops).	Increases in dairy and meat yields when replaced by intensive temporary grasslands or other fodder crops; or to cereal and other crops for direct consumption (with higher food production efficiency than meat production)
Biodiversity	• Reduced landscape-scale biodiversity due to polarisation in farming systems • Decrease of species richness in intensive crops and grasslands, due to reduced suitability for breeding and feeding etc • Reduced plant and invertebrate diversity and abundance as a result of direct impacts of pesticides • High mortality rates as a result of frequent farming operations and high stocking rates • Decrease of species richness due to indirect pressures via change in environmental conditions (fertilizer, low water levels, pesticides)	• Decrease of cropland species and meadow flowering species requiring disturbance, and related fauna. • Increase of early successional (weedy) species. • Subsequent increase of scrub, and tree layer species, with associated fauna; loss of open habitat species. • Biodiversity conservation impacts vary according to context (esp. scale and type of input reduction and diversity of surrounding habitat).	• Impacts vary according to context, but typically include significant reductions in the diversity of plants associated species; the most significant impacts occurring when old and semi-natural grasslands are replaced by intensive temporary grasslands or other crops. • Loss of grasslands can also reduce landscape-scale diversity, especially in arable dominated areas. • Indirect impacts result from increased pollution of water courses (from silty run-off following cultivations and increased use of fertilisers etc).
Water retention / quality	Increased run-off rates, and nutrient pollution from high fertiliser use and nutrient rich runoff from cultivated fields and intensive stockyards. Pesticide pollution from spray drift and run-off. Point source pollution from spills etc.	Recovery of natural hydrological processes and reductions in pollutant loads in ground- and surface waters	Dependent on soil and hydrology at the location, and new land use/cover, but significant reduction in water quality if old low intensity grasslands replaced with intensive cultivated crops.
Soil organic matter	Reduced levels of organic matter under continuous intensive cultivations.	Slow restoration of natural soil processes, leading to significant increases in SOM. But temporary risk of losses from erosion in some cases (e.g. where terraces fall into disrepair)	Dependent on soil and hydrology of the location, and new land use/cover; but significant loss of soil carbon from ploughing of old grassland, especially if then placed under intensive cultivation.

It is not possible within the scope of this study to assess the likely impacts of the projected land use changes on the overall production of food in the EU. Nevertheless, there is little evidence that the projected declines in productive area will lead to declines in overall production and contribute to food shortages or food security issues in the EU. This is primarily because the projected decline in productive agricultural area is a result of market forces that arise from an over supply of food in the EU market. Any future shortfall would therefore be expected to result in a correction through the markets, that would through increased prices, lead to an increase in supply, such as through reduced abandonment or further intensification. In fact it seems likely that the decline in production area (even if at 13%) may well be more than matched by increases in productivity following the expected intensification over large areas of eastern Europe.

It is also important to note that some increases in intensification may only lead to short-term term yield increases at the cost of longer-term productivity, for example as a result of soil erosion or compaction. Recent estimates based on the Pan European Soil Erosion Risk PESERA model indicate that a substantial area of Europe has annual erosion rates over 1 tonne per ha, with significant areas, especially in southern Europe subject to rates of over 5 tonnes per ha (Kirby *et al*, 2004). It is estimated that 33 million ha of agricultural land in the EU now suffer from soil compaction with yield losses of 5–35% (Anon, 2006, cited in Stoate *et al*).

Water retention and quality

The spatial distribution of the effective soil water storage capacity (SWSC_eff) is shown in Figure 8.2 (reproduced from Chapter 4). High values (up till 180 mm/100 cm) occur in relatively deep, well drained soils, mainly Luvisols and Podzols, in Northern Europe. Soils with small values of SWSC_eff are mainly found in shallow soils (Leptopsols, Regosols) or soils with hard pan layers of calcium carbonate (Calcisols), mostly in Southern Europe. The effects across Europe on water retention and water quality of intensification and marginalization can only be estimated at the level of regions in Europe. When the map in Figure 8.4 is compared with the CLUE 2030 B1 scenario map (Figure 8.3) it is clear that part of the projected *abandonment areas* are in the Northern part of Europe (e.g. Germany, Northern France), on soils with a high water storage capacity, and partly in Southern Europe (e.g. Spain and Italy) on soils with low water storage capacity. This would imply that with soil recovery processes in abandoned areas, the water retention service in these areas will increase. Intensification is expected to mainly take place between 2000-2030 in the eastern Member States of the EU, most of it on soils with high storage capacity. Losses of water retention can therefore be expected in these areas.

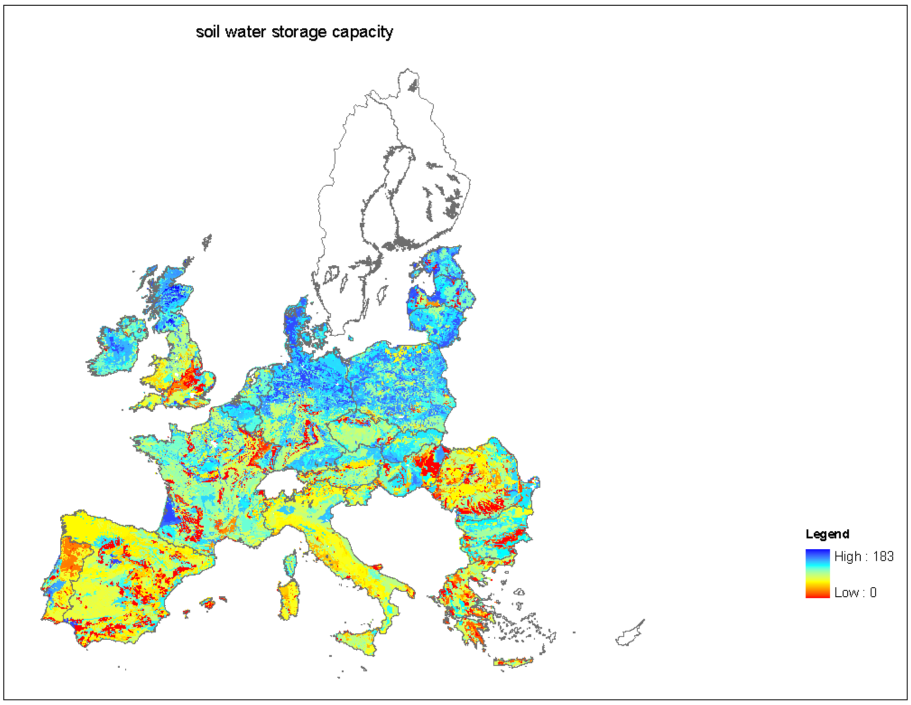


Figure 8.2. Effective soil water storage capacity (mm for the first 100 cm of soil). Adapted from the PESERA database. Source data from Brian Irvine, University of Leeds, UK. See Section for 4.4.6 for details.

Agricultural activities have a wide range of documented detrimental impacts on water quality, including:

- Ploughing and other cultivation practices: Encourages erosion, with sediment–rich runoff and wind blown particles increasing sediment loads and turbidity: sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds has an impact of riverine habitats and associated species (including fish spawning).
- Artificial fertiliser use: runoff of nutrients, especially phosphorus (attached to soil particles), leads to eutrophication. Nitrate is highly mobile and leaches readily into the groundwater; excessive levels are a threat to public health.
- Manure spreading: similar impacts to artificial fertilisers, but spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination. Contamination of ground-water, especially by nitrogen.
- Pesticides: Spray drift and pesticide contaminated run-off can disrupt aquatic ecosystems; potential public health impacts from eating contaminated fish. Some pesticides may leach into groundwater causing human health risks.
- Feedlots/animal stockyards: Runoff can be highly nutrient rich, causing eutrophication. Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces. Potential leaching of nitrogen, metals, etc. to groundwater.

- Irrigation: Runoff of salts leading to salinisation of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts. Enrichment of groundwater with salts and/or nutrients.

Agricultural pollution has been shown to have widespread and significant impacts on aquatic ecosystems and biodiversity. The most important and common impact being eutrophication, which disrupts aquatic ecosystems by causing changes in the vegetation composition (ie. from macrophytes to algae) and associated species communities, and in extreme cases deoxygenation and ecosystem collapse. Freshwaters are typically most vulnerable to phosphate pollution, whilst eutophication of marine waters is normally triggered by nitrogen enrichment. There is also good evidence that a large proportion of nutrient loads in freshwater bodies and coastal waters arise from agricultural sources (Stoate *et al*, 2009). Indeed, this was clearly illustrated by an observed decrease in nitrogen and phosphate pollution in freshwater bodies in central and eastern Europe following the collapse in the use of fertilisers in the region in the early 1990’s (Stalnacke *et al*, 2004; cited in Stoate *et al*, 2009).

The required data are not available to quantify the likely impacts of the projected trends in intensification and marginalisation from this study on water quality. However, it is highly likely that the projected land use changes would lead to increased pressures on water quality, primarily as a result of the expected agricultural intensification in central and eastern Europe, and the associated expected increase in fertiliser use etc. It is also expected that there will be wider and ongoing conversion of permanent grasslands to arable systems, which will increase silty–nutrient rich run off.

Some improvements in water quality may occur as a result of the abandonment of agriculture, especially where this reduces soil erosion and run-off from overgrazed grasslands. Abandonment of fertilised arable land is unlikely to occur very often and thus water quality benefits from this land use change will be small. In some cases abandonment may trigger increased erosion, eg as a result of terraces falling into disrepair or increased incidences of severe fire as vegetation builds up. However, such impacts are likely to be relatively localised and often short-lived.

Improved farming practices (including precision use of fertilisers) may reduce fertiliser use and the enrichment of watercourses etc., but impacts on water quality are likely to be variable and depend on local circumstances.

Biodiversity

Intensification

Widespread intensification of agriculture across Europe has had profound impacts on biodiversity, including well documented declines birds in farmland bird populations since the 1970s, particularly in western Europe (Newton, 2004; O'Connor and Shrubb, 1986; Pain and Pienkowski, 1997; Tucker and Evans, 1997, Wilson *et al*, 2009; Stoate *et al*, 2009). Furthermore, an analysis of bird populations in the EU found that downward trends are significantly correlated with cereal yields, indicating a strong link to the intensity of agricultural production (BirdLife International, 2004). Non-crop plants and invertebrates have also declined massively, primarily as a result of the use of fertilisers and pesticides (Aebischer, 1991; Donald, 1998).

The causes of these declines in relation to intensification have been relatively well studied and in an in depth review, Stoate *et al* (2009) distinguish the following three clusters of intensive management practices as being particularly damaging:

- **Drainage of grasslands** is a wide-scale phenomenon across Europe (from the Netherlands to Hungary). Land drainage has impacted upon many wetland bird species (Ausden *et al*, 2001). Many Lepidoptera species are affected by drainage of wet grassland (Wynhoff, 2001). Extraction of groundwater in The Netherlands has lowered the groundwater level with negative consequences for groundwater-dependent ecosystems (Melman *et al*, 2008)
- **Increased soil fertility**, as a result of the use of artificial fertilisers (and some atmospheric deposition). High fertilisation levels, regular re-seeding, and frequent mowing or intensive rotational grazing have led to dramatic declines in grassland biodiversity (Stevens *et al*, 2004a; Kahmen and Poschlod, 2008 for plants; Verhulst *et al*, 2004 for birds, Wenzel *et al*, 2006 for butterflies). For example, in the UK grassland diversity was found to be inversely related to nitrogen inputs (McCracken and Tallowin, 2004). In Finland, rare and declining grassland plant species on the remaining semi-natural grasslands are associated with low-nutrient sites and patches (Raatikainen *et al*, 2007). Long-term changes in butterfly and moth abundance in grassland sites in Sweden showed contrasting trends for species dependent on nutrient-poor conditions, which tended to decrease, and species dependent on nutrient-rich conditions, which tended to increase (Ockinger *et al*, 2006).
- **High stocking densities on pastures**, which affect biodiversity, nutrient leaching, and erosion rates. Until the 2005 reforms, CAP headage payments favoured high stocking rates, but the transition to area payments has led to a reduction of stocking levels especially in marginal areas such as the uplands of the UK (Gaskell *et al*, 2007). High grazing intensity is usually recommended to maintain and restore high species richness of vascular plants in grasslands (Pykala *et al*, 2005), but this may be less suitable for birds and insects (Soderstrom *et al*, 2001). More rapid and dense grass growth of competitive species, as well as higher stocking densities, alter the habitat properties significantly, reducing botanical diversity, grazing opportunities for wildfowl, and the range of seed resources (McCracken and Tallowin, 2004).

The increased use of fertiliser and herbicides is a particular threat to the remaining areas of semi-natural grassland in Europe. This is because evidence from both empirical studies and field surveys suggests that herbage production from semi-natural grassland is generally low, especially when botanical diversity is high, and is typically less than half that which may be obtained from agriculturally improved grassland in the same localities (Peeters and Janssens, 1998). However, herbage production is only a partial measure of forage value. A review of factors affecting forage digestibility from semi-natural grassland (Bruinenberg *et al*, 2002) concluded that digestibility is usually lower than in forages from grasslands used in intensive production. Consequently, one of the first steps to be taken in intensification is the increased use of artificial fertilisers (and drainage where this is necessary achieve this) and, to a less frequent extent, herbicides, with the aim being to retain the grassland but to improve its forage quality.

Further intensification is the main driver of the loss of permanent grasslands, because the agricultural benefits of drainage and the use of fertilisers and pesticides etc are increased by converting permanent grassland to arable farming or other crops (e.g. vegetable or fruit). Arable systems may include temporary grasslands in rotation with other crops, but these are frequently ploughed and reseeded with productive cultivars (e.g. *Lolium* spp). This in turn enables grasslands to support very high stocking rates. Or in many arable systems livestock are taken off the grassland, and the forage is cut, stored and then taken to animals that are held in high density stockyards. This is detrimental for biodiversity, as animal dung (particularly from cattle), supports invertebrates, some of which are important prey for several species of bat (Duverge and Jones, 2003) and many birds (Vickery *et al*, 2001). Furthermore, such temporary grasslands often only contain one or two agricultural cultivars with few if any other plant species present. They typically support few other species as result of their rapid and dense growth, and frequent use of herbicides and their frequent cutting and rolling (which destroys the eggs or kills the young of ground nesting birds) and ploughing. Intensive management also has a detrimental impact on birds' food supply (both plants and invertebrates) (Henderson *et al*, 2004; Vickery *et al*, 2001).

In southern Europe, intensification is being driven by increasing demand for Mediterranean products such as olive oil and wine, which is leading to the widespread conversion of traditional HNV arable systems. For example, in Portugal, declines in the economic viability of extensive farming systems is resulting in large-scale conversion of open arable and pastoral landscapes into vineyards and intensive irrigated olive orchards (with densities up to 1,700 trees ha-1). This conversion is considered a major threat for open farmland specialists (Stoat *et al*, 2009).

Abandonment

The results of this study and others (as discussed in Sections 3.4.2, 7.3.2 and 8.2.1) indicate that abandonment is likely to affect a significant proportion extensively managed grasslands and low quality arable fields (including a high proportion of HNV habitats). The principal effect of abandonment in such habitats that ecological succession processes takeover. As a result abandoned arable fields quickly develop ruderal vegetation communities, which then more slowly develop into grasslands. The biodiversity quality of naturally regenerating grasslands will very much depend on the extent to which the soils have been improved by fertiliser use and drainage etc. The availability and diversity of viable seeds will also affect the development of the grassland, such that land that has been under long-term cultivation will have an impoverished seed bank and therefore the development of a diverse sward will be reliant on seeds from elsewhere. External sources of seeds of plants of high biodiversity importance may be rare in many agricultural landscapes. Furthermore, invasive alien species often thrive in abandoned fields and can dominate the vegetation, which can create greater problems than benefits.

In the absence of grazing by livestock it is likely that in many areas of abandoned existing grassland and regenerating grassland succession will continue, thereby producing shrubland or scrub dominated communities, and eventually forest. However, this will not always occur, e.g. as a result of grazing and browsing by wild animals (which in many situations is sufficient to maintain open grasslands or grassland mosaics), climatic conditions (such as in many peatlands or steppic areas) and the absence of seed sources for trees and shrubs. Also some areas that are no longer under agricultural production are nevertheless occasionally cut, or at least kept clear of scrub, in order to comply with cross-compliance rules and thereby continue to receive single farm payments.

It is therefore clear that a variety of habitats types can develop following abandonment, in the short, medium and long-term, depending on circumstances. The size of regenerating patches of habitat and their landscape context will also vary according to the drivers of abandonment. In more intensive areas of farming, abandonment is likely to be rare and will occur in relatively small patches (e.g. on steep slopes or poorly drained patches that are not worth farming or improving). In extensively farmed areas with harsh climates, poor soils etc. that have little prospect for agricultural improvement, then large areas of abandonment may occur, which may transform the landscape.

The impacts on biodiversity in the EU of these various changes in habitat that occur as a result of abandonment will vary according to circumstances, but in most situations they are likely to be significantly detrimental (e.g. Anon, 2005; Stoate *et al*, 2009). In general terms the impacts of abandonment on biodiversity vary according to complex interactions amongst the following factors:

- the biodiversity importance of the existing habitat and its associated species that will be lost as a result of abandonment;
- the potential short- to long-term biodiversity importance of the habitat and its associated species that will be gained as a result of abandonment;
- the extent and proportion of the habitat type that will be lost;
- the extent and proportion of the habitat that will be gained;
- the diversity of habitats within the landscape; and
- the degree of habitat fragmentation within the landscape.

Thus some small-scale abandonment can be beneficial when a habitat of moderate or low biodiversity value is replaced by a higher biodiversity value habitat, especially where this increases habitat and species diversity at a landscape scale (i.e. by creating opportunities for new species communities to develop). Small-scale abandonment may be particularly beneficial when it creates patches of habitat in an otherwise agricultural landscape. Such patches may help to restore ecological connectivity across the landscape (see Section 6.2). It will also be especially beneficial when the gained habitat is potentially of high value (e.g. where a poorly drained area could be restored to a wetland). As discussed, small scale abandonment may occasionally occur in areas of intensive farmland, but it is unlikely to be commonplace; large-scale abandonment in extensively farmed landscapes is more likely to be the norm.

Large-scale abandonment may provide opportunities for large-scale habitat regeneration (or pro-active restoration projects) that in the long-term may produce high value habitats. Such large-scale habitats may be more resilient to climate change and may also help to reverse the impacts of fragmentation, by creating/joining up large blocks of habitat (that may be less disturbed than agricultural habitats). This can provide the large areas of high quality habitat (and perhaps wilderness) that are essential for some species of very high conservation importance (e.g. large carnivores such as the Brown Bear *Ursus arctos*).

But more often large scale abandonment is likely to lead to declines in habitat heterogeneity and species diversity across the landscape, without major conservation benefits for highly threatened species. This is because most abandonment is likely to occur in HNV farming areas systems which are already often key habitats for some species of high biodiversity importance in the EU (including many listed in the EU Habitats and Birds Directives). Furthermore, many of the habitats that will be gained from land abandonment will only be of moderate biodiversity value (at least for many tens if not hundreds of years) as they will be dominated by relatively common and generalist species. Thus, although abandonment of some HNV farming areas may increase species richness amongst generalist species in some situations (e.g. by creating new habitats in otherwise open habitats) it will more often be detrimental to habitats and species of high conservation value.

For example, an assessment of the habitat requirements of farmland birds by BirdLife International (involving a range of European farmland habitat experts), revealed that some 28 species listed on Annex I of the Birds Directive are considered to be threatened by agricultural abandonment in the EU (Table 8.2). Of these eight are considered to be globally threatened by BirdLife International[95] according to IUCN criteria. More recently, an assessment of impacts on Important Bird Areas, revealed that some 40% are affected by abandonment to some extent (Anon, 2005).

The detrimental impacts of abandonment can be exacerbated by inappropriate afforestation. In particular, in Mediterranean Europe afforestation has occurred primarily in marginal agricultural land, following a long-term trend of rural depopulation and abandonment (Stoate *et al*, 2009). Afforestation has been strongly supported by EU funds (such as those resulting from Regulation 2080/92). In recent years, climate change has prompted a new interest in large-scale afforestation to reduce atmospheric concentrations of carbon dioxide, which is likely to affect European farmland landscapes. The forest patches create edge effects that can affect 200m of adjacent farmland, which increases the diversity of forest, shrubland and generalist farmland birds, but reduces habitat quality for the more specialist open grassland species (which avoid forest edges, eg to reduce predation risks).

[95] http://www.birdlife.org/datazone/index.html

	Arable and improved	**Steppe habitat**	**Montane grassland**	**Wet grassland**	**Orchards and perennial**	**Pastoral woodlands**
Black Stork (*Ciconia nigra*)						C
Red-breasted Goose (*Branta ruficollis*)	**H**					
Black-shouldered Kite (*Elanus caeruleus*)						H
Black Kite (Milvus migrans)						H
Red Kite (Milvus milvus)						H
Lammergeier (*Gypaetus barbatus*)			H			
Egyptian Vulture (*Neophron percnopterus*)			**H**			
Griffon Vulture (*Gyps fulvus*)			H			
Long-legged Buzzard (*Buteo rufinus*)		H				
Spanish Imperial Eagle (*Aquila adalberti*)						**H**
Imperial Eagle (*Aquila heliaca*)		**H**				
Lesser Kestrel (*Falco naumanni*)		**H**				
Saker Falcon (*Falco cherrug*)		**H**				
Rock Patridge (*Alectoris graeca*)			H			
Common Crane (*Grus grus*)						C
Great Bustard (*Otis tarda*)		**H**				
Great Snipe (*Gallinago media*)				H		
Pin-tailed Sandgrouse (*Pterocles orientalis*)		H				
Black-bellied Sandgrouse (*Pterocles alchata*)		H				
Roller (*Coracias garrulus*)					H	
Dupont's Lark (*Chersophilius duponti*)		H				
Short-toed Lark (*Calandrella brachydactyla*)		H				
Thekla Lark (*Galerida thekla*)					H	C
Woodlark (*Lullula arborea*)			H			H
Tawny Pipit (*Anthus campestris*)			H			
Aquatic warbler (*Acrocephalus paludicola*)				**H**		
Red-backed Shrike (*Lanius collurio*)					H	
Chough (*Pyrrhocorax pyrrhocorax*)			H			

Table 8.2 Bird species on Annex I of the Birds Directive that are considered to be potentially subject to high or critical impacts as a result of agricultural abandonment. (Source: Tucker and Evans (1997). Assessments were based on the combined views of an expert habitat working group).

Globally threatened species are highlighted in bold.
C = Critical: the species is likely to go extinct in the habitat in Europe within 20 years as a result of abandonment if current trends continue. H = High: the species population is likely to decline by >20% in the habitat in Europe within 20 years as a result of abandonment if current trends continue.

Overall impacts of intensification/marginalisation and the loss of permanent grassland

As a result of ongoing and widespread changes in farming practices a high proportion of rare and vulnerable species of EU conservation importance are dependent on grasslands and other semi-natural habitats of HNV farming systems; and these are now threatened by further agricultural change. For example, 22 percent of all threatened species in Finland are dependent on semi-natural grasslands (Poyry *et al*, 2004), and 60% of butterflies associated primarily with them have declined during the past 50 years (Kuussaari *et al*, 2007). Many of the most important remaining grasslands are now found in central and eastern Europe, as a high proportion of receive no or little artificial fertiliser – and therefore their natural vegetation communities are relatively intact. In Hungary only about 5% of grasslands were being fertilised in the 1990s (Nagy, 1998). Some grasslands are also relatively unique in the EU. For example, the steppe-like grasslands in Romania have particularly high conservation value for vascular plants, gastropods, and diurnal and nocturnal Lepidoptera (Baur *et al*, 2006).

Despite the recognition of the biodiversity importance of many of these semi-natural grasslands and other extensive traditional farmland, including as HNV habitats, and their protection and management through EU directives and agri-environment measures, it is apparent that they continue to decline in extent and quality. HNV farmland has undoubtedly declined considerably in recent decades (although there are no EU wide monitoring data to quantify this) and may species-rich agricultural habitats are now rare. Consequently, a recent assessment of the status of habitats and species of Community Interest[96] concluded that habitats linked to agriculture generally have a worse conservation status than others, with 7% of agricultural habitats having a favourable conservation status compared to 21% of other habitats (European Commission, 2009). Furthermore the conservation status of grasslands is of particular concern, as only about 8% are in favourable condition, and over 50% are in unfavourable-bad condition. The Commission also notes that "abandonment of traditional management practices has resulted in a loss of biodiversity in some locations whereas in others the shift towards more intensive agricultural practices is the root of the problem".

There is also good evidence that many species associated with farmland habitats have declined substantially in recent decades and continue to do so. Although the European Common Farmland Bird indicator suggests that declines have levelled off since 1990 (EBCC/RSPB/BirdLife/Statistics Netherlands, in EEA, 2009), an assessment in 2004 of all farmland birds found that EU (and pan-European) farmland birds populations continue decline (BirdLife International, 2004). Moreover, some of the apparent levelling off of declines in common species was probably a result of the introduction of set-aside, and therefore it is possible that further declines will result from its abolition (Tucker *et al*, in press).

It is also important to note that some species seem to be more significantly affected by agricultural changes than birds (many of which are relatively generalist and adaptable). For example, since 1990, grassland butterflies have suffered even bigger

[96] In accordance with Article 17 of the Habitats Directive

declines than birds, with a reduction of grassland butterfly abundance by almost 60%, and there is little sign of improvement (Van Swaay *et al*, 2008). The main causes of the decline are thought to be agricultural intensification in some areas and land abandonment in others.

Soil organic matter

The total soil organic carbon (SOC) stock of mineral soils up to a depth of 30 cm is about 25 Gton C for the EU27 countries, and therefore even moderate losses of carbon from soils could significantly undermine attempts to reduce greenhouse gas emissions and reach climate stabilisation targets. The potential impacts of intensification are therefore of great concern as it is well known that intensive farming reduces SOC levels. In fact carbon losses from croplands are considered to be the largest biospheric source of carbon emissions to the atmosphere in the EU, with estimated losses of 78 (S.D. 37) Mt C per year (Smith, 2004). Impacts of intensification in northern and temperate countries are of particular concern because soils in wet and colder climatic zones have higher SOC stocks with more than 90 ton C per hectare. In Mediterranean countries SOC stocks are much lower, about 30 ton C/ha. The conversion of permanent grasslands (especially those that are much older then five years) is particular damaging in terms of SOC losses.

Conversely, extensification and abandonment increases organic matter in the soil due to higher inputs from crop residues and less soil disturbance. Thus the expected losses as result of the expected intensification in parts of the EU and conversion of permanent grasslands to arable, may be offset to some extent by land abandonment, especially where arable fields revert to grasslands and forest. The carbon sequestration potential from the conversion of cropland to grassland in Europe is estimated at 1.2-1.7 t C ha^{-1} $year^{-1}$ (Smith, 2004). However, a large proportion of abandonment will probably be on existing permanent grasslands which will already have high carbon stores, and therefore potential carbon storage benefits will be less and slower to accrue.

Overall Smith (2004) calculated that the potential biological carbon storage in EU-15 Member States cropland is of the order of 90–120 Mt C per year with a range of options available including reduced and zero tillage, set-aside, perennial crops and deep rooting crops, more efficient use of organic amendments (animal manure, sewage sludge, cereal straw, compost), improved rotations, irrigation, bioenergy crops, extensification, organic farming, and conversion of arable land to grassland or woodland. However, as a result of socio-economic and other constraints realistically achievable storage is probably only about 20% of the biological potential. And it is also important to note that the potential impacts on non-CO2 trace gases need to be factored in.

With the currently available data a spatial match between losses from intensification and gains from marginalisation cannot be made. For example, in the Netherlands both processes occur in mosaics at very small geographical scales. It is therefore not possible to quantify the overall likely SOM impacts of the land use change projections from this study's models.

8.2.3 Conclusions

Although there is some uncertainty over the magnitude and exact locations of agricultural land use change between now and 2030, it is reasonably certain that further intensification of production will occur in the EU, mainly in the EU-12 Member States. It is also likely that substantial areas of farmland, and especially extensively managed marginal farmland will be abandoned in terms of agricultural production. Abandonment will be relatively widespread in the EU, but will occur predominately in mountainous regions and areas with poor soils or climates that are not conducive to agriculture. It is expected that both intensification and abandonment will lead to significant losses of permanent grassland across much of the EU, with particularly large losses in southern Europe and some of the EU-12. HNV farmland habitats will be especially vulnerable to agricultural abandonment, which will result in the loss of a high proportion of grassland and semi-natural habitats (other than forests) within them.

The likely impacts of these expected trends in intensification/marginalisation and loss of permanent grasslands on land services are difficult to quantify with the data that are currently available, and are subject to some uncertainty. In particular it is not possible to quantify overall impacts on food production, as expected increases from intensification in some parts of the EU may be offset to some extent by the expected decline in total agricultural area. There may also be some negative impacts on food production as a result of climate change and ongoing soil degradation and erosion (which may be exacerbated by climate change). Nevertheless, there is little indication that there could be potentially significant declines in overall production that could contribute to food shortages or food security issues in the EU.

There is good evidence that the projected intensification of conventional agricultural systems will contribute to further losses of soil carbon, and reductions in soil water retention and water quality. But this may mitigated to some extent by improved farming practices and extensification and abandonment of farming in some areas, especially where these coincide with erosion prone soils. It is not possible to quantify these changes or establish the net impact resulting from intensification in some areas and marginalisation in others.

There is little doubt that the projected levels of intensification/marginalisation and associated losses of permanent grassland would have significantly detrimental impacts on biodiversity. These impacts are likely to be most significant in central and eastern Europe, because agricultural production in these areas is most likely to be intensified or abandoned, and these areas hold a high proportion of remaining HNV habitats and associated species of conservation importance. Abandonment is also significant threat to biodiversity and HNV habitats in other parts of the EU, such as parts of Sweden and Finland, Iberia, southern France, Italy and south-east Europe. Abandonment may also occur in parts of north-west Europe, but the location and magnitude of these impacts are less certain. In some situations abandonment could provide some biodiversity benefits, particularly if combined with strategic and proactive habitats restoration measures, but overall, abandonment is expected to be a signifcant threat to biodiversity in the EU.

9 ASSESSMENT OF OVERALL IMPACTS OF PRESSURES ON LAND SERVICES

Leon Braat (Alterra) and Graham Tucker (IEEP)

9.1 INTRODUCTION

This chapter addresses the following component of Task 6 (synthesis and recommendations) as described in the Technical Specification for the study. *On the basis of the information collected and analysis under tasks 1 to 5, the contractor shall: assess how limiting soil sealing, designing and preserving biodiversity corridors, and influencing intensification/marginalisation of land and permanent grassland can contribute to optimizing/keeping the land services abovementioned, including the added value of the interrelations between them. This assessment shall be accompanied by reference to appropriate scientific evidence and, to the extent feasible, be quantified.*

The other 3 components of Task 6 are described and undertaken in Chapter 10.

The chapter therefore firstly includes a concise integrated summary of the quantitative results of the assessments carried out under Tasks 1-5 as described in the previous chapters. In particular, key interrelationships, such as synergistic or opposing impacts, amongst the land use pressures (i.e. soil sealing, intensification / marginalisation, permanent grassland loss and habitat fragmentation) are identified and assessed. The analysis aims to quantify the overall impacts of pressures where possible, by drawing on and summarising the most relative results from this study. Where necessary cross-references are given to relevant previous maps, figures or tables etc., rather than repeating them in this section – although a couple of key tables and figures are repeated where these are necessary to illustrate important issues.

Relevant results from other studies are also used and referred to where necessary, but it is not within the scope of this study to carry out an exhaustive literature review on each land service or pressure.

The principal aim of the synthesis of the results is to provide a clear and reliable picture of the likely impacts of the four studied pressures on land services over the coming 25 years. This summary then guides the development and prioritisation of policy measures in Chapter 10; the primary aim being to ensure that the most important impacts are addressed.

9.2 SUMMARY AND QUANTIFICATION OF PROJECTED CHANGES IN LAND USES AND THEIR POTENTIAL IMPACTS ON LAND SERVICES

9.2.1 Land use changes 1960 -2000

From the Task 1 investigations described in Chapter 3 it is obvious that annual conversions of land use were relatively high between 1960 and 1990, with particularly high rates of grassland loss and increases in forest cover (Table 9.1; see Chapter 3 for detailed explanation and discussion of assumptions and limitations). Over the following 10 years, annual rates of change declined and almost halted for forest and non-agricultural land, whilst small increases in urban land (only 40% of the 1960 – 1990 annual increase) continued resulting in very small losses of arable land and grassland. Out of the total area of almost 8.9 million km^2, almost 2.2 million km^2 was subject to changes in land cover, almost half of that accounted for by conversions of grassland into other forms of land use.

Table 9.1. Observed land cover stocks and changes in Europe from 1960 to 1990 and 1990 to 2000 (Source: Table 4.2)

	HISLU						PLCM1990-	PLCM2000-
Classes	HISLU60		PLCM1990		PLCM2000		HISLU60	PLCM1990
	km^2	%	km^2	%	km^2	%	km^2 (per yr)	km^2 (per yr)
Urban	87057	0.97	149620	1.67	157924	1.76	62563 (2085)	8304 (830)
Arable land	3432502	38.27	3595102	40.09	3587947	40.01	162600 (5420)	-7155 (-715)
Grassland	1716263	19.13	643819	7.18	640629	7.14	-1072444 (-35748)	-3190 (-319)
Forest	2260972	25.21	2935273	32.73	2935987	32.74	674301 (21810)	714 (71)
Non-agri.land	1205102	13.44	1416475	15.79	1416887	15.80	211373 (7045)	412 (41)
Inland waters	193284	2.15	219111	2.44	219956	2.45	25827 (860)	845 (84)
Sea	74259	0.83	8786	0.10	8769	0.10	-65473 (2182)	-17 (-1.7)
Total	8969439	100	8968186	100	8968099	100		

Over the past decades, built-up areas grew quickly across Europe from 1960 to 1990, and continued growing but at a slower rate after 1990. This has led to an almost a doubling of the share of land-cover (c. 1% to 1.8%). A rough comparison of the total stocks of urban land in the EU27 in 1960 (87057 km^2) and artificial surfaces in 1990 (149,620 km^2) indicates an increase of 62,563 km^2. Over Europe (24 countries), land take by urban development from 1990 to 2000 amounted to 9,741 km^2, or 6.0% of the stock of urban land in 1990. For the EU-27, this amounted to 10,557 km^2. The largest increase of built-up area has occurred in Western Europe for housing, services and recreation; and this has been at a faster rate than the population growth. Most of the new built-up areas are on land previously used for agriculture (84% of the total land take, EU-24). Loss of agricultural land to urban development has been very prominent in North-western Europe (e.g. the Netherlands), former GDR, the French and Spanish Mediterranean coast, and central/south-east England. Urban sprawl in central and eastern European countries has been generally lower than in the other EU countries. However, uptake of land for industrial and commercial sites was important in some of these countries.

The modelled projections of land use change up to 2030 carried out in Task 1 (Section 3.4) suggest that, on the basis of the Global Cooperation (B1) reference scenario, 10,300 km^2 will be converted to built-up areas between 2000 and 2030 in the EU27 (Table 3.6). This would be a significantly lower annual growth rate in built-up area (343 km^2 y^{-1}) than in the period 1990-2000 (1060 km^2 y^{-1}).

The analysis of land cover data also shows that there has been a substantial increase in forest cover through afforestation in Europe since 1960. This has been an important contributor to the substantial loss of grasslands in central Europe (e.g. Czech Republic, Slovakia and Hungary), parts of France, UK and Portugal and northern

Spain. However, these large rates of increase in forest cover have slowed in the last decade, with projections for the 2000-2030 period now forcasting a 12% increase (Table 3.6).

Some parts of Europe have shown a complex mosaic pattern of opposing processes of intensification and marginalisation over the past decades. Intensification trends were strong in north-western Europe (the Netherlands), Ireland and Spain. Intensification also occurred in some parts of eastern Europe (e.g. the former GDR, Hungary and Baltic States) in the late 1990s following a period of widespread extensification and abandonment, triggered by political changes in the region and a collapse in agricultural support and investment. At the same time abandonment occurred in the some parts of the Netherlands, Ireland, the former GDR and Hungary. As discussed in Section 3.4.2, there is some uncertainty over the actual extent of abandonment in parts of Europe as conclusions from land cover data do not always match well with more reliable assessments of abandonment from case studies. However, abandonment was prominent in parts of Slovakia, Denmark, Sardinia, Portugal and central Spain.

The modelled projections for land use change up to 2030, suggest that significant intensification will mainly occur in the eastern EU (Baltic States, Poland, Czech Republic, Hungary and southern Romania; see Figure 3.9), while abandonment by 2030 is still expected to be prominent in all of the Mediterranean countries, mountainous regions of southern France, Romania and Bulgaria, and parts of Sweden and Finland. Parts of north-west Europe may also be affected, but there is much less certainty over these projections.

The data reviewed in this study show that permanent grassland (in all its different forms) is widely distributed over Europe, generally in landscape mosaics with cropland, forest and natural ecosystems. It is a relatively dominant land use type in Ireland, the Western Parts of the United Kingdom, the Netherlands, Brittany and Central Massif in France, and the mountain ranges in Scandinavia and the Alps countries. Although the losses of grazing land in Europe wide are minor in the period 1990 – 2000 compared to the decades before, most of these regions do still show serious losses, greater than 10% in this period. The rate at which pastureland decreases and its trends reflect both the different assumptions on intensification in livestock production (e.g. increasing productivity, less grazing) and a shift from grass-based production systems towards fodder crops. However, it is important to note that the results of the modelled projections based on the B1 scenario reflect assumptions on grassland preservation as part of both environmental policy goals and restrictive planning.

As discussed in Chapters 2 and 7, the structure of agricultural production and spatial patterns of agricultural land use in Europe are expected to face major changes over the next few decades due to changes in global trade, technology, demography and policies. It is therefore not surprising that the results of 25 scenario-studies show large differences in future land use/cover changes ranging from moderate decreases (15%) to large increases (30%) depending on their assumptions about global trade, potential increases in agricultural productivity and biofuel production (Busch, 2006). However, it is apparent that domestic demand is a minor factor of land use/cover change since the EU population is only changing slightly, and consumption levels are relatively stable and decoupled from economic growth.

Considerable shifts towards grassland abandonment in many scenarios reflect possible changes in agricultural management. However, increasing biofuel production driven by increasing energy demand and pro-active climate policies (in particular the EU's targets under the Renewable Energy Directive) may take up considerable areas according to many scenarios and may thereby prevent substantial abandonment of agricultural land.

9.2.2 Impacts on land services

Table 9.2 provides a synthesis of this study's results with regard to the extent of the areas affected by pressures and their likely impacts on land services, both over the last decade (from observed land cover changes etc) and from modelled projections to 2030. The assessments of extent and trends in pressures are based on this study's consideration of drivers of land use change, the quantitative analyses of historic land use change and the modelled projections from this study based on the B1 reference scenario (see Chapter 3). The assessment of the relative impact of the pressures on each land service, in isolation and in combination, are judgements made by this study's authors. They draw on the analysis carried out in all the tasks as described in the preceding chapters. However, they are not based on numerical calculations and should therefore be treated with caution. Nevertheless, it is considered that some of the larger impacts and obvious trends are captured in the simple analysis and are reliable enough to help to prioritise actions that could maintain and restore land services in future (as described in Chapter 10).

The key trends in pressures are briefly discussed below and a more detailed discussion of the impacts on land services is provided below.

Table 9.2. The likely impacts of projected land use changes up to 2030 on land services

Potential impacts: ↑ = high positive (beneficial); ↑ = moderate positive, ↑ = low positive; ↓ = high negative; ↓ = moderate negative; ↓ = low negative. ♎ = no significant change; ? = uncertain. Symbol combinations indicate the range of impacts that may occur depending on circumstances.

Pressures	**Trend / projection**	**% EU area affected by change[1]**	**Overall impact on services**			
			Food production	**Biodiversity**	**Water retention and quality**	**Soil organic matter**
Soil sealing	1990-2000	0.2%	↓	↓	↓	↓
	2000-2030	0.2%	↓	↓	↓	↓
Intensification	1990-2000	5%	↑	↓	↓	↓
	2000-2030	>20%	↑/↓	↓	↓	↓
Marginalisation/ abandonment	1990-2000	2%	↓	↓/↑	↑	↑
	2000-2030	>5%	↓	↓/↑	↑	↑
Permanent grassland loss	1990-2000	0.1%	↑/↓	↓/↑	↓	↓
	2000-2030	2%	↑/↓	↓/↑	↓	↓
Fragmentation	1990-2000	-	♎	↓	↓	↓
	2000-2030	-	♎	↓	↓	↓
All pressures combined	1990-2000	-	↓	↓	↓	↓?
	2000-2030	-	?	↓	↓	↓?

Notes: 1. Estimates are judgements drawing on the analyses, data and existing literature described in Chapters 3, 4 and 5 (including the 2000-2030 projections based on the B1 reference scenario) and are highly approximate. Estimates of past and projected intensification and marginalisation are particularly uncertain. It is not possible to assess the extent of areas affected by fragmentation as these will extend beyond the footprint of measured changes in land cover and will vary amongst habitats and species.

From this summary the following key observations are made regarding pressures (further discussion of impacts on land services is provided below):

- Soil sealing (see Chapter 4) as a result of urbanisation and the development of infrastructure etc. has devastating negative impacts on all land services where it occurs but only a very small proportion of the surface area of the EU is affected. The proportion of land areas affected by soil sealing differs per country in past and future, but only in The Netherlands is more than 2% of the land area urbanised in the 1990 – 2000 period (see Chapter 3). In four countries it is between 0.5 – 1% (Belgium, Luxembourg, Germany and Portugal), in all other countries it is not close to 0.5%. Infrastructure developments and some other causes of soil sealing also contribute to fragmentation of the landscape and interference with the population dynamics of many species (see below).

- Intensification (estimated from Figures 3.7 and 3.8) and the aggregated map for the B1 -2030 scenario (Figure 3.9) generally increases food production, but can lead to local declines, especially in the longer-term, e.g. as result of increased soil erosion. Intensification has well documented negative impacts on the other land services. Compared to soil sealing it is not as devastating to the other land services, but impacts are widespread and therefore substantial overall. Biodiversity suffers from direct land conversions (e.g. from grassland to cropland) and from the application of fertilisers and (ground) water management (see Section 8.2). Soil quality and water storage capacity are negatively impacted, although the magnitude of these impacts will vary.
- Marginalisation, with the extreme case of abandonment, are taking place across the EU to various intensities in different regions of the EU. The modelled projections (under the B1 scenario) suggest that abandonment is expected to increase and be widespread. The consequences for the land services are therefore also expected to be widespread across Europe, but will vary according to circumstances (see Section 8.2). In some cases biodiversity benefits may occur, particularly in the long-term, but most impacts will be detrimental as the areas most likely to be affected will be biodiversity rich HNV farming systems. Extensification and abandonment will provide signifcant benefits in terms of soil water retention, water quality and soil carbon levels, especially where arable systems are restored to grassland or semi-natural habitats. Most abandonment however will affect existing grasslands and semi-natural habitats. In some cases abandonment may trigger increased erosion, e.g. as a result of terraces falling into disrepair or increased incidences of severe fire as vegetation builds up. However, such impacts are likely to be relatively localised and often short-lived.
- Permanent grassland loss was extensive until the 1990s, but the rate of loss then declined between 1990 and 2000. However, the projections from this study suggest that the area of permanent grassland will decline by some 13% (Table 3.6) up to 2030 as result of conversion to more intensive temporary grasslands, abandonment and possibly conversion to biofuels, biomass crops and regular afforestation. Losses due to intensification will have negative impacts on biodiversity, soils and water. Losses of semi-natural and other HNV grasslands will have much more severe impacts on biodiversity than losses of other grasslands, e.g. recently ploughed or otherwise agricultural improved permanent grasslands.
- Fragmentation occurs as a consequence of urban, infrastructural and even agricultural land use change. The impacts are generally negative, mostly for biodiversity in terms of reductions in survival of isolated populations, habitat area (for species that need large patches of contagious habitat) and dispersal to climate refugia. Indirect impacts may occur on soils and water services, e.g. as a result of reduced protection of soils and water courses from vegetation.

Food production

The main factors affecting food production in the EU is the intensity of agricultural systems and the area of land available to them and taken up by them. Soil sealing has obvious major impacts on the availability of the soil as a growing medium for land-based food production. With soil sealing, the growing environment for plant roots and working environment for agricultural activities is reduced or entirely replaced by land developed for other uses. As a result, net primary productivity is locally eradicated and the performance of all related soil functions is reduced. Nevertheless these impacts are relatively small compared to the other factors affecting land use.

It is clear from this study that there are two trends that will have opposing impacts on food production in the EU. On one hand further intensification is expected, mainly in central and eastern European countries. This trend will undoubtedly generally increase food production in the areas affected, although in some cases inappropriate intensification and management may lead to reduced yields as a result of soil erosion or compaction (especially in the longer-term). On the other hand the area of land being used for food production is expected to decline as a result of competition for urban and industrial development and infrastructure developments (i.e. soil sealing), biofuel crops, afforestation and other minor land uses.

Overall, it is not possible within the scope of this study to assess and quantify in a meaningful way the overall net change in food production in the EU as a result of the projected changes in agricultural intensification and land use (let alone the impacts of climate change and other indirect influences on food production). Quantification of impacts on food production is also dependent on where land use changes occur, and what kind of crops or products are affected. Nevertheless, there is no evidence from this study that the EU will face a risk of undersupply of food. According to the modelled projections from this study losses of agricultural land to soil sealing are likely to be small and there is the potential for more significant increases in production in the new Member States. Furthermore, as a temperate region with reasonably robust soils, the EU may be able to withstand the negative effects of climate change more successfully than many other parts of the world (see Section 2.2.2). As such, it could become an increasingly competitive supplier of several commodities in the longer term.

The projections of relatively large-scale abandonment are mainly likely to affect extensive grazing systems and although some loss of meat and diary production is inevitable, it is unlikely to have major impacts on EU requirements. Indeed, the market economics that drive abandonment indicate that production in these systems is not necessary for the EU. Instead the market drivers appear to be resulting in increased production through intensification and/or displacement of production outside the EU where this is more cost-effective. This does, however, raise the issue of whether this is desirable from considerations of food security. In this respect it is useful to recall that one of the five original objectives of the CAP as set out in Article 33 (39) of the EC Treaty refers to food production in Europe notably ‘to increase agricultural productivity’ and ‘to assure the availability of supplies’. However, the architecture of the CAP does not give these objectives a high priority. Moreover, the challenges relating to food security do not appear to relate to shortages in supply - in the immediate future at least - and therefore the justification for significant increases in agricultural production in Europe on the back of arguments of food security is less robust than is often described. What perhaps is more critical in a European context, is to ensure the maintenance of a sustainable resource base, including safeguarding water supplies, managing the land to improve its resilience to flooding, maintaining soil fertility, and safeguarding the integrity and resilience of ecosystems – all land services in their own right – as a means to secure the long term capacity of the land to produce food in Europe over the longer term (LUPG and BfN, 2007; BirdLife, 200[]; House of Commons Efra Committee, 2009; SDC, 2009). Coupled with this, it will be expedient to reduce dependency on fossil fuels, to protect land from excessive urbanisation, to retain a skilled labour force, and to invest in research and development to facilitate agriculture's adaptation to climate change (Royal Society, 2009).

Biodiversity
It is clear from this study that recent trends in all four pressures are having observed significant detrimental impacts on biodiversity (Table 9.2). Furthermore, it is clear from the projections of land use change that these pressures and impacts will continue and increase in some areas of high biodiversity importance.

Of the considered pressures, soil sealing has the most obvious, immediate and profound impact on biodiversity. It replaces habitats for ecosystems by pavement and buildings or non-native ecosystems in green areas, and causes fragmentation of areas. Fragments of previously existing ecosystems are too small or too isolated to support a variety of sensitive species. Urbanization has impacts on the areal coverage of ecoregions, rare species and protected areas due to the shrinking distance between cities and protected areas. However, soil sealing impacts on diversity are relatively restricted, and therefore (excluding indirect fragmentation impacts – as described below) are low overall (see Section 4.4.5). The impacts of soil sealing are also much lower overall than the much wider impacts of land use change, particularly those associated with farming and forestry.

As discussed in Chapters 1 and 8 there are a wide range of detrimental biodiversity impacts from agricultural intensification and associated losses of permanent grassland. Such intensification trends include increasing simplification and scale, which has happened across Europe, and led to a decrease in the diversity of rural landscapes (Stoate *et al*, 2009). At the farm scale there has been widespread removal of landscape features such as hedges, woodland and ditches, or at least a cessation in management of the landscape features (Farmer *et al*, 2008). Intensification in the form of conversion of permanent grasslands to arable use leads to loss of historic landscape features and local grassland biodiversity, versus the gain of new crop landscapes and biodiversity related to cropland. Increases in the intensity of fertiliser and pesticides use changes the physical and chemical environment in the soils, production fields and wider environment (e.g. through drift, atmospheric deposition and transport through water bodies). Increased drainage changes the physical structure first and the chemical composition secondly (due to more aeration of the soils).

Overall, there is considerable evidence that intensification results in substantial declines in species richness (across a wide range of flora and fauna). Indeed, the impacts of sufficient extent and magnitude that they now threaten a significant number of species of Community interest (i.e. listed in the Birds and Habitats Directives), including some globally threatened bird species (e.g. Red-breasted Goose *Branta ruficollis*, Great Bustard *Otis tarda*, Eastern Imperial Eagle *Aquilla heliaca*, and Saker Falcon *Falco cherrug*). Furthermore, a high proportion of such species occur in the new Member States, where according to this study intensification of agricultural systems is likely to be widespread (see Table 9.3 below).

Marginalisation (i.e. extensification and abandonment) will also undoubtedly have major impacts on biodiversity. Initial effects are typically a resumption of ecological succession processes, which change relatively species-poor cropland levels to relatively species-rich pioneer successional stages, or relatively species-rich grassland levels to relatively poorer scrubland. Forests can develop in favourable circumstances, but these take decades or hundreds of years to attain a high biodiversity value. Impacts on biodiversity may therefore be variable and will depend much upon the scale and context of abandonment. However, it is clear that many habitats and species of high conservation importance (including those of Community interest and protected under the Habitats and Birds Directives) are particularly associated with extensive farming systems that are most prone to abandonment (see Chapters 7 and 8). The development policy actions that can support extensive farming systems of high importance for threatened species and habitats is therefore a high priority, especially given this study's projections of high rates of abandonment. Such measures should be targeted to the most important areas, in particular the Natura 2000 network, but also more broadly to HNV farmland.

The HNV farming concept emphasises that biodiversity conservation goals in Europe cannot be met only by protecting particular habitats or species, or designating certain areas for their management, such as Natura 2000 sites. There is also an ambition to also maintain the low-intensity land uses that favour the dynamics of natural processes and create opportunities for biodiversity to flourish across large, contiguous areas of land. These different approaches are entirely complementary. Biodiversity (species richness) tends to be higher when areas are under low-intensity use, providing a mix of habitats that are used by a range of plant and animal species. More intensive use of the grassland, and the removal of landscape features, will lead to a rapid decline in biodiversity. Peripheral semi-natural features, such as hedges, other field-margins and trees are often abundant in HNV farmland. These provide additional habitats and will tend to increase biodiversity (Stoate *et al*, 2009).

As discussed in Chapter 3, this study's projections of high rates of abandonment are uncertain. However, they are in accordance with other studies, for example, according to the EUruralis scenarios up to 2030 (e.g. Verburg *et al*, 2008), one of the most striking features of the European landscape will be land taken out of agricultural production. Moreover, it is prudent on the basis of the precautionary principle to develop policy instruments that can be used if necessary to mitigate the most significant detrimental impacts on biodiversity. In this respect a key requirement will be to establish which specific habitats are at most risk of abandonment, the biodiversity and ecosystem values of these habitats and the scale and location of likely abandonment. Such information could then be usefully used to develop a strategic approach to dealing with abandonment. The principles aims would be to prevent abandonment where it would be most harmful and to maximise benefits in circumstances where it could be beneficial, such as where it could reverse fragmentation impacts (e.g. through proactive habitat restoration and management).

This study's analysis of recent and projected fragmentation impacts on biodiversity in Chapter 5 showed that most land uses changes are likely to increase fragmentation with detrimental impacts that vary in magnitude depending on landscape scale patterns of change and the species involved. For example, afforestation increases forest habitat area, but this often occurs in already forested areas where the effects on connectivity are limited (Figure 9.1). Deforestation mainly occurs in a limited number of clearly distinguishable, mixed landscape areas, where the negative impact on forest connectivity is relatively large.

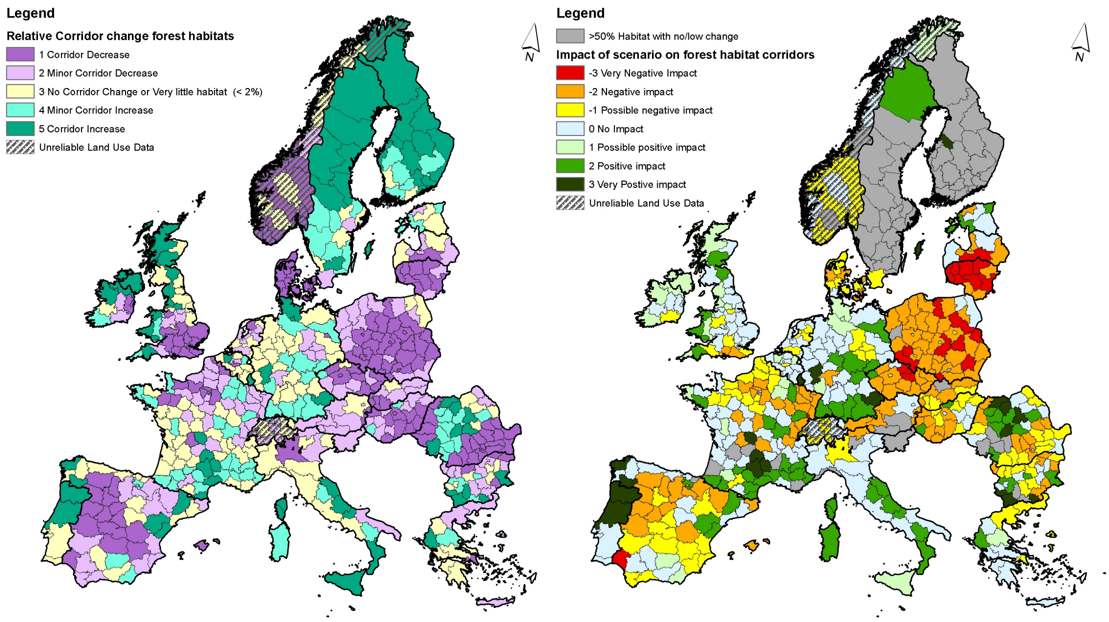


Figure 9.1. Relative connectivity change for forest (history; left) and the impact of land use and traffic density changes on corridor functioning for forest habitat (right)

Although it is expected that some semi-natural non-wetland habitats will increase, these will be primarily low quality ‘new nature’ developing on abandoned agricultural land and overall there is expected to be a net loss off higher quality habitats. This will have a negative impact on habitat connectivity and biodiversity. But with appropriate planning and proactive restoration management, some areas of new habitat could in time play an important function in providing additional habitat and biodiversity corridors. These could help to reverse some fragmentation impacts and facilitate climate change adaptation measures (Huntely, 2008; Tucker and de Soye, 2009).

The impacts of increasing road traffic is generally clear for medium to large terrestrial species (and is in reality likely to be at least as strong for small terrestrial ones). The combined effects of the predicted land use changes and increase of road traffic densities is expected to have large negative impacts on the connectivity / corridor function of important natural habitats in large parts of the EU, especially in areas with mixed landscapes, if they are not mitigated by conservation efforts (Figure 9.1). However, this study also found that there has been limited implementation of measures to maintain and enhance ecological connectivity, e.g. through biodiversity corridors and ecological network (as reviewed in Chapter 6). This is of significant concern and emphasises the need for better targeted and prioritised ecological network initiatives that are realistic and where possible integrated with other ecosystem service requirements and existing practical land use management measures (e.g. agri-environment schemes).

In conclusion, it is evident that the four land-use related pressures considered in this study will continue to have significant impacts on biodiversity in the EU. In particular, many of the most valuable remaining areas of semi-natural habitat are likely to be threatened by the agricultural intensification or abandonment. These pressures will also interact, and contribute to habitat fragmentation, which in turn together with soil sealing, will exacerbate the impacts of intensification or abandonment. These impacts will be further exacerbated by climate change, which will make habitats and species more susceptible to the impacts of habitat loss, degradation and fragmentation (EEA, 2004b; Olofsson *et al*, 2008; Thuiller *et al*, 2005).

Water retention and quality

Many studies have evaluated the effects of urbanization on infiltration and runoff production, and found reduced infiltration, reduced recharge of groundwater and increased discharge of surface runoff to adjacent areas (see Section 4.5.3 for details). The flow rate of water from development sites with high proportions of sealed surfaces can be two to three times that from predominantly vegetated surfaces. This may exert a greater pressure on the sewerage system and increase the risk of flooding within and around urban areas.

It is therefore of concern that this study's projections forecast a 6% increase in the total extent of built up areas between 2000-3020. However, the actual impacts on effective soil water storage capacity (SWSC_eff) are likely to be relatively small. Averaged over the EU, the effective soil water storage capacity decreased by 0.5% between 1990-2000, compared to this study's projections of a 0.8% decrease over the period 2000-2030. The largest changes are expected in The Netherlands followed by Portugal and Ireland. Relatively small changes in SWSC_eff are expected in Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovenia and Slovakia, due to either small relative increases in built-up area in these countries, or constraints on the effective soil water storage capacity of the soils.

As discussed in Chapter 8, intensification results in soil compaction, which reduces infiltration and the capacity for soils to retain water. This is estimated to affect some 33 million ha of agricultural land in the EU, and to reduce yields by 5-35% (Anon, 2006). It has not been possible to quantify the impacts of this project's projected trends in intensification and marginalisation on water retention. However, intensification is expected to take place between 2000-2030 in the eastern Member States of the EU, mostly on soils with high storage capacity. It therefore seems likely that losses of water retention will occur in these areas and therefore affect a large proportion of Europe. On the other hand, significant areas of agricultural land are likely to be abandoned and this may slowly increase soil water storage capacities. However, a large proportion of the abandoned areas will be semi-natural grasslands that are less likely to have been compacted by machinery (though they could be by high livestock densities on some soils). Furthermore, some of the areas that are most likely to be abandoned occur on soils with low storage capacities (e.g. in Spain and Italy) and therefore have a restricted potential for water retention.

The required data are not available to quantify the likely impacts of this study's projected trends in intensification and marginalisation on water quality. However, it is highly likely that the projected land use changes would lead to increased pressures on water quality, primarily as a result of the expected agricultural intensification (including conversion of permanent grasslands to regularly cultivated and highly fertilised temporary grasslands) in central and eastern Europe. But as with water retention, benefits may arise as a result of agricultural abandonment, but these will depend on local circumstances. Water quality benefits are most likely to occur where abandonment occurs on fertilised arable land or on areas that are affected by soil erosion as a result of overgrazing. Although abandonment may trigger increased erosion in some cases (e.g. as a result of terraces falling into disrepair or increased incidences of severe fire as vegetation builds up) such instances are expected to be relatively localised and often short-lived.

In conclusion it appears that of the pressures considered by this study, soil sealing and intensification (and in some cases habitat fragmentation) will have clearly negative impacts on water retention and quality. Abandonment will have positive impacts, whilst the impacts resulting from the loss of permanent grasslands will vary, and primarily depend on the type of grassland that is lost and the type of land cover that is gained. It is not possible to quantify the overall combined impacts of these pressures on water quality and water quantity, but it does seem likely that the negative impacts of intensification and soil sealing will be more widespread and greater then the potential benefits of the expected abandonment of predominantly extensive farming systems.

Soil carbon

This study has highlighted the fact that there is considerable potential for improving the protection of existing soil organic carbon (SOC) stocks in soils and increasing carbon sequestration rates. This can hep to mitigate the increase in concentration of greenhouse gases in the atmosphere and its effects on global warming (Trumper *et al*, 2009). The conservation of carbon in soils is also highly relevant to the EU Thematic Strategy for Soil Protection (see Section 4.3.2).

The current loss rate of SOC due to land use change is estimated at 1.6 ± 0.8 Pg C per year (Smith, 2008). However, depending on interactions with previous land use, climate and soil properties, changes in management practices may induce increases or decreases in SOC stocks. Overall Smith (2004) calculated that the potential biological carbon storage in EU-15 Member States cropland is of the order of 90–120 Mt C per year with a range of options available including reduced and zero tillage, set-aside, perennial crops and deep rooting crops, more efficient use of organic amendments (animal manure, sewage sludge, cereal straw, compost), improved rotations, irrigation, bioenergy crops, extensification, organic farming, and conversion of arable land to grassland or woodland. However, as a result of socio-economic and other constraints realistically achievable storage is probably only about 20% of the biological potential. Furthermore, it must be remembered that carbon sequestration in mineral soils has a finite potential and is non-permanent.

It is particularly worth noting that there is considerable potential for reducing carbon losses from peatlands. Upland peatland soils are extensive in parts of north-west Europe and represent a particularly large terrestrial carbon store. Many such areas are subject to extensive agricultural management (and associated activities, such as hunting) or afforestation. Management activities associated with these uses, in particular drainage, over-grazing and inappropriate burning practices, can reduce carbon sequestration rates and lead to losses of stored carbon (Holden *et al*, 2007). For example, Hargreaves *et al* (2003) found that while an undisturbed peatland was a sink and had a Net Ecosystem Exchange (NEE) of 25 tonnes C $km^{-2}yr^{-1}$, a newly drained peat was a source with a NEE between 200 to 400 tonnes C $km^{-2}yr^{-1}$. More recently, in a study of the Peak District in the UK, Worral *et al*, (2009) estimated that the region is presently a net sink with an average export of −136 tonnes CO2 equivalent/km^2/yr. However, if management interventions (including drain blocking and cessation of grazing and burning) were targeted across the area the average export rate could increase to −219 tonnes CO2 equivalent/km^2/yr. Moreover, Worral *et al*, calculated that the carbon savings were potentially sufficient over about half of the area for the management interventions to be profitable as carbon offsets, though this depends to a large extent on the trading price for carbon.

However, it is also important to note that if carbon sequestration in soils is to be used in helping to meet emission reduction targets, then changes in soil carbon must be measurable and verifiable. According to Smith (2004), most countries can currently only achieve a low level of verifiability whilst those with the best-developed national carbon accounting systems will be able to deliver an intermediate level of verifiability. Very stringent definitions of verifiability would require verification that would be prohibitively expensive for any country.

Nevertheless, despite these problems and limitations, Smith (2004) concludes that carbon sequestration should form a central role in any portfolio of measures to reduce atmospheric CO2 concentrations over the next 20–30 years, whilst new energy technologies are developed and implemented. Moreover, as this study has demonstrated, many of the measures that would provide increased carbon benefits would increase the benefits from other land services. For example, reversing drainage impacts and increasing the environmental sensitivity of burning and grazing practices in upland peatlands could have considerable benefits in terms of water retention, water quality and biodiversity (e.g. see Box 10.3). There is therefore considerable scope for developing land use strategies that could provide multiple “wins”.

10 POLICY ANALYSIS AND RECOMMENDATIONS FOR MEASURES TO MAINTAIN AND ENHANCE LAND SERVICES

Graham Tucker, David Baldock, Catherine Bowyer, Kaley Hart, Clunie Keenleyside and Andrew McConville (IEEP)

10.1 INTRODUCTION

This chapter addresses the following component of Task 6 (synthesis and recommendations) as described in the Technical Specification for the study.

On the basis of the information collected and analysis under Tasks 1 to 5, the contractor shall:

- *collect best practice legislation, guidelines, voluntary codes, pilots and case studies etc. across Member States to ensure contributing to enhancing or avoid hindering the land services above mentioned.*
- *identify any gaps and shortcomings of existing legislative or policy instruments at EU level and suggest appropriate modifications to achieve an adequate protection of land services crucial for sustainable development across Europe in a context of a changing climate;*
- *develop a series of recommendations to overcome these gaps and shortcomings, to the extent feasible, results be also quantified.*

10.1.1 Aim and scope of the policy analysis

The overall aim of this part of the study is to identify measures that may significantly influence the four key pressures that impact on the provision of the four land services that are the focus of this study. Namely the impacts of soil sealing, habitat fragmentation (including loss of corridors), intensification / marginalisation and the loss of permanent grassland on food production, biodiversity (ie. its respective benefits), water retention and water quality and soil organic matter (ie. carbon stocks). Although other pressures and land services and their interactions may also be of importance these are not fully considered here, though important co-benefits are identified and discussed briefly.

To focus the development of the policy recommendations it has been necessary to make assumptions on the specific objectives concerning the impacts of each pressure on each land service. These are outlined in Table 10.1 below. Overall, the objectives aim to primarily avoid further losses of the services provided by biodiversity, water and soil carbon, and secondarily, to restore these services where feasible; whilst avoiding significant impacts on net food production capacity in the EU.

Table 10.1. Proposed policy objectives for each of the four pressures and land services that are the focus of this study

	PRESSURES			
LAND SERVICES	**Soil sealing**[1]	**Intensification/ marginalisation**	**Loss of permanent grassland**[2]	**Fragmentation (absence of biodiversity corridors)**[3]
Food production	Minimise the impact of soil sealing on the **net** productive capacity of existing agricultural land	Minimise any negative impacts of intensification /marginalisation on the **net** productive capacity of existing agricultural land *(e.g. from intensification - damage to soil structure and SOM content, increased soil erosion: from extensification - natural regeneration of scrub/trees on land with very low stocking rates)*	Minimise the impacts of loss of permanent grassland on the **net** productive capacity of existing agricultural land *(e.g. by ensuring that potentially highly productive land remains in a state where it can be returned to productive use within a year)*	Minimise any negative impacts of fragmentation on the **net** productive capacity of existing agricultural land *(e.g. increased soil erosion, loss of habitat for pollinating insects)*
Biodiversity	Minimise the impact of soil sealing on: • habitats and species of EU importance • other land of biodiversity value	Minimise direct and indirect negative impacts of intensification and maximise positive benefits of extensification on: • habitats and species of EU importance • other farmland of biodiversity value *(e.g. from changing N fertilisation rates, grazing levels, cropping, removal of unfarmed features important for spp; indirect effects on wetland habitats e.g. fertiliser/pesticide contamination, effects on water table from altering drainage or abstraction rates)*	Minimise the impact of loss of permanent grassland on: • grazed habitats and species of EU importance • other land of biodiversity value *(these may be direct, or indirect e.g. where a mixed farm converts to arable or permanently housed livestock, and no longer has grazing livestock to maintain the parcels of grassland unsuitable for arable cropping or inaccessible to forage harvesters)*	Minimise the impact of fragmentation on: • habitats and species of EU importance • other land of biodiversity value
Water retention	Minimise the impact of soil sealing on water runoff and aquifer recharge rates	Minimise any negative impacts of intensification and maximise positive benefits of extensification for water runoff/infiltration, aquifer recharge rates, and abstraction rates	Minimise the impact of loss of permanent grassland on water runoff/infiltration, aquifer recharge rates, and abstraction of water for agricultural use from surface and groundwater	Minimise the impact of fragmentation on water runoff/infiltration, and aquifer recharge rates
Water quality	Minimise the impact of soil sealing on pollution of surface waters (including by sediment)	Minimise any negative impacts of intensification and maximise positive benefits of extensification on pollution of surface waters (including by	Minimise the impact of loss of permanent grassland on pollution of surface waters (including by sediment)	Minimise the impact of fragmentation on pollution of surface waters (including by sediment)

		sediment)		
Soil organic matter	Minimise the impact of soil sealing and associated activities (soil disturbance, improved drainage) on carbon loss from soils with high SOM (peaty soils)	Minimise any negative impacts of intensification and maximise positive benefits of extensification on retention and accumulation of soil organic matter	Minimise the impact of loss of permanent grassland on retention and accumulation of soil organic matter	Minimise the impact of fragmentation on retention and accumulation of soil organic matter

Notes: 1. Covers not just presence of soil sealing but also location and type of sealing. 2. Policy responses may be location specific and should reflect the fact that the impact of the loss on different land services very much depends on the subsequent 'destination' use (e.g. temporary grassland, arable crops, permanent or semi-permanent crops, afforestation, built development). 3. Policy responses may be location or habitat specific (eg water, woodland).

This analysis integrates the assessments of the gaps and opportunities in existing policies from the perspective of the combined effects of the projected changes in land use pressure and their impacts on land services (as summarised in Chapter 9), in contrast to the previous pressure-specific assessments. Thus the policy analysis aims to avoid the development of conflicting policy measures, and instead identifies measures that have multiple and potentially synergistic benefits.

The policy gap analysis and recommendations build on the reviews and cases studies in previous chapters on legislation, policy instruments and practices that may influence the provision of land services. Background policy information and associated best practice case studies are therefore not repeated here. Instead, the main output of the chapter is a series of priority policy recommendations that aim to maintain and/or restore the four land services that are the focus of this study.

For each broad policy area described below, consideration has been given to the need for strategic changes to policy objectives, better implementation or improvements to existing policy instruments (e.g. relating to timing, funding, enforcement and gaps) and, where necessary the need for new measures. A number of important issues were taken into account during the formulation of each policy recommendation, including the range of pressures and services addressed and the likely degree of benefits that may arise (considering the scale of protection and range of land uses affected and associated risks and uncertainties), suitability for the various parts of the EU (new Member States, regions, protected areas etc), compatibility with existing policies (e.g. added value versus potential conflicts with existing measures) and opportunities to influence ongoing policy reforms. It has not, however, been possible to assess the likely costs of the policy proposals or their impacts on other issues and sectors outside the scope of this study.

Specific recommendations are made for each of the policy areas below (other than sustainable development). Each of these are coded and repeated briefly in a combined table (Table 10.2) at the end of the chapter. The table also aims to provide a semi-quantified assessment of the potential impact of each recommendation on each of the pressures and land services that are the focus of this study. Although rather subjective and subject to some uncertainty (and geographical variation of impacts etc) these assessments are considered to be adequate to identify measures that would most probably provide significant multiple-benefits.

10.1.2 Overview of policy analysis findings

As a result of the policy analyses carried out in this and previous tasks it is clear that a relatively strong and comprehensive framework of environmental legislation and other instruments exist that can help to maintain and restore the provision of the land services. Consequently, although a range of potential policy recommendations have been made below, most focus on improving implementation of existing instruments. This is partly because there appears to be relatively little need for new instruments, but also because it is difficult to develop new measures that are likely to be practically feasible or politically acceptable, especially given the current economic climate and the associated desire to reduce the EU budget and minimise regulatory burdens etc. In other words, most of the easy options to secure and restore land services have already been identified. Nevertheless, a few more ambitious policy proposals are made that relate to, for example, coordinated implementation of instruments to provide ecosystem services at a landscape or catchment scale, and the strategic planning of land use. These suggestions are made because their potential benefits for land services are considerable. But it is recognised that they would be longer-term measures and would require considerably more analysis to develop practical and politically feasible proposals, which would then require full impact assessments.

Another conclusion from the analysis is that the concept of “land services” like “ecosystem services”, of which it could be considered a component, is helpful in challenging compartmental modes of thinking. It draws attention to the importance of different forms of land management and the links between them and has value as an analytical tool. It is only recently that soil has started to get the attention devoted to other environmental media, such as air, water, even marine and the land use perspective adds a further dimension easily overlooked at a European level.

However, in operational policy terms the various elements inside the circle described by land management services are rather disparate and straddle different policy fields. Some introduce large questions, such as the future of agricultural land management, others the cumulative impact of relatively small individual decisions, such as progressive urbanisation leading to soil sealing. In some fields there is a high level of EU competence to act, in others rather little. Some issues are primarily sectoral, other spatial and localised. In this sense, there is only a limited place for general policy responses. What seems appropriate is an enhanced awareness of the different dimensions of the challenge and concrete action in a series of relatively specific and not necessarily related policy domains. The analytical value of the concept does not give rise to an elegant policy application. Consequently, we have note recommended the development of a dedicated policy instrument for ecosystem services, such as a framework directive.

Looking ahead, however, it is worth considering whether land use and land services should figure more strongly in strategic thinking on the environment in the EU. For example, if there is a Seventh Environmental Action Programme this is a theme that could be explored more fully, in the same way that soil policy was given some prominence for the first time in the Sixth Environmental Action Programme.

10.1.3 Strategic measures

Sustainable development

Before consideration of sector specific policy instruments, it is important to note that some overarching strategic EU level actions could contribute to the maintenance of land services. These underpin sectoral policies instruments or support them through the provision of funds etc. In particular the overall sustainability of the European economy and the patterns of land use within this will remain central issues in determining the services that will be supplied from the land in future. Specific measures to tackle individual sectoral issues such as transport infrastructure are important but in isolation these are not sufficient to relieve the pressures on the European land resource. In addition an overall change in the pattern of economic activity is needed. The Sustainable Development Strategy (SDS – see Box 10.1) is one tool available at the EU level to promote a more resource conserving economy and maximum use should be made of the renewed strategy over the next two years. Beyond this a revised SDS might be a lever to assist the promotion of more sustainable policies across the full spectrum of economic sectors where EU policy is a significant driver. The EU SDS also provides a framework within which policy objectives in different sectors can be brought together. At a mechanistic level such comparative assessment is taken forward through the Impact Assessment process for development of Community policies.

Box 10.1. The EU Sustainable Development Strategy (SDS)

History of the EU SDS

The EU first adopted a sustainable development strategy in Gothenburg in 2001[97]. The document translated the 1987 Brundtland definition of sustainable development (World Commission on Environment and Development, 1987) into an operational strategy that demarcated a series of themes and actions necessary to put the economy on a sustainable footing. In preparation for the 2002 Johannesburg conference an international dimension added and subsequently modified to reflect the commitments made following the conference, becoming an integral part of the SDS. However, given the backdrop of continued unsustainable trends, and a 2004 public consultation on the effectiveness of the strategy, a modified strategy was launched and adopted in 2006, which is the strategy operational today.

The aims of the EU SDS

The renewed EU SDS provides a framework for a long-term vision of sustainability in which economic growth, social cohesion and environmental protection are mutually supportive. It forms the overall framework for all EU strategies and policies, within which the Lisbon Strategy provides the motor for growth and jobs, and maintains the principle that sustainable development is to be integrated into policy-making at all levels. Seven key challenges are identified, each with corresponding targets, operational objectives and actions.

[97] See Presidency Conclusions, European Council, 15-16 June 2001, Gothenburg, Sweden, at: http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/00200-r1.en1.pdf

The EU SDS has a strong focus on climate change, clean energy and sustainable transport, setting its priorities on achieving Kyoto Protocol commitments (an 8% cut in greenhouse gas emissions on 1990 levels for the EU-15). Economic growth should be decoupled from the demand for transport, and the sector is tasked with reducing pollution and halving road transport deaths by 2010. On consumption the strategy seeks a decoupling of environmental degradation from economic growth through increasing Green Public Procurement, engaging with business on targets for products and promoting social and eco-innovations.

The strategy also seeks to improve management and avoid overexploitation of renewable natural resources including biodiversity, water and soil. Actions should include renewed efforts on rural development programmes and legislative frameworks for organic farming, the completion of the Natura 2000 network and the implementation of the EU Biodiversity Strategy. It calls for the improvement of integrated water resource management and integrated coastal zone management. The SDS also aims to ensure that chemicals, including pesticides, are produced and used in ways that do not pose significant threats to the environment or human health, and sets out to increase information on the links between environmental pollutants and health impacts.

Effectiveness and implementation

While assessing the effectiveness of the SDS influence on policy development is difficult, its impact does not appear to have been very significant, with increased attention afforded to the growth and competiveness agenda of the Lisbon Strategy. The second European Commission progress report (16818/09) on the implementation of the EU SDS highlights a number of key trends and notes that some objectives and targets are unlikely to be met (e.g. halting the loss of biodiversity).

The report therefore puts forward a number of proposals which include:

- Increasing synergies, and improving coordination / linkages with the Lisbon Strategy and other cross-cutting EU strategies;
- Streamlining or refocusing the SDS on its overarching nature to provide the general framework for policy-making;
- Using mechanisms in the Lisbon Strategy to monitor implementation of the SDS; and
- Expanding the scope of the SDS to reflect new and emerging challenges such as adaptation to climate change.

The recent European Council meeting[98] reiterated support for the strategies to remain distinct, with the SDS providing the over-arching policy framework for all EU policies and strategies. However, it acknowledged that the challenges posed by ageing populations, increased inequalities and climate change need to be considered in the future EU 2020 strategy (previously the Lisbon Strategy) to ensure competitiveness and sustained growth and that the strategy must consider the benefits to be reaped from a greener economy. The European Council emphasises the importance of renewing the economic and social contract between financial institutions and the society they serve to ensure that the public benefits in good times and is protected from risk. There should also be clearer links between the EU SDS and the future EU 2020 strategy and other cross-cutting strategies through better governance, including reinforcement of implementation, monitoring and follow-up mechanisms.

[98] Presidency Conclusions, European Council, 10-11th December 2009, Brussels. At http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/111877.pdf

The EU budget

The European Union budget provides resources for expenditure in a range of areas including agriculture, regional assistance, research and development, transport networks and fisheries. It has an influence on land services in at least two respects. On the one hand it provides funding for incentivising positive forms of land management, principally through agri-environment schemes and other measures within the CAP, but also through LIFE + and elements of the Structural Funds. On the other hand it provides finance for activities that are environmentally detrimental, such as the building of new trunk roads as part of the "Trans European Networks" (TENs). As clearly shown in Chapter 5, such roads can give rise to habitat fragmentation for example.

In 2006 the European Parliament, the Council and the Commission agreed to undertake a substantive review of the EU budget and a proposal is expected from the Commission in 2010 following a lengthy consultation period. There is an opportunity to consider how far the budget could contribute to beneficial land management after 2013 when the next budgetary period begins. The debate on the future of the CAP, the largest element of which is financed through the budget, represents the greatest opportunity to increase the focus of expenditure on a range of land services, including improved biodiversity, soil and water management as well as agriculture and forestry (Kettunen *et al.,* 2009). Estimates concerning funding requirements have demonstrated the significant difference between the scale of funding likely to be needed to achieve European environmental targets, and the funds currently available from CAP measures that are targeted towards the provision of public goods from agriculture (Cooper *et al*, 2009). At the same time, regional funding through ERDF and the Cohesion Fund will be relevant to some forms of land service provision.

Recommendations are therefore:

B1. For the Commission to review opportunities to improve the effectiveness and integration of the different elements of the EU budget that could be used to encourage and support the provision of land services [of food production capacity, biodiversity, water and soil organic matter]where these services are not[likely to be] provided by the market

B2 To secure sufficient budgetary resources for the CAP to deliver revised CAP priorities for the provision of environmental services (see recommendation AF1), *allocated between Member States/ regions according to robust criteria appropriate to the CAP objectives.* These allocation criteria must recognise that environmental assets and pressures on existing land services, and the opportunities to improve levels of provision, are not distributed evenly across EU-27, and the criteria must be evidence-based and clearly defined to ensure both effective implementation and subsequent monitoring and evaluation.

B3 To consider the establishment of a new EU biodiversity fund to address issues outside the scope of the CAP and Common Fisheries Policy which are likely to be the principal sources of EU funding for biodiversity beyond 2013.

B4. Take the necessary steps to improve the screening of expenditure on infrastructure investments through EU funds to minimise soil sealing and the fragmentation of habitats (see also Section 9.3.8).

10.1.4 Biodiversity

EU Biodiversity target and Biodiversity Action Plan
The EU has a good framework for biodiversity conservation with relatively comprehensive and effective legislation, wide-ranging environmental policies and potentially high levels of funding. Accordingly, in 2001 the EU Heads of State and Government undertook to halt the decline of biodiversity in the EU by 2010 and to restore habitats and natural systems. To achieve this aim a number of strategies and plans evolved, leading to the May 2006 communication on 'Halting Biodiversity Loss by 2010 – and Beyond: Sustaining ecosystem services for human well-being' (European Commission, 2006a). The Communication underlined the importance of biodiversity conservation and included a detailed EU Biodiversity Action Plan (BAP) to achieve its objectives.

However, according to the European Commission's mid-term assessment the EU will fail to meet its target of halting the loss of biodiversity by 2010 (European Commission, 2008). The assessment also shows that this is at least in part due to an inadequate implementation of the EU BAP. The BAP aimed to provide a comprehensive list of actions that deliver the 2010 target; but there is little evidence of additional actions by Member States or that the BAP has been taken into account in the development and implementation of sectoral policies. According to a review by IEEP and UNEP-WCMC[99] the main problems seem to have been:

- Gaps in policy instruments (e.g. the absence of a general no-net loss biodiversity policy and the absence of EU legislation to protect soils).
- Slow development of some important policy instruments (e.g. the Water Framework Directive).
- Slow or incomplete implementation of existing policy instruments (e.g. designation of Natura 2000 sites and implementation of the Nitrates Directive).
- Implementation problems with aspects of some existing practical measures, such as the unfulfilled potential of some agri-environment schemes as a result of the use of generic management prescriptions and a lack of sufficient advice and training due to limited capacities in conservation agencies (as discussed in Section 7.4.9).
- Information failures, such as incomplete monitoring of many habitats and species of Community Interest (especially outside protected areas), inadequate monitoring of the impacts of developments and effectiveness of mitigation and compensation measures, and inadequate monitoring of the effectiveness of conservation management measures (e.g. agri-environment schemes).
- Insufficient mainstreaming of biodiversity concerns into some sectoral policies (e.g. energy, transport and regional development), for example relating to the need to proactively contribute to the achievement of the 2010 biodiversity target.

[99] Working paper on "Assessment of reasons for 2010 target failure" as part of the Biodiversity Knowledgebase Contract (Service contract 07.0307/2008/513998/SER/B2).

A major reason for the limited progress on achieving the biodiversity target within the EU is that the target does not have the wider support of policy makers outside the environmental sector. Furthermore, ownership of the 2010 target rests too heavily on the EU institutions. As a result most Member States do not feel obliged to pursue the EU BAP goals very vigorously. This is probably because Member States and key stakeholders were not sufficiently involved in the development of the target and BAP. As a result, although good progress has been made in some sectoral policies (most notably the CAP), inadequate mainstreaming of biodiversity conservation issues at the EU and Member states level has frequently been identified as a key constraint on effective biodiversity conservation.

Another key constraint has been the result of inadequate funding for practical biodiversity measures (such as the appropriate management of Natura sites) and the limited capacities of government environmental agencies and other conservation organisations to support and monitor actions.

It is therefore clear that specific measure to reduce the biodiversity pressures that are the focus of this study should be underpinned by a renewed and more strongly supported post-2010 biodiversity target for the EU and the improved implementation of the existing BAP (and subsequent plans). The following recommendations are therefore made to achieve this.

Bd1. The Commission should develop and agree with the Member States a strong and binding post-2010 target to stimulate urgent action to halt and reverse losses of biodiversity and related ecosystem services. It seems likely that further losses of biodiversity and associated land services will occur under all the options currently proposed by the European Commission (see Box 10.2) and these could be significant, unless a shorter-term target is introduced, such as reducing the rate of loss of biodiversity by 2015 (i.e. Option 1 by 2015). Although this might be difficult to monitor an option could be to set short-term targets in relation to clearly measurable key actions (such as some of those described below).

But most importantly, whatever target is adopted, it will be necessary for all Member States and EU institutions etc to fully engage with and adhere to it, to achieve the agreed objectives for biodiversity and associated ecosystem services. Many of the key actions necessary to achieve this are described in Action Bd2.

Bd2. Further encourage the implementation of the EU BAP, through cross-sectoral actions by EU institutions and Member States. Faster, more effective and better targeted implementation of the BAP actions is necessary. In particular, priority should be given to more actions to manage and restore sites in the Natura 2000 network, to restore ecosystem health and services in the wider EU countryside and to combat habitat fragmentation. A new more comprehensive and stronger BAP should be developed to extend the current plan beyond its current endpoint of 2013. The new BAP should be developed with closer collaboration of Member States and all EU institutions, to facilitate ownership and agreement on clear responsibilities, timetables and funding etc.

Box 10.2. Proposals for a post-2010 biodiversity target for the EU

As noted in the Message from Athens[100] which summarises the conclusions from a European Commission Conference on Biodiversity Protection Beyond 2010 - Priorities and Options for Future EU Policy (Athens 26 to 28 April 2009), the post-2010 target should be ambitious, measurable and clear. It should maintain the emphasis given to the intrinsic value of biodiversity while also recognising the value of healthy and resilient ecosystems and the services they provide. However, the target should not overemphasise or only focus on the provision of a few key narrow ecosystem services (such as carbon storage), as areas of high intrinsic biodiversity value do not always match up with those of importance for ecosystem services (e.g. Anderson *et al*, 2009). The Message from Athens also recognises that urgent actions are necessary.

The European Commission has subsequently produced "Options for an EU vision and target for biodiversity beyond 2010" (COM(2010)4/4)[101]. The vision relates to 2050 and is ambitious and seems to focus on conserving biodiversity for its intrinsic values, though this would also provide ecosystem benefits. The proposed target options in increasing order of ambition are:

- Option 1: Significantly reduce the rate of loss of biodiversity and ecosystem services in the EU by 2020.
- Option 2: Halt the loss of biodiversity and ecosystem services in the EU by 2020.
- Option 3: Halt the loss of biodiversity and ecosystem services in the EU by 2020 and restore them as far as possible.
- Option 4: Halt the loss of biodiversity and ecosystem services in the EU by 2020 and restore them as far as possible, and step up the EU's contribution to averting global biodiversity loss.

Option 3 is broadly equivalent to the current target, except that the need to halt the loss of ecosystems services is explicitly introduced. This therefore appears to be a more ambitious target than the 2010 target in some respects, but in terms of their timescales all the options are less ambitious than the 2010 target, which aimed to halt biodiversity loss over 9 years. Given the progress that has been made so far and existence of a reasonably comprehensive framework, a shorter-term target ought to be feasible.

Measures under the Birds and Habitats Directives

As noted in the mid-term review of the BAP good progress has been made with the implementation of many aspects of the Birds and Habitats Directives, in particular the designation of the terrestrial components of the Natura 2000 network. Furthermore there is now evidence (Donald *et al*, 2007) that measures under the Birds Directive are having measurable beneficial impacts on birds that are the focus of conservation measures under the Directive[102]. However, it is also apparent that some aspects of the directives require stronger and more comprehensive implementation, in particular those relating to the management of sites and protection of landscape features that help to maintaining ecological connectivity.

---

[100] http://ec.europa.eu/environment/nature/biodiversity/conference/pdf/message.pdf

[101] http://ec.europa.eu/environment/nature/biodiversity/policy/pdf/communication_2010_0004.pdf

[102] Ie. Listed in Annex 1.

The principal constraint on the effectiveness of the Natura 2000 is the difficulty of securing the appropriate ongoing management of sites. This is because it is often difficult to maintain or restore the specific land management practices (e.g. traditional extensive livestock grazing on semi-natural grasslands) that habitats and species of conservation importance often depend on. Most Member States attempt to secure appropriate management of protected areas by a combination of voluntary measures (sometimes agreed through site management plans) and financial incentives (e.g. through agri-environment schemes). However, some land owners are reluctant to participate and therefore management plans may not be able to solve difficult issues concerning established property or user rights; and if they do significant financial compensation is normally required. Consequently, the costs to society of voluntary approaches are often very high, and the implementation of management plans is often constrained by inadequate funding (see Section 9.3.2 above).

Numerous studies and Chapter 5 of this report, have clearly demonstrated that the ongoing fragmentation of habitats is a substantial threat to biodiversity in the EU. It is also constraining the establishment of the Natura 2000 network, (which aims to be a coherent network of protected areas, which are, where necessary, functionally connected) and the wider maintenance and restoration of Favourable Conservation Status of habitats and species (which is the overall aim of the Habitats Directive). Furthermore, it has broader implications regarding the maintenance of ecosystem functions and the provision of ecosystem services and their socio-economic benefits.

The importance of ecological connectivity amongst habitat patches and species' populations across the landscape is widely recognised. Consequently there are provisions to maintain and, where necessary, enhance ecological connectivity amongst protected areas and across the wider environment within the Birds Directive and in particular under Article 10 of the Habitats Directive. However, a study for DG Environment found that few new measures (e.g. legal provisions or funding streams) have been developed to meet the requirements of Art 10 on connectivity (Kettunen *et al*, 2007). Furthermore, this study (Chapter 6) and related studies (such as the Green Infrastructure project for DG Environment) have found that where measures have been developed (e.g. to create biodiversity corridors or ecological networks), then implementation has been very slow, primarily as a result of limited legal powers and the costs of large-scale land purchase and long-term management.

The following recommendations are made to address these deficiencies in the implementation of the Birds and Habitats Directives:

Bd3. Member States should increase their efforts to establish management plans and measures for Natura 2000 sites (and other areas of high biodiversity importance) and to integrate these with the provision of other ecosystem services where there are mutual benefits. In particular, opportunities to facilitate ecosystem-based adaptation to climate change should be identified and acted on (Berry *et al*, 2008; AHEWG, 2009). This would help to justify increased targeting of Natura sites and biodiversity under existing funding instruments, in particular agri-environment schemes (see Sections 7.4.9 and 10.1.6). It could also be a first step to widen the range of funding options for management plan measures that provide land service benefits (such as carbon sequestration and protection, or water resources). In particular the potential of using instruments to purchase and/or manage areas for ecosystems services, such as recently carried out through a public / NGO/ private company partnership in the UK to improve the quality of water supplies and provide other land services merits investigation (see Box 10.3). Such integrated management and payments for ecosystem services could be encouraged and supported by Member States through strategic mapping, valuation and planning of key ecosystem services (see D5 in Section 10.1.8 and Box 10.5).

Bd4. Further encourage Member States to implement Article 10 of the Habitats Directive (and similar measures implied in the provisions of the Birds Directive), through the establishment of national frameworks for assessing functional connectivity needs, and planning, integrating and implementing necessary actions, as recommended in the fragmentation guidance report for DG Environment (Ketunnen et al., 2007). This framework suggests that Members States should:

1. Identify species and habitats of Community interest that are already impacted by or vulnerable to fragmentation and/or changes in suitable climate space (using a proposed risk assessment framework).
2. Assess the functional connectivity requirements of vulnerable species and habitats, taking into account likely habitat fragmentation and climate change impacts where necessary.
3. Integrate functional connectivity requirements into ecological networks and generic habitat measures across the wider environment.
4. Implement connectivity measures through existing mechanisms, such as protected area management plans (see Bd3), planning regulations and policies, land-use policies, and EU funding mechanisms.

Bd5. Further promote and support the implementation of existing ecological networks and other biodiversity corridor initiatives that have the potential to deliver significant biodiversity benefits (as assessed within the Bd4 framework). Actions should focus on those that have been found to be associated with successful implementation (see Section 6.3.4), including:

- Development (or revision) of a clear vision focussing on priority objectives and measurable targets to guide the management and delivery of the initiative, facilitate communication with stakeholders and measure success.
- Ensuring that there is comprehensive engagement with local stakeholders from as early as possible with the project (e.g. following the guidelines of Lawrence-Jones *et al.*, 2009), with sufficient flexibility built into the project to facilitate revisions to planned networks and adaptive management where opportunities or problems arise.
- Establishing a clear delivery plan, including how to achieve local stakeholder buy-in and the training of local officials.
- The inclusion of adequate and effective protection measures for corridors or landscape elements that are of significant importance for the maintenance of ecological connectivity (e.g. ranging from strict legal protection for the most important habitats / features to indicative planning guidance maps for corridors of lesser or substitutable importance).
- The promotion of multi-functional uses of the areas included within the network where this is possible and compatible with biodiversity conservation objectives.

- The securing of adequate funding for the design and long-term implementation for the initiative, through for example integration with existing protected area funding programmes, the LIFE+ programme, agri-environment schemes (see 9.3.5), the EU Structural Funds, Member States measures to deliver River Basin Management plan requirements (see 9.3.6), habitat banking initiatives (see 9.3.8) and other payments for environmental services.
- The monitoring of progress with regard to the implementation of the delivery plan actions, physical achievements and ecological impacts, with reporting and feedback to facilitate adaptive management.

Box 10.3. Sustainable Catchment Management (SCaMP) in the South Pennine UK uplands

Background

The upland areas of the South Pennines in the north of England have long suffered from pressures on water quality, soaking up heavy metals and sulphur from the industrialised cities nearby. From the 1970s, the Common Agricultural Policy incentives to increase productivity of land led to widespread drainage of moorlands to intensify animal production. The construction of long ditches or “grips” for drainage led to the drying out of peat soils and blanket bogs causing erosion, increased risks of wildfire, downstream flooding and the loss of vegetation and associated biodiversity. The impacts on water quality has been increases in discolouration, turbidity and pathogens, which has increased the need for and costs of water treatment processes.

Land management initiative

Since 2005, the United Utilities water company has led an innovative conservation initiative, called the Sustainable Catchment Management Programme (SCaMP), which seeks to use land management approaches to reduce water quality risk. The SCaMP area covers 20,000 ha of United Utilities owned land, 13,500 ha of which is designated as a Site of Significant Scientific Interest, with smaller sections also falling within an SAC and a National Park. The overall aim of SCaMP is to develop an integrated approach to catchment management of uplands which succeeds in meeting government and EU targets for nature protection, improves raw water quality and provides a viable living for tenant farmers, developed in close collaboration with stakeholders including RSPB and local farmers. Overall, United Utilities is providing £9m over 5 years with public support amounting to £3.5m. Moorland restoration accounts for the biggest portion of the funds (£10.5m) with the remainder (£2m) being spent on farm buildings and fencing etc.

The central element to deliver the program is through the development of farm plans, ensuring that farmers can access high-level agri-environment support grants. The main activities include:

- Blocking of drains and the rewetting of dried moorland, to create new habitat for wildlife,
- Revegetating bare peat and heath moorland,
- Re-establishing woodland through deciduous tree planting to reduce erosion, and
- Fencing to limit stock access to watercourses (hence reducing pathogen risk).

Result of intervention

By 2009 around 60% of the overall programme was complete with 294 ha of woodland planted, 33 km of grips blocked and 101 km of fencing installed. It is assessed, qualitatively, to have supported key services including water supplies (quantity and quality regulation), recreational activities, greenhouse gas regulation and biodiversity, whilst at the same time improving farming economic activities.

Future and application

SCaMP is due to finish in 2010, and although it may be some time before the impacts can be properly assessed, it is already being regarded as a success. It provides a unique opportunity to show how investment in sustainable land management can make business sense and contribute to tangible water quality benefits. It faces risks from a potential lack of funding once the scheme finishes, from changes in biota due to climate change and the very present risk of wildfires. It has also been made easier by United Utilities ownership of the land. In many other circumstances it is likely that careful development of management agreements with local landowners and close working relationships would be essential to replicate the project in other areas.

Source: Tinch, R. (2009)

10.1.5 Soil

Soils represent a media of fundamental importance in the functioning of key environmental cycles Carbon, Nitrogen and the hydrological cycle. Within this project soils and their management are of significant importance when considering any of the services this project is attempting to conserve. They are needed to retain biodiversity, food production and water availability. Moreover, organic mater content is obviously a key factor in determining the nature of a soil and the opportunities it represents in terms of carbon sequestration, water storage and fertility.

As discussed in Chapter 4, soil sealing, at its most extreme, inhibits the ability of soil to perform any of these functions prioritised within this study. Moreover, loss of soil functionality (via sealing or extreme degradation by erosion or contamination) can lead to fragmentation and habitat loss. Intensification and marginalisation are also often associated with changes to soil functionality and composition (see Chapter 8). Hence soil issues generically are of significant importance to delivering this studies aims.

Despite its important functions, soil is not treated akin to other environmental media (ie air or water), and there is no overarching EU law coordinating or structuring action to protect soils. This has been noted as a challenge in some Member States (see work under the SoCo report http://soco.jrc.ec.europa.eu), particularly in Eastern Europe. With limited funds to take forward environmental action and no clear mandate to address soil issues, these can be de-prioritised and hence ineffectively dealt with.

When it comes to the particular soil threat considered within this work, soil sealing, policy making is hampered both by a lack of mandate to address soil issues at the EU level, but also a lack of competency over planning issues.

This section addresses generically the needs in the soil policy arena and more specifically, given the focus of this project, the policy steps that might be needed to address soil sealing in particular. Key policy issues and recommendations are set out in the points below with recommendations related to soil policy number S1- 6.

Taking forward EU legislation on soil protection

As demonstrated in Section 4.3 there is a wide array of policies at the EU level that exist and have an impact on soil issues. As there is no policy framework for addressing soils directly these focus on soil issues indirectly through the need to:

- protect water quality and quantity;
- protect soil function to deliver agricultural productivity in a sustainable way;
- limit contamination of the environment and industrial pollution;
- deliver environmental protection through new developments; and
- protect key valued areas for nature conservation.

Currently, the Thematic Strategy for Soil Protection is the only official EU document that directly addresses soil issues. This was, of course, to be followed by a framework Directive for soil protection. While proposed in 2006 the approval of this dossier, under codecision, has been blocked by a minority of Member States.

In terms of advancing priority soil policies, step one should therefore be to attempt to take forward some form of EU policy on soils, mandating the importance of the protection and remediation of this media and the functions this offers to society. Importantly, it must be acknowledged that these functions have an important role in delivering a wide range of priority land services in the EU including nature conservation, water availability and quality, food production and climate mitigation.

The existing soil framework proposal focuses largely on the identification of priority areas for action or negatives to be addressed and remediated. This follows a traditional approach to soil policy i.e. to identify hot spots of erosion, organic matter decline and contamination. In the future a more proactive approach to protecting soils is also importantly needed. A mechanism needs to be put in place to recognise the locations with the most ‘valuable’ soils delivering functions from food productivity to water and carbon storage. In light of ongoing developments, especially in the field of climate change, food security and water availability, it must be considered whether the soil framework proposal is sufficiently broad and coverage appropriate to consider all these needs. At present within the proposal there is a more limited focus on climate change and agriculture for example. This does not seem to reflect the current and future priorities anticipated. In response to this recommendation S1 is put forward as a key need to deliver soil protection.

S1. Finalise a robust Soil Framework Directive. This must provide a mandate to address both soil problems (i.e. priority areas for remediation) and protect valuable soil functions. It must give adequate weight to issues such as carbon sequestration, water management, the delivery of food and the maintenance of soil functions through agricultural management.

While the Commission proposal does make reference to these issues, for example linking to climate change or agriculture, this is only within the recitals and Article 3 relating to the integration of soil concerns when considering impacts of policy decisions in these areas. Given the rising priority placed upon delivering climate mitigation and adaptation via land use and the rising understanding of the importance of maximising the positive and minimising the negative impacts of agricultural production on soil function more proactive clauses related to these issues are arguably needed. Moreover, while climate change generically is referenced, the importance of high quality soils in delivering increased resilience in terms of adaptation – securing food production and water availability - to climate change does not receive attention.

It is therefore proposed that the Commission work with the Parliament and Member States to ensure that any Directive, when it emerges from the codecision procedure, takes account of climate priorities both to deliver mitigation via sequestration and adaptation. This should include proactive action to ensure this and also to ensure that the benefits associated with soil protection are properly taken into account in land use decisions, rather than simply addressing soil issues after they have become problematic.

In order to inform an approach focused on protecting soil functionality and soil characteristics of value (versus traditional approaches to soil mapping which predominantly focus on identifying degradation) there needs to be further research and analytical systems developed. Firstly there is a need to better understand the delivery of soil functions, how these vary across a landscape and can be assessed in a given locality. Secondly, there is a need to understand better how the debate on soil functionality relates to other important environmental concepts under development, including ecosystem services delivered through land management.

There is, therefore, both a policy need but also two clear research activities that need to be undertaken to facilitate the protection of soil function. The development of such analysis should arguably be coordinated at the EU level to ensure that positive soil functions are not ignored or sidelined during the implementation of either the framework Directive or new policy concepts. Recommendations S2 and S3 therefore reflect these specific research needs.

S2. Undertake research looking at mechanisms for valuing soil functions and identifying functionality of land parcels and how this varies across the landscape. This should ultimately lead to a tool or approach that can be used to support the implementation of soil policies but also the integration of the protection of soil function in other policy areas including EIA, SEA and implementation of water policies etc.

S3. Undertake research to examine soil functions and the relationship and importance, and comprehensive nature of coverage within emerging policy concepts including inter alia the development of approaches to assessing ecosystem services, public goods and carbon sequestration. This should identify if soil issues are being comprehensively addressed and how soil functionality can most effectively be integrated into future decision making.

Reviewing the Thematic Strategy on Soil Protection

Within the Thematic Strategy on Soil Protection there is no date set for its review. This is in contrast, for example, to the waste prevention and recycling Thematic Strategy or the natural resources Thematic Strategy; both of which are to be reviewed in 2010. Moreover, the Sixth Environmental Action Plan, the dossier that mandated the soil Thematic Strategy, is to be reviewed in 2010. It would, therefore, make sense to take this opportunity to better consider the debate over soil priorities in particular related to agriculture (in light of the upcoming funding review) and climate change (in light of an anticipated focus on sequestration and water scarcity). The debate related to these issues has substantially opened up and shifted since the Thematic Strategy on soil was debated in 2004/2005.

Box 10.4 below sets out the actions anticipated under the Thematic Strategy on soil protection. Many of these have yet to be taken forward or, where these have been undertaken ideally the effectiveness of changes are in need of assessment to ensure that further actions on soils can be structured effectively. There needs to be a consideration as to whether these issues remain priorities and whether actions taken forward have delivered the anticipated benefits for soil protection. Moreover, there are additional priorities (reflected in the services being examined within this work) that should be better considered. A review of the Thematic Strategy, might also allow soil policy to shift beyond the impasse in the approval of the Soil Framework Directive, which it surely must given its rising importance on a variety of agenda.

S4. Undertake a review of the Thematic Strategy on Soil Protection to develop a policy document that reflects the increasing importance of soil issues on a variety of agenda from climate change, through food security to water availability. This review should set a basis for soil priorities going forward and evaluate the success the Strategy in ensure better consideration of soil issues.

Box 10.4. Next steps and actions set out within the Thematic Strategy on Soil Protection (COM(2006)231)

- Develop calls for research projects to support policymaking in line with the objectives of this strategy and incorporate in decision-making any new knowledge acquired on soil biodiversity from 2006 onwards.
- Review the Sewage Sludge Directive in 2007, as also announced in the Thematic Strategy on Waste Prevention and Recycling10, to ensure that maximum benefit is reaped from the reintroduction of nutrients while further limiting the release of dangerous substances into the soil.
- Review the Integrated Pollution Prevention and Control (IPPC) Directive in 2007 to strengthen its soil protection and contamination prevention aspects by exploring, in particular, harmonisation of the basic obligation to avoid any pollution risk, returning the site of IPPC installations to a “satisfactory state”, and periodically monitoring soil on the site.
- Monitor closely whether the need to protect soil is adequately taken into account in the RDPs for 2007-2013, and thereafter, check the contribution made to soil protection by the minimum requirements for good agricultural and environmental condition defined by Member States in accordance with Article 5 and Annex IV of Regulation 1782/2003.
- Initiate activities to develop best practices to mitigate negative effects of sealing on soil functions in 2007.
- Prepare a Common Implementation Strategy for the Framework Directive and the other pillars of the strategy, in partnership with Member States, while maintaining an open dialogue with experts who participated in the stakeholder consultation. This will allow initiating activities to support Member States in identifying and developing the most cost effective measures to achieve the objectives of the strategy. This will also allow better cooperation between Member States in reaching comparable approaches to soil protection.
- Build a robust approach to address the interaction between soil protection and climate change from the viewpoints of research, economy and rural development so that policies in this areas are mutually supportive.

- Assess possible synergies between measures aiming at protection and sustainable use of soil and measures incorporated in river basin management plans under the Water Framework Directive in 2009.
- Assess possible synergies between measures aiming at protection and sustainable use of soil and measures aiming at the protection of coastal waters, including those incorporated in the Thematic Strategy on the Protection and Conservation of the Marine Environment.
- Ensure integration of soil protection aspects in product policy to prevent contamination of soil.
- Ensure that the actions of this strategy and the initiatives taken under the UNCCD, the UNCBD, the Kyoto Protocol and the Alpine Convention are mutually supportive, consistent and complementary.

Taking forward the integration of soil issues into other environmental policy areas

As set out above, there are many EU environmental policies that indirectly impact upon soil protection. In several cases, particularly that of the EIA, SEA and Water Framework Directives, these offer a significant opportunity to protect soils and their functions. However, at present these opportunities are not being fully utilised. This is due to soil issues not being recognised as of central importance in some cases, but also due to a lack of knowledge concerning the soil issues of concern. As a consequence key interactions are failing to be capitalised upon, alternatives to current approaches are not fully utilised, clear guidance as to the importance of soil functionality and the mechanisms for protection is lacking.

There is a need to consider soil functions, their preservation and implications of their loss when implementing the EIA, SEA and Water Framework Directives at the national and local level. It is therefore proposed that clearer guidance on the manifestation of soil functions and how to deal with soil issues during the implementation of these Directives should be developed. Rather than generating new policy tools it is sensible to use existing policies and networks better. This guidance should be in a form that it can be taken on board by practitioners both implementing and undertaking EIA and SEA assessments and river basin management plans.

For example, in protecting a river basin a key element for many Districts is retaining soil quality and functionality, due to the associated pollution and quantity problems that may otherwise occur. As identified in the SoCo project, under these circumstances measures are often focused only on protecting waterways rather than retaining soil functions *in situ* and this can result in some perverse impacts. For example, sediment traps might be fitted at great expense, paid for by government grants. While these will prevent sediment entering the waterway, the soil and associated functions, are still being lost from the fields. Rather than funding hard engineering it would be more effective for overall environmental protection to better educate a farmer to reduce erosion and undertake in-field actions using funding to support a more effective extension service.

S5 – Developing guidance to support the effective integration of soil function considerations into the implementation of the EIA, SEA and Water Framework Directives. This should include both identification of priority issues of importance and practical methods and tools of use by practitioners. This should support the implementation of these Directives and ensure opportunities for the protection of soil functions are maximised.

Addressing soil sealing – key opportunities

The key concern associated with soil sealing is that, at its most extreme, this removes the ability of the soil to perform any of its key functions. This immediately leads to the loss of the land for other uses (e.g. biomass production or biodiversity protection). As described in Chapter 4, sealing also leads to ongoing changes in water flow patterns leading to reduced base flow and groundwater recharge, which can increase water shortages, and conversely increase peak river flows and hence flooding.

To effectively address soil sealing, however, there are three additional, more specific needs.

- better understanding within industry and by decision makers of the problem of soil sealing and improved information resources to provide clarity over best practice approaches;
- ensuring that the tools the EU does have to support planning decisions are effectively implemented; and
- ensure that water availability is appropriately taken into account during the development of water protection measures, especially river basin management. This should ensure that soil sealing impacts on availability are more appropriately considered.

The above needs lead to two additional recommendations of importance to soil sealing :

S6. Better disseminate the need to avoid soil sealing and provide clear best practice approaches to development, akin to the BAT approach under the IPPC Directive. This should set out what different types of development should do to address sealing issues.

Wa1 - *Ensure that during the implementation of the Water Framework Directive (see below), river basin management plans thoroughly consider impacts on water availability (quantity) as well as quality.* See Section 9.3.6 on water policies.

10.1.6 Agriculture and forestry

Given that agriculture and forestry account for approximately 82% of land use in the EU-27 Member States (Eurostat, 2009), it is not surprising that the policies that relate to these sectors have a significant influence on all the pressures covered in this study (apart from soil sealing) and on the scale and quality of the land services provided. They do so by influencing the management decisions taken by land managers, with subsequent impacts on food production, biodiversity, water retention, water quality and soil organic matter.

Underpinned by a regulatory baseline of EU and national legislative requirements, the Common Agricultural Policy (CAP) is the main funding instrument that exerts an influence over land management practices across the EU and hence the provision of this suite of land services, alongside other public goods. CAP policies affect the decisions of managers responsible for the vast majority of agricultural land and also have the potential to influence the actions of many forest managers.

Chapter 7 provided an overview and analysis of current CAP policies which influence these pressures. In this chapter we make recommendations for future agricultural policy responses to secure the provision of land services that have public good characteristics, and are therefore unable to be provided by the market and require public policy intervention to ensure future provision. This public goods quality applies to the four land services of biodiversity, water (retention and quality) and soil organic matter, but the fourth land service, that of ‘food production’, needs to be more clearly defined in considering a suitable policy response. Markets are generally the best regulators of food supply, although there may be some justification for policy intervention to avoid hazards to human welfare arising from a potential shortfall in supply. As noted in Section 6.2, the EU does not face a risk of undersupply of food, at least not in the timeframe of this study, and therefore the policy objective defined in Section 9.3.1 is to secure the productive capacity of existing agricultural land. This requires maintenance of a sustainable resource base, including the provision of the other land services dealt with in this study.

The CAP policy tools currently most capable of supporting the provision of land services are the environmental land management measures (Axis 2 of Pillar 2), where Member States have a high degree of choice and level of subsidiarity in using EAFRD funds to meet locally identified needs; and the Member State-defined GAEC cross-compliance standards that apply to farm-level payments under both Pillars 1 and 2. Several other CAP policies with non-environmental primary objectives (e.g. income support, improving competitiveness or the quality of life in rural areas) may have indirect positive or negative impacts on land services and could have a more positive impact in future if changes are made to the way measures are implemented.

Most of the tools for improving the provision of land services already exist within the current CAP policy framework, but in many cases the effectiveness of these measures is constrained either because they do not receive sufficient funding or priority within the current policy framework, or because the way in which they are implemented at the Member State or regional level limits their impact on land services (Farmer *et al*, 2008; European Commission, 2004[103]).

The agricultural and forestry recommendations relevant to the four land services in this study are set out below and summarised in the tables that follow. The relevance of each policy recommendation for the four land services is noted in the text, with cross-references to more detailed background in Chapter 7.

Refocusing the CAP

The CAP continues to be focused on providing income support, but the progressive decoupling of Pillar 1 payments has broken the causal relationship between the current area of crops or number of livestock on a farm and Pillar 1 payments, thus removing one of the drivers of intensification. Nevertheless, on almost all EU-15 farms the Pillar 1 income support payment rates are still based on the historic cropping and stocking patterns of that farm, not on current needs or forward-looking policy objectives. In order to secure real improvements in the provision of land services and other environmental public goods, a refocusing of the CAP is needed towards objectives that are both economically efficient and publically justifiable. The

[103] COM (2004)(431)

provision of public goods is one such justification (Cooper *et al*, 2009; BirdLife *et al*, 2009; Bureau and Mahé, 2008).

Although the CAP has most of the measures required, a recent report for DG Agriculture noted that 'there are a number of reasons why the current policy framework has not achieved the improvement in the provision of public goods on the scale that is required' (Cooper *et al*, 2009). Reasons for this shortfall include the relative weight afforded to the different objectives of policy, the choice of policy instruments, the design and subsequent implementation of policy measures, the extent of governance and institutional capacity and, critically, the adequacy of budgetary resources. Current levels of expenditure on rural development measures with environmental objectives appear insufficient when compared to the scale of societal demand and estimates of the scale of funding required to meet EU targets for specific public goods (Cooper *et al*, 2009).

AF1: Refocus the CAP to provide a stronger and more consistent emphasis throughout the policy framework on delivering environmental services which the market does not provide. A restructuring of support payments will be needed to make more effective and efficient use of existing instruments and available budgets, and to target these more closely on objectives, locations and recipients that will protect existing land services, deliver improved services and help to protect these services from current and future pressures. The roles and responsibilities of different levels of governance have an important bearing on this. Whilst budgetary allocation (of common funds) and the objectives, scope and limitations of policies are determined at EU level, many of the key decisions are necessarily made at Member State (or regional) level and involve trade-offs between competing policy objectives. Guidance on implementation will be required, together with advice and capacity building. To be successful the refocused CAP policy will have to be implemented in a way that recognises that land services are highly location-specific, and are underpinned by a clearly defined regulatory baseline.

Maintaining a clearly defined regulatory baseline

The regulatory baseline has two elements - common EU level legislation which has been transposed nationally in all Member States, and relevant national or regional legislation which necessarily differs across Member States. The regulatory baseline applies to all farmers and foresters whether or not they receive CAP support, and together with GAEC cross-compliance standards forms the basic reference level for all CAP payments relating to farmland (some Member States have included elements of national regulations in their definition of GAEC cross-compliance). Agricultural policy needs to recognise that the regulatory baseline may change over time to reflect environmental (and other) priorities, thus redefining the regulatory protection provided for land services.

AF2. The environmental regulatory baseline at EU-level should be strengthened to protect soil functionality, particularly by adopting the Soil Framework Directive (see S1). Since 2006, Member States have failed to agree on the scope of the proposed Soil Framework Directive, largely because of the potential impact on farmers' property rights. The proposed framework would bring significant benefits for soil organic matter and water retention, through national programmes of measures in areas at risk of soil erosion, organic matter decline, and salinisation. Such measures at farm level could limit or remove the pressure of future intensification on susceptible arable soils, and help to reverse past damage (e.g. by improving soil organic matter content).

AF3. At Member State level review and if necessary improve the definition and implementation of national or regional regulations (and also the controls and sanctions applied) to ensure that these provide a baseline level of protection for specific land services. The national regulatory baseline differs from one Member State to another, reflecting environmental and cultural differences. Using regulations to limit potentially damaging activities (rather than using GAEC cross-compliance or agri-environment payments) has the advantage of applying to all farmland, not just land receiving CAP payments. Keeping a clear distinction between 'polluter pays' and 'provider gets' ensures that effective use is made of agri-environment budgets - but the level at which this distinction is made can limit the scope for offering agri-environment incentives for beneficial management. A balance therefore has to be struck between incentive policies with payments above the baseline reference level, and obligations below the reference level. Some Member States define national regulations more stringently than others, for example in prohibiting stubble burning (which improves soil organic matter) and on the abstraction of water for irrigation (which helps to limit the pressure for intensification). There are also variations between Member States in the effectiveness of the controls and sanctions applied to regulations affecting farmland. In some cases improved implementation of existing regulations would help to safeguard the provision of land services.

Using cross-compliance to reduce the pressures on land services

The usefulness of cross-compliance in the context of land services could be enhanced by both short-term and longer-term measures to improve its focus and implementation.

AF4. While SMR cross-compliance remains a policy instrument within the CAP it should be updated to include new farm-level requirements in EU legislation relevant to land services. SMR cross-compliance requirements should be kept under review and updated as relevant new EU legislation is put in place in the future - for example by adding any farm-level standards arising from the Water Framework Directive (see Section 10.1.7) and the Soil Framework Directive (see S1). Such updates of SMR cross compliance may also require the adjustment of related GAEC standards (in this example, for water or soil issues) in order to avoid overlaps and double penalties.

AF5. While GAEC cross-compliance remains a policy instrument within the CAP, the current GAEC framework should be maintained and further guidance should be provided for Member States on defining and implementing verifiable GAEC standards appropriate for different regions/farming systems in their area, with the aim of reducing the pressures of intensification and fragmentation on biodiversity and water and soil carbon, and protecting biodiversity from the effects of abandonment. These national/regional standards should follow the broad principles that:

- agricultural land does not have to be used for commodity production, but its capacity for food production should be protected;
- where the current habitat management/farmland features have a positive effect on biodiversity, soil organic matter or water, GAEC standards should, at a minimum, protect these from removal or destruction (leaving scope to pay for active management through agri-environment or other measures); and

- where current land management practices have a negative impact on soil organic matter, water or biodiversity, the implementation of GAEC standards on land in receipt of CAP payments provides an important tool to limit those effects and also helps to safeguard the productive capacity of the land.

Member States design GAEC farm-level cross-compliance standards appropriate to the characteristics and needs of the situation in their region, within a framework which currently includes a suite of compulsory and optional standards (see Section 7.4.5. and Table 7.2). Often Member States have based some GAEC standards on pre-existing national or regional legislation, but most have introduced standards that specify actions going beyond those required by national legislation. This is particularly the case for standards that relate to soil organic matter, given the current lack of legislation in this area, but some Member States have also introduced more demanding standards that have positive impacts on water quality and biodiversity (for example, the requirement to maintain a certain proportion of land under environmental cover in France – see Box 7.5). There is a limit to the management requirements that can be introduced under GAEC standards and a balance needs to be struck between those actions for which it is reasonable to expect the farmer to bear the cost and those for which he/she should be compensated, for example through agri-environment payments (see Section 7.4.5). That said, there are a number of standards that can benefit the land services of biodiversity, water retention/quality and soil organic matter and at the same time help maintain the productive capacity of the land – for example introducing legume crops into the rotation.

Without compromising the ability to pay for environmental services through agri-environment schemes, Member States could, however, make more effective use of the current GAEC framework to protect land services by:

- ensuring that farm level standards are clearly defined and appropriate to the local conditions and farming structures;
- improving advisory services;
- improving technical inspection capacity; and
- ensuring that the compliance inspection effort is proportionate to the risks to land services (habitats, species, water pollution), and that appropriate penalties are applied.

AF6. Member States should provide better safeguards for species-rich grasslands important for biodiversity by reviewing and if necessary amending the design and implementation of:

- *the national transposition of the Habitats Directive;*
- *national or regional nature conservation legislation; and*
- *relevant cross-compliance standards on protection of permanent pasture.*

The aim of these amendments should be to prevent agricultural intensification of species-rich grasslands or their conversion to arable or other uses. Improved safeguards can be achieved in several ways, as some Member States have already shown – for example national legislation in Sweden protects species-rich grassland from cultivation and fertilisation, while in the UK the EIA regulations require farm-level prior approval for the cultivation or agricultural improvement of permanent pasture over 15 years old, to protect important biodiversity services. For a discussion on the current permanent pasture rules see Section 7.4.6. Another important issue is the potential exclusion from both income support and agri-environment payments of small, low-risk livestock enterprises (which have significant biodiversity benefits) because cross-compliance presents too much of a barrier. Member States could help to overcome this problem by making better use of the opportunities for derogations within the Directives and Regulations underlying the SMRs, for example on food law requirements for small-scale producers.

AF7. Keep under close review the use and potential benefits of the new, optional GAEC standard for establishment and/or retention of habitats, particularly on intensive arable farms. Investigate the potential consequences and effectiveness of requiring a proportion of the farmed area to be allocated as Environmental Priority Areas[104] (EPAs) under cross-compliance. The EPA mechanism is well-established in Switzerland, at 7 percent of the UAA (in the case of specialised crops 3.5 percent), although payment rates are not directly comparable to those elsewhere. In the EU, two Member States are taking differing approaches to the new, optional GAEC standard, both of which are likely to reduce pressures of intensification (and existing intensive management) with benefits for soil organic matter, water quality, water management and habitat connectivity. In France, the government is proposing to increase the farmed area that is required to be kept under environmental management (grassland, hedgerows, field margins, groups of trees, etc) from 1% in 2010 to 5% in 2012 (Cooper *et al*, 2009). England (UK) has chosen not to apply the new optional GAEC standard at this stage, but instead has adopted an industry-led voluntary approach[105] aiming to restore the benefits for water quality and farmland birds that were lost when set-aside was abolished; the voluntary approach will use advice and information to improve the uptake of agri-environment measures, particularly in arable areas, rather than introduce a compulsory cross-compliance requirement (although this remains an option if the voluntary approach fails). In both these examples farmers can, to a certain extent, reduce the impact on farm productivity by choosing the most marginal land to be used as EPA (as they did with set-aside).

In the future, making an EPA requirement a compulsory GAEC standard across the EU-27 would increase the area of permanent grassland and other habitats (where these had to be created), thus contributing not just to biodiversity but also to improved water quality, soil organic matter and habitat connectivity, although not necessarily in the most targeted or efficient manner. A refinement of this option would be to consider some form of ‘orange ticket’ cross-compliance for EPAs, for example where specific habitats or locations are a priority or there is a need to avoid over-burdening low-intensity, low profitability farming systems with additional GAEC costs. This concept (discussed in more detail in Section 7.4.9) would permit, for example, the combination of agri-environment support for habitat creation and management with a requirement for a proportion of the farm to be kept as an EPA.

---

[104] An Environmental Priority Area is a proportion of the total area of a farm (including unproductive land such as hedges) that must be managed for environmental purposes, either as a condition of cross-compliance or in the context of another policy.

[105] Campaign for the Farmed Environment http://www.cfeonline.org.uk/x42296.xml

Using integrated packages of CAP measures to support land service provision in different types of farming systems

A number of drivers (for example, increasing arable commodity prices, reduced labour availability, climate change, and changes to policies such as energy policy) have been shown to have a negative impact on the future provision of the four land services and the impact will be different within different farming systems. To secure the long-term effective provision of land services at the farm level, there is a need for greater coherence and integration of policy measures, designed to meet the needs of, and to respond to the pressures facing land services within different farming systems. Recommendations are set out below in relation to High Nature Value (HNV) farming farming systems and intensive arable, dairy or beef farming systems.

High Nature Value (HNV) farming systems

These farming systems are particularly beneficial for the land services of biodiversity, soil and water, but are particularly vulnerable to marginalisation, intensification and conversion to other land uses, especially in some of the new Member States where there are associated socio-economic and infrastructure problems (these are well-documented in the 2007-13 RDPs, for example of Poland and Bulgaria). Long-term support is required, therefore, to improve the social and economic viability of vulnerable HNV farming systems*,* with the objective of maintaining a sufficient resource of HNV farmland (and associated rural communities) capable of providing land services in the future. The 'preservation and development of HNV farming and forestry systems and traditional agricultural landscapes' is identified in the Community Strategic Guidelines as a priority for the use of EAFRD Axis 2 (see Box 7.2), and agri-environment and forest-environment payments and other Axis 2 measures will continue to be very important, and form the basis for the 'purchase' of public goods such as biodiversity and water quality in the future. But in the shorter-term, without introducing new measures, there are other ways of improving support for HNV farming systems, particularly in the face of very strong pressures of marginalisation (and abandonment) in certain parts of the EU (as discussed in Section 8.2).

AF8. Give higher priority across both Pillars of the CAP to using existing measures in a more integrated and effective way to ensure that existing HNV and traditional farming systems are able to counter the pressures of marginalisation, intensification and conversion to other land uses, and continue to provide high quality land services, especially biodiversity. Provide guidance for Member States on the design and implementation of HNV-specific integrated packages of existing CAP support measures.

For example, without designing any new measures, it would be possible to make more effective use of the current CAP framework and funding by:

- Treating the environmental, economic and social needs of HNV farming systems and communities as an inter-dependent whole, recognising that small, part-time farm units can have an important long-term role in the provision of land services where the environmental benefit depends on the complex mosaic of land uses that small farms provide.

- Using environmental, not just economic or administrative criteria to determine eligibility for CAP support for HNV farming systems now at risk of exclusion from CAP support (for example HNV semi-natural grazing land with tree/shrub growth, land used only seasonally or communally, systems where biodiversity is maintained by landless graziers).
- Improving the economic viability of HNV farms (to help support the long term provision of land services) through innovation, investment and micro-enterprise support; advice and training; co-operatives; and improved market access – all specifically designed to maintain HNV farming systems (rather than support conversion to other systems).
- Encouraging Member States to use habitat and species-specific agri-environment and non-productive investment measures to support labour-intensive practices (e.g. shepherding, hand mowing) where these have biodiversity benefits, and to use forest-environment and non-productive investment measures combined with agri-environment measures to support the restoration and management of wood pastures and similar areas, for their biodiversity benefits (see Box 7.8 for examples).
- Reviewing the scope, coherence, targeting and level of CAP support (from both Pillars and all three axes of EAFRD) for HNV farming systems and management practices; and, if necessary, designing and delivering of targeted, coherent packages of CAP support that reflect the full, long term costs to farmers and the benefits to society of the land services provided (especially biodiversity); support should take into account the particular needs of small farms/parcels of high biodiversity value, the risks of marginalisation and the opportunities to add value to the outputs of HNV farming systems without losing biodiversity benefits.
- Promoting the use of Leader, local development plans and other Axis 3 measures to support HNV farming and forestry systems, involving farmers and local communities in HNV-specific support, facilitating the production of management plans for Natura 2000 and other HNV areas and providing technical support for implementation; also improving public awareness of the contribution of HNV farming systems to land services.
- Ensuring that environmental impact assessments of CAP policies (including revisons to RDPs) eliminate conflicting signals to farmers and guard against unintended and potentially environmentally damaging impacts, for example from investment aid, cross compliance requirements or technical advice.
- Requiring Member States to identify (in addition to Natura 2000 sites) other semi-natural grasslands of high biodiversity value on national databases used to implement CAP schemes (for example, the Land Parcel Information System), and to keep these records up-to-date; and, within Member States' annual records of permanent pasture, to separately record and report actual areas of HNV permanent pasture, distinguishing them from other types of permanent pasture.
- Requiring Member States to define criteria and implement procedures for afforestation projects on farmland, to ensure that grasslands of high biodiversity value are protected.
- Requiring Member States using EAFRD funded advisory services to provide specific technical advice to farmers on HNV management.

Intensive arable, dairy or beef farming systems
In contrast to HNV and low-intensity livestock systems the continuation of these farming systems is not threatened by market forces, although restructuring will continue, with a shift in production to the parts of Europe with greatest competitive advantage (see Section 7.2.2 for discussion of the threats). Further intensification is anticipated in some parts of the EU-12. These trends are likely to have a detrimental impact on biodiversity, water retention/quality and soil organic matter, and unless these resources are protected, could have an adverse impact on the productive capacity of the land in the longer term - in some areas the productive capacity of the land is already diminished by reduced levels of soil organic matter.

AF9. Use CAP measures for intensive arable, dairy or beef farming systems to secure a basic level of provision of land services for biodiversity, water and soil and to incentivise enhanced provision.
Key measures would include, in the short-term:

- the maintenance of current GAEC standards to improve soil organic matter and protect surface water (e.g. winter cover, crop rotation, buffer strips along water courses, limitations on cultivation of slopes) and ensure these are implemented in all Member States;
- innovation and advisory support measures to develop and adopt techniques which improve 'land services efficiency' of intensive farming – for example nutrient management planning, water conservation and storage, trickle irrigation, cropping to increase soil organic matter; precision farming; (investment support should not necessarily be required because most of these techniques either reduce costs and/or improve productivity);
- agri-environment, non-productive investment and agro-forestry measures to improve quality and level of biodiversity and to protect water from pollution; and in the longer-term
- reviewing the potential of Environmental Priority Areas (see recommendation AF7 above).

Ensure the provision of advice, training and capacity building for land managers
Many of the measures used to supply land services will be voluntary for farmers or foresters and involve entering into a contractual agreement with the State. The concept of payment for the provision of environmental services will be unfamiliar to some farmers (particularly HNV farmers in the EU-12) and for others may involve using different decision-making processes or understanding different management practices (e.g. the selection of land for buffer strips, afforestation, the benefits of beetle banks for pest control etc). The provision of effective advisory services will be crucial to the successful delivery of CAP support for land services.

AF10. The provision of advisory services should be tailored to the needs of different farming systems and the specific land services these systems provide.

Improve geographical targeting of policy measures
The location-specific nature of many land services and the pressures on them means that there is increasing need for geographical targeting of policy measures, at several spatial scales (from EU region to within individual land parcels) to ensure effective provision of land services.

AF11. The geographical targeting of policy measures should be improved. To facilitate this, the quality, availability, digital accessibility/compatibility and use of data needed to identify areas, types of land and locations which are a priority for targeting action to protect/provide land services, needs to be improved at appropriate scales from pan-European to farm-level.

These data would be able to be used for many different purposes, including:

- the allocation of EU budgetary resources to vulnerable farming systems important for land service provision at Member State level, and Member State allocation of funding at regional/local level;
- to identify cross-boundary areas (ownership or administrative) where there are specific pressures (e.g. habitat fragmentation and soil erosion);
- design and targeting of measures (e.g. agri-environment, afforestation and Leader) and of areas to be protected from land use change (e.g. for biofuel production and built development); and
- for farm-level targeting, for example of nutrient use, buffer strips, habitat creation, species specific agri-environment management.

AF12. Landscape scale approaches to delivery need to be further encouraged and supported

Securing the effective provision of land services will require intervention across multiple, contiguous land ownership parcels at the required spatial scale – for example: to reduce diffuse pollution of surface and groundwater all farmers in a catchment may need to take measures to improve infiltration; to provide new semi-natural habitats to link fragmented existing habitats for biodiversity, several farmers may need to manage adjoining areas of key habitats such as species-rich grassland; to manage water tables (e.g. to prevent organic peat soils drying out) all farmers in a drainage basin must participate; and to safeguard the landscape scale biodiversity benefits of existing high densities of small traditional farms, a high level of uptake of agri-environment support measures will be important.

Key changes to the way in which existing policy measures are used could include:

- offering higher agri-environment payment rates for group applications, to reflect the greater public benefit of scale (and cover the transaction costs);
- geographically defined cross-compliance standards; and
- sophisticated spatial targeting of afforestation and creation of permanent grassland at farm-level (using digital mapping) where this is critical, for example for water infiltration and soil protection services.

Improve the integration of CAP policy instruments with those of other EU policies pursuing similar objectives

Actions under the CAP will not provide all the solutions to the challenges facing the provision of land services in the face of the pressures identified. Other EU policy instruments may rely on action under the CAP to achieve objectives relating to land services and *vice versa*. As such, it is critical that the policy instruments that are needed to achieve the objectives of these land services (and other public goods) are implemented in a coordinated and integrated way. This is particularly important in the case of the EU target of producing 10% of energy from renewable sources by 2020 under Renewable Energy Directive (2009/28/EC), which may drive further intensification of agricultural systems and the loss of permanent grasslands in the EU, potentially leading to impacts on food, soils, biodiversity and water resources (as discussed in Chapter 8).

However, the Directive attempts to limit the negative consequences of expanded European demand for bioliquids and biofuels by proposing a series of sustainability criteria, set out under Article 17. Biofuels and bioliquids must fulfil the Directive's sustainability criteria if they are to be taken into account when complying with national targets set under the Directive, or to be eligible for financial support. Paragraph 3 of Article 17 states that biofuels and bioliquids 'shall not be made from raw material obtained from land with high biodiversity value'. It then goes on to qualify this statement by clarifying that for the purposes of the Directive this means land 'that had one of the following statuses in or after January 2008, whether or not the land continues to have that status':

- Primary forest and other wooded land.
- Areas designated for nature protection.
- Highly biodiverse grasslands that is:
    - natural, namely grassland that would remain grassland in the absence of human intervention and which maintains the natural species composition and ecological characteristics and processes; or
    - non-natural, namely grassland that would cease to be grassland in the absence of human intervention and which is species-rich and not degraded, unless evidence is provided that the harvesting of the raw material is necessary to preserve its grassland status.

The European Commission is now tasked (under the comitology procedure) with establishing 'criteria and geographic ranges to determine which grassland shall be covered. This is a real and present opportunity to regulate direct pressures on EU grasslands from biofuel production. However, neither the Renewable Energy Directive nor the Habitats Directive provide an EU mechanism to protect grasslands of high biodiversity value (outside Natura 2000 sites) from the indirect risks of conversion to grow arable crops that have been displaced by biofuel production on what is now arable land. However Member States already have a range of mechanisms available which they could use for this purpose, including cross-compliance rules on permanent pasture (if strengthened as suggested in AF6), national nature conservation regulations and EIA regulations. The following recommendations are therefore made:

AF13. Strong and practical criteria should be developed by the Commission and by Member States to protect permanent grasslands that are of high value for biodiversity in the EU from the direct and indirect threats arising from biofuel production.

In particular it is recommended that:

- The Commission should recognise the broader context of protection of the environment identified within the Recitals of the Directive; the varying interpretation of "highly biodiverse" depending on the natural or non-natural classification of grassland; and the lack of hierarchy between the requirements for the protection of natural and non-natural highly biodiverse grasslands, ie that both should be treated as equally important.

- A broad definition of grasslands is used, which includes biotopes that can have a high proportion of species or habitats other than grass, such as shrubs, trees, mosses, other plants, bare soil or exposed rock.
- The requirement for grasslands to maintain their natural species composition and ecological characteristics and processes to qualify as natural should not be based on a strict standard based solely on vegetative composition. Similarly, the consideration of species-richness in non-natural grasslands should not be restricted to plants.
- Consideration of species-richness should not be solely based on small-scale assessments, e.g. species per m^2. Larger scale species diversity patterns are equally important. Thus grasslands should also be protected if they hold rare or otherwise threatened species or species assemblages, the loss of which would reduce national, regional or global scale biodiversity.
- Any assessment of the biological character of a natural grassland (including species richness) should be appropriate to the biogeographic region of that grassland.
- Member States should be encouraged and advised to implement as soon as possible national or regional mechanisms to protect permanent grasslands of high value for biodiversity (including grasslands outside Natura 2000 sites) from the indirect effects of biofuel production (especially the dispacement of arable crops).

Provision of adequate evidence to ensure effective monitoring and evaluation of the use of the CAP framework to support the provision of land services

Although the availability of data on the state and trends of different environmental media have improved over recent years, there are still significant gaps, particularly at the national/regional level in many Member States. This can limit evaluations of the impacts of policies on the environment at the local scale. Effective and efficient use of CAP funds to provide land services will require significant effort in monitoring the impacts and evaluating and adjusting policies to improve their targeting and delivery. The Common Monitoring and Evaluation Framework (CMEF) provides a solid foundation for the collation of such information, and this approach needs to be developed further. In particular:

AF14. Investment is needed for the collation of the necessary data at the most appropriate spatial scale, to provide evidence for assessing the impacts of policies on land services.

AF15. Common monitoring and evaluation programmes need to be developed, adapted and implemented to assess the pressures on land services and the impact of CAP policies on their provision with the aim of providing an evidence base for future policy decisions.

10.1.7 Water

As described in Section 7.4.12, the Water Framework Directive and Nitrates Directive have important influences over agricultural intensification pressures on water quality and quantity, especially through their interaction with agricultural policy measures. The WFD and Floods Directives may also help to reduce soil sealing. Some potential water policy recommendations relating to these pressures are therefore outlined below, although it is not within the scope of this study to assess and develop water policies concerning the full range of pressures on water retention and quality.

River basin management planning required by the European Union Water Framework Directive aims to achieve good ecological status for water bodies. These objectives must be developed in conjunction with stakeholders and therefore should involve cooperative working at a catchment scale between a range of statutory and non-statutory bodies. The EU Floods Directive similarly requires the production of flood risk management plans, to reduce the risk of flooding to human health and the environment. These two sets of plans share the same time cycle and the requirement for stakeholder participation, although there is no obligation to ensure plans are co-ordinated at the same scale. There is therefore a significant opportunity to use these two mechanisms to achieve parallel objectives of reducing soil sealing and agricultural intensification pressures on water resources and biodiversity. Measures to reduce soil sealing, restore flood plain wetlands; create riparian corridors; improve in-channel habitat; and create flood retention basins can be designed not only to improve ecological status and reduce flood risk, but also to maintain or restore riverine habitat corridors and provide other biodiversity benefits.

To achieve this the following recommendations are made:

Wa1. Ensure that during the implementation of the Water Framework Directive, river basin management plans thoroughly consider impacts on water availability (quantity) as well as quality. Importantly, this should consider anticipated changes to the hydrological flows in the catchment.

Wa2. Provide policy guidance that encourages Member States to ensures that relevant biodiversity objectives are considered alongside Water Framework Directive and Flood Directive objectives in river basin management plans and flood risk management plans. This should include measures that strengthen requirements for competent authorities to enhance delivery of biodiversity targets through river basin planning and sustainable flood management stakeholder groups.

Wa3. Ensure that agri-environment schemes (see above) and habitat restoration initiatives maximise synergies between biodiversity, flood management and ecological status objectives at local and catchments scales. Measures prescribed by the Commission stress the importance of the development of locally or regionally appropriate solutions. However, this study's assessment of the implementation of ecological corridor initiatives demonstrated the difficulty in implementing and integrating measures into devolved regional plans, in particular as a result of capacity constraints. Therefore, measures to share learning between officials at these levels, target funds to increase capacity and improve consultation in the development of policy could be an important approach to integrating flood management, biodiversity and water quality and retention measures into local and regional spatial plans.

10.1.8 Development and land use planning, assessment and control

A no-net-loss policy and habitat banking

An important existing policy weakness relates to the assessment and treatment of the potential impacts of commercial, housing and infrastructure developments etc on biodiversity in the wider environment. This is partly because the EU has no competency over spatial planning and therefore development control standards vary considerably between Member States. Although the EU has legal requirements for SEA of plans and programmes and project specific EIAs (see below), the application of these is variable particularly with respect to their treatment of biodiversity. Most importantly, the legislation focuses on the impact assessment process rather than the appropriateness of decisions in the relation to potential impacts. Consequently the requirements for measures to avoid, minimise or compensate for impacts are often weak; and where such measures are required enforcement is often lacking (Eftec and IEEP, 2009). This is primarily because the EU does not require Member States to implement a general policy of ensuring no net loss of biodiversity. Compensation[106] measures are mandatory for residual impacts on designated habitats and species within Natura sites (in accordance with Article 6(4) of the Habitats Directive). But there is no policy requiring or promoting compensation measures for residual biodiversity impacts in the wider environment.

As residual impacts from development projects have been an unavoidable and widespread reality in the EU, it is evident the target of halting biodiversity loss could not have been achieved without a no-net biodiversity loss policy. But such a policy will require practical measures for delivery, such as the promotion of offsets, e.g. through market-based habitat banking schemes. Habitat Banking could provide an effective and efficient mechanism for developers to pay for compensation measures that ensure no net loss of biodiversity, or potentially a net gain (Latimer and Hill 2007, Briggs *et al* 2009). Habitat banking organisations (private, public or community bodies) would secure funds from developers and provide land for habitat enhancement, restoration or creation. Such habitat banks have been successfully established in the USA, Australia, South Africa and several other countries, but have yet to be developed widely in the EU (Eftec and IEEP, 2009). An advantage over project-specific offsets is the potential to strategically locate compensation actions, for example by enlarging or connecting fragmented habitats. The concept of no-net-loss can also be extended to cover related land services (e.g. no net loss of soil carbon, or water resources).

However, as noted in a recent study for DG Environment (Eftec and IEEP, 2009), the introduction of such compensation measures could bring significant risks, such as potentially reducing acceptable thresholds for residual impacts whilst providing compensation with uncertain long-term additionality. Such a policy and compensatory framework would therefore need be introduced carefully with appropriate regulatory safeguards. In particular a strong and independent regulator would be needed to ensure that compensation measures are at least equivalent to impacts and only taken after appropriate avoidance and mitigation measures, and that they provide sufficient additionality to ensure that there is no net loss of biodiversity.

The following recommendations are therefore made to implement a no-net-loss policy for biodiversity and related ecosystem services.

D1. Include an explicit target of no-net biodiversity loss from projects and programmes in a revised EU BAP, for individual projects and programmes.

---

[106] Compensation must be in terms of biodiversity outcomes, rather than monetary compensation

D2. Establish a habitat banking policy framework to support and regulate a habitat banking market involving developers who would purchase credits that would then be used by landowners or land managers to enhance or create land areas for biodiversity and ecosystem service gains. This should consider two levels of compensation. Firstly, specific compensation requirements calculated for individually significant impacts on important biodiversity. Secondly, a simple fee in lieu scheme (with the received funds allocated according to conservation priorities by an independent private or public fund) for cumulative impacts of individually insignificant developments.

SEA and EIA

SEA and EIA are key tools that help with the implementation of sustainable development policies and when carried out according to best practices procedures can help to avoid or reduce environmental impacts. However, they have a number of weaknesses. Of particular concern is that they rarely give adequate consideration to the impacts of plans, programmes and projects on land services (especially those resulting from soil sealing or changes in land use). Thus impacts on carbon stores and sequestration, water resources and flooding are often overlooked or subject to superficial assessments.

Another weakness of SEA and EIA is that they do not address fragmentation impacts adequately, particularly where they result from the cumulative effects of minor but numerous impacts. For example, the loss of small patches of habitat are often disregarded in impact assessments because they are considered unlikely to support biodiversity of high importance. However, such habitat patches may play an important role in terms of functional connectivity, by providing ‘stepping stones’ linking areas of core habitat (e.g. sites in the Natura 2000 network). The need to maintain such patches of habitat and to maintain the permeability of the landscape is being increasingly recognised as an important strategy to counteract fragmentation, especially in the context of climate change (Donald and Evans, 2006; Huntley, 2007; Kettunen *et al*, 2007).

DG Environment has, however, already recognised this problem and has a commissioned a study that is currently underway on “Dealing with conflicts in the Implementation and Management of the Natura 2000 Network – Strategic Planning[107]”. This is now giving a high priority to the production of guidance on best practice methodologies for the assessment of the impacts of developments on connectivity amongst habitat networks and the coherence of the Natura network.

To address these weaknesses the following recommendations are made:

D3. Ensure the appropriate implementation of the SEA and EIA Directives to improve their use as tools to assess the environmental impacts of plans, programmes and projects and help determine the most environmentally friendly approach to support spatial planning.

[107] Contract Number N° 070310/2008/515135/SER/B2

D4. Improve the assessment of fragmentation impacts, and cumulative impacts on biodiversity in SEA and EIAs, e.g. through the implementation of recommendations from the DG Environment project on strategic planning and the Natura network.

Strategic guidance on land uses and the provision of land services
Planning systems in most Member States provide little if any control or guidance on the location of land uses, such as agriculture and forestry (other than through SEA for large-scale programmes). As a result the spatial distribution of land use is primarily influenced by historic factors and current economic drivers. Consequently, in some situations the use of land may not be optimal in terms of the provision of the full range of services required by society (for example with respect to the need to reduce greenhouse gas emissions from land use, as indicated in Chapters 8 and 9).

This is being increasingly recognised and consequently mapping and valuation of ecosystem services is underway in some Member States and is being used to help develop holistic visions for land use that incorporates the delivery of a wide range of ecosystem serivces (e.g. see Box 10.5). Such strategic visions may then be combined with indicative strategic land use planning to encourage and support the optimal use of the land by spatially targeting the use of public funds (or other incentives) to deliver the most desired land services. The following recommendation is therefore made.

D5. Encourage and guide Member States to develop holistic visions of land use and policy instruments that support the strategic provision of land service requirements. For example, indicative mapping of existing and potential land uses and associated ecosystem services (e.g. with respect to afforestation, biomass crops, agricultural systems, soil/peat protection and water/flood management) could be used to develop agreed visions for the land use that include the provision of a wide range of ecosystem serivces. Such strategic visions could then greatly help guide and design Rural Development Programmes and target agri-environment measures (see AF11) and facilitate landscape scale provision of land services (see AF12). The provision of ecosystem services might also be added to the remit of competent authorities (e.g. regional planning authorities). Guidance and capacity building measures could also facilitate public/private partnership initiatives for ecosystem service provision, as described in Box 10.3 above.

Box 10.5. The development of a vision or England's upland environment

Natural England commissioned studies that have mapped and valued ecosystem services in the uplands of England (Natural England 2009a). This has confirmed their importance for food production, carbon storage and climate regulation, flood management, and water resources, recreation and cultural values and biodiversity conservation. This information has been used to develop a proposed vision for the uplands in a report "Vital Uplands" (Natural England 2009b). The report and the detailed description of environmental services that goes with it aims to be a starting point for dialogue for stakeholders and describes how the uplands might look and be managed in fifty years' time, with future land management targeted towards delivering:

- Sustainable production of food, wood and other raw materials.
- Mitigation and reduction of climate change.
- Resilient upland ecosystems.
- Vibrant upland communities and economies.
- Clean water supplies from upland rivers and lakes.
- Reduction of 'natural' hazards – such as flooding and wildfire.
- Health and wellbeing benefits.

To achieve these goals, Natural England is exploring how upland communities can be better supported by focusing land management on the following critical food and environmental services:

- Upland soil and peat resources need to be managed sustainably. Action is needed to ensure that eroding peat soils and blanket bog are stabilised, properly vegetated, and can actively absorb carbon. At present - because of erosion, oxidation, and burning - up to 4 million tonnes of CO2 are being released per year from English peatlands, comparable to CO2 emissions from domestic aviation.
- Open upland heaths, bogs and grasslands are a major part of what makes our upland landscapes distinctive and these habitats need to be sustainably managed alongside grouse moor management that involves sustainable grazing and burning.
- The level of upland grazing needs to be matched to deliver different environmental services. In some areas, higher grazing levels will be needed for food production; in others, lower grazing is required to secure benefits such as water quality improvement and peatland re-vegetation.
- More, and better managed, woodlands. Grazing levels may need to be adjusted to allow natural regeneration of native woodlands, increase woodland cover and link existing woodland areas. In 50 years' time Natural England would like to see up to 25% of the uplands with some form of woodland cover.
- Green energy. The uplands can provide green energy in the form of renewable wood-fuel, water power, ground source heat, solar and wind technologies in appropriate locations.
- Low-carbon growth. More can be done to promote upland business, built development and transport focussed on low-carbon growth.

To support the Vital Uplands vision, Natural England is starting three pilot projects in 2010 (in Cumbria, the South West uplands and Yorkshire), to examine how the provision of a broader range of environmental services can be turned into genuine business opportunities for farmers and land managers. The pilots will trial ways in which local upland management can be geared to the delivery of multiple public benefits
See http://www.naturalengland.org.uk/ourwork/securefuture/default.aspx

Table 10.2. Recommended policy measures that may address the impacts of key pressures on land services

Key:
Pressures: SS = soil sealing; Fr = fragmentation; I = Intensification, M = marginalisation; PG = Permanent Grassland loss.
Land services: Food; Bd = Biodiversity; Wat = Water retention and quality; SOM Soil organic matter.
Potential impacts: ●●● = high positive (beneficial); ●● = moderate positive, ● = low positive; ○ = low negative; **?** = uncertain; **v** = variable (ie depending on circumstances).

Principal types of measure: Yellow = revision of strategic policy objectives; orange = measures to improve implementation of existing instruments; blue = increase funding; purple = development /adoption of new instruments; Green = research, monitoring, guidance and capacity building.

Policy / recommendation	Impact on pressures					Impact on services				Comments
	SS	FR	I	M	PG	Food	Bd	Wat	SOM	
B1. The Commission should review opportunities to improve the effectiveness and integration of the different elements of the EU budget that could be used to encourage and support the provision of land services [of food production capacity, biodiversity, water and soil organic matter]where these services are not[likely to be] provided by the market		●	●	●●	●●	○	●●●	●	●●	Some redirection of funding could result in a small reduction in food production. Impacts on other services would depend on allocations.
B2 Secure sufficient budgetary resources for the CAP to deliver revised CAP priorities for the provision of environmental services, allocated between Member States/ regions according to robust criteria appropriate to the CAP objectives		●●	●●●	●●●	●●●	?	●●●	●●●	●●●	See also AF1. Increases incentives and funding for location specific provision of environmental land services.
B3 Consider the establishment of a new EU biodiversity fund to address issues outside the scope of the CAP and Common Fisheries Policy which are likely to be the principal sources of EU funding for biodiversity beyond 2013.		●●					●●	●	●	Potential water and soil co-benefits from ecosystem protection / restoration
B4. Take the necessary steps to improve the screening of expenditure on infrastructure investments through EU funds to minimise soil sealing and the fragmentation of habitats (see also Section 9.3.8).	●●	●●				v	●●	●	●	Potentially some reduction in food production from reduced infrastructure (e.g. irrigation) but some benefits from reduced soil sealing.

Policy / recommendation	**Impact on pressures**					**Impact on services**				**Comments**
	SS	**FR**	**I**	**M**	**PG**	**Food**	**Bd**	**Wat**	**SOM**	
Biodiversity										
Bd1. Develop in close collaboration with the Member States a strong and binding post-2010 target for halting and reversing biodiversity loss and related ecosystem services.	●	●●	●●	●●	●●		●●●	●	●●	
Bd2. Further encourage the implementation of the EU BAP, through cross-sectoral actions by EU institutions and Member States.	●	●●●	●●	●●	●●		●●●	●	●●	
Bd3. Member States should increase their efforts to establish management plans and measures for Natura 2000 sites (and other areas of high biodiversity importance) and to integrate these with the provision of other ecosystem services where there are mutual benefits.		●		●●	●●		●●●	●●	●●	Integrated management plans for biodiversity and ecosystems services would help secure funding from existing instruments and could be supported by targeting of agri-environment measures (AF11) and strategic assessments of land services and land use guidance (D5)
Bd4. Further encourage Member States to implement Article 10 of the Habitats Directive (and similar measures implied in the provisions of the Birds Directive), through the establishment of national frameworks for assessing functional connectivity needs, and planning, integrating and implementing necessary actions.	●	●●	●	●	●		●●	●	●	As recommended in the fragmentation guidance report for DG Environment (Ketunnen *et al*, 2007) - see text for framework components.
Bd5. Further promote and support the implementation of existing ecological networks and other biodiversity corridor initiatives that have the potential to deliver significant biodiversity benefits	●	●●	●	●	●	○	●●	●	●	
Soil policy										
S1. Finalisation of a soil Framework Directive that provides a mandate for action to address soils of concern (termed priority areas) but also protect valuable soil functions giving adequate weight to issues such as carbon sequestration, waste management and delivery of food/maintenance through agriculture	●●●	v	●●		●●	●●	●●	●●	●●	All depends upon the wording of the final directive and whether this can adequately address the protection of positive soil functions, and issues associated with agriculture, water and climate.
S2. Research programme looking at mechanisms for	●●		●		●	●●	●●	●●	●●	This should deliver a resource that helps the better

Policy / recommendation	**Impact on pressures**					**Impact on services**				**Comments**
	SS	**FR**	**I**	**M**	**PG**	**Food**	**Bd**	**Wat**	**SOM**	
valuing soil functions and identifying functionality of land parcels and how this varies across the landscape.										consideration of soil function during development and the implementation of other policies
S3. Research programme to examine soil functions and the relationship and importance, and comprehensive nature of coverage within emerging policy concepts such as ecosystem services and carbon sequestration to identify where soil issues can be most effectively addressed	●					●●	●●	●●	●●	Soil function is anticipated to be an important priority going forward, key to delivering many policy goals. There is a need to ensure that soil issues are considered comprehensively and that clear policy paths are identified for addressing all functions.
S4. Review of the Soil Thematic Strategy to examine successes since 2004/2005, take account of the shifting policy priorities including more effectively covering the protection of soil function in light of debates on agriculture, climate change and water resources.	●●					●●	●	●●	●●●	
S5. Development of a guidance document setting out how soil issues should be taken into account when implementing river basin management, the EIA and SEA Directives. This should support Member State implementation and ensure the opportunities afforded by these instruments are maximised	●		●			●●	●●	●●	●●	
S6. Develop a BAT approach for different development types to set out mechanisms that should be put in place to limit sealing under different circumstances	●●					●		●		
S7. Ensure that during the implementation of the Water Framework Directive (see below), river basin management plans thoroughly consider impacts on water availability (quantity) as well as quality. Importantly, this should consider anticipated changes to the hydrological flows in the catchment.	●●●							●●●		See Section 9.3.6 for further details on the improved use of water policy for land service protection
S8. Ensure the appropriate implementation of the SEA Directive (see below) to ensure its use as a tool to assess the environmental impacts of plans and programmes and help determine the most environmentally friendly approach to support spatial	●●	●			●	●●	●●	●●	●●	See Section 9.3.10 for further details on improvements considered of importance in the field of landuse planning and the SEA Directive

Policy / recommendation	**Impact on pressures**					**Impact on services**				**Comments**
	SS	**FR**	**I**	**M**	**PG**	**Food**	**Bd**	**Wat**	**SOM**	
planning.										
Agriculture										
AF1. Refocus the CAP to provide a stronger and more consistent emphasis throughout the policy framework on delivering environmental services which the market does not provide.		●●	●●●	●●●	●●●	●?	●●●	●●●	●●●	Reduces all pressures except soil sealing, by countering drivers of market forces and current CAP policies
AF2. The environmental regulatory baseline at EU-level should be strengthened to protect soil functionality, particularly by adopting the Soil Framework Directive.		●	●●●	●●	●●●	●●	●	●●	●●●	Potential to improve compliance with measures to protect soil functionality (see also S1).
AF3. At Member State level review and if necessary improve the definition and implementation of national or regional regulations (and also the controls and sanctions applied) to ensure that these provide a baseline level of protection for specific land services.		●●	●●●	●●●	●●●	?	●●	●	●	Protect HNV grasslands and water resources from intensification and reduce losses of soil organic matter
AF4. While SMR cross-compliance remains a policy instrument within the CAP it should be updated to include new farm-level requirements in EU legislation relevant to land services.		●	●●●	●●●	●●●	●	●	●	●	
AF5. While GAEC cross-compliance remains a policy instrument within the CAP, the current GAEC framework should be maintained and further guidance should be provided for Member States on defining and implementing verifiable GAEC standards appropriate for different regions/farming systems in their area		●	●●●	●●●	●●●	●	●	●	●	Protects productive capacity of land from abandonment, and provides reference level of protection from intensification for habitats, species, water and soil. Leverage at farm level limited by scale of CAP payments relative to other income.
AF6. Member States should provide better safeguards for species rich grasslands important for biodiversity by reviewing and if necessary amending the design and implementation of: the national transposition of the Habitats Directive; national or regional nature conservation legislation; and relevant cross-compliance standards on protection of permanent pasture. The aim of these amendments should be to		●●	●●●	●●●	●●●	?	●●	●●	●●	Uses GAEC to address location specific pressures from intensification and marginalisation, and to support existing ‘hot-spots’ of land service provision

Policy / recommendation	**Impact on pressures**					**Impact on services**				**Comments**
	SS	**FR**	**I**	**M**	**PG**	**Food**	**Bd**	**Wat**	**SOM**	
prevent agricultural intensification of species-rich grasslands or their conversion to arable or other uses.										
AF7. Keep under close review the use and potential benefits of the new, optional GAEC standard for establishment and/or retention of habitats, particularly on intensive arable farms. Investigate the potential consequences and effects of requiring a proportion of the farmed area to be allocated as Environmental Priority Areas (EPAs) under cross-compliance.		●●●	●●●	●	●●	○	●●	●	●	If adopted counters the pressures of intensification and improves the delivery of land services across existing intensively managed farmland
AF8. Give higher priority across both Pillars of the CAP to using existing measures in a more integrated and effective way to ensure that existing HNV and traditional farming systems are able to counter the pressures of marginalisation, intensification and conversion to other land uses, and continue to provide high quality land services, especially biodiversity. Provide guidance for Member States on the design and implementation of HNV-specific integrated packages of existing CAP support measures.		●●	●●●	●●●	●●●	●	●●●	●●●	●●	Counters pressures of marginalisation, restructuring, conversion and intensification of HNV farmland, improves long term capacity to provide important land services, especially biodiversity at landscape scale Uses GAEC to address location specific pressures from intensification and marginalisation, and to support existing 'hot-spots' of land service provision
AF9. Use CAP measures for intensive arable, dairy or beef farming systems to secure a basic level of provision of land services for biodiversity, water and soil and to incentivise enhanced provision.		●●	●●●	●	●●	v	●●	●●	●●	Goes beyond reference level to reverse negative impacts of previous intensification on biodiversity, soil and water, and to limit impacts of future intensification. Leverage increased by use of targeted payments. v for food capacity because some land will be converted to woodland etc, other will have improved soils
AF10. The provision of advisory services should be tailored to the needs of different farming systems and the specific land services these systems provide.		●●	●●●	●●●	●●●	●	●	●	●	Important element of securing effective implementation by different farming systems of measures to improve provision of land services, and adoption of sustainable food production techniques.
AF11. The geographical targeting of policy measures should be improved.		●●	●●●	●●●	●●●	?	●●	●●	●	Essential to address intensification/ marginalisation/fragmentation pressures at the appropriate scale to provide land services, especially for water and biodiversity (e.g. link targeting to D5).
AF12. Landscape scale approaches to delivery need to be further encouraged and supported		●●	●●●	●	●●	v	●●	●●	●●	

Policy / recommendation	**Impact on pressures**					**Impact on services**				**Comments**
	SS	**FR**	**I**	**M**	**PG**	**Food**	**Bd**	**Wat**	**SOM**	
AF13. Strong and practical criteria should be developed by the Commission and by Member States to protect permanent grasslands that are of high value for biodiversity in the EU from the direct and indirect threats arising from biofuel production		●●	●●●	●●●	●●●	●	●●●	●●	●●	Application of sustainability criteria in Renewable Energy Directive to protect permanent grasslands important for biodiversity
AF14. Investment is needed for the collation of the necessary data at the most appropriate spatial scale, to provide evidence for assessing the impacts of policies on land services.		●	●●	●●	●●	●	●	●	●	
AF15. Common monitoring and evaluation programmes need to be developed, adapted and implemented to assess the pressures on land services and the impact of CAP policies on their provision with the aim of providing an evidence base for future policy decisions.		●●	●●●	●●●	●●●	?	●●	●●●	●	Essential element of effective and efficient policy delivery
Water										
Wa1. Ensure that during the implementation of the Water Framework Directive (see below), river basin management plans thoroughly consider impacts on water availability (quantity) as well as quality.	●		●●			○	●	●●	●	
Wa2. Provide policy guidance that encourages Member States to ensures that relevant biodiversity objectives are considered alongside Water Framework Directive and Flood Directive objectives in river basin management plans and flood risk management plans.			●		●		●●	●	●	
Wa3. Ensure that agri-environment schemes (see above) and habitat restoration initiatives maximise synergies between biodiversity, flood management and ecological status objectives at local and catchments scale.			●●	●●	●●		●●	●●	●●	

Policy / recommendation	Impact on pressures					Impact on services				Comments
	SS	FR	I	M	PG	Food	Bd	Wat	SOM	
Development and land use planning, assessment and control										
D1. Include an explicit target of no-net biodiversity loss from projects and programmes in a revised EU BAP.	●	●●			●	●	●●●	●	●	
D2. Establish a habitat banking policy framework to support and regulate a habitat banking market involving developers who would purchase credits that would then be used by landowners or land managers to enhance or create land areas for biodiversity and ecosystem service gains.		●●		●	●		●●●	●	●	
D3. Ensure the appropriate implementation of the SEA and EIA Directives to improve their use as tools to assess the environmental impacts of plans, programmes and projects and help determine the most environmentally friendly approach to support spatial planning.	●●	●					●●	●●	●●	
D4. Improve the assessment of fragmentation impacts, and cumulative impacts on biodiversity in SEA and EIAs.		●●●					●●	●		E.g. through the implementation of recommendations from the DG Environment project on strategic planning and the Natura network.
D5. Encourage and guide Member States to develop holistic visions of land use and policy instruments that support the strategic provision of land service requirements.	●	●	●●	●●	●●	○	●●	●●●	●●●	E.g. with respect to afforestation, biomass crops, agricultural systems, soil/peat protection and water/flood management. Link also to AF11 and AF12.

11 REFERENCES

Adriaensen, F., Chardon, J. P., De Blust, G., Swinnen, E., Villalba, S. Gulinck, H. and Matthysen, E. (2003) The application of ‘least-cost’ modelling as a functional landscape model. *Landscape and urban planning*, 64, pp 233-247.

AEA (2007) Adaptation to Climate Change in the Agricultural Sector. Report to the European Commission Directorate-General for Agriculture and Rural Development.

Aebischer, N. J. (1991) Twenty years of monitoring invertebrates and weeds in cereal fields in Sussex, in Fairbank, L.G., Carter, N., Derbyshire, J. F. and Potts., G. R. (eds.) *The ecology of temperate cereal fields*. Blackwell Scientific Publications, Oxford.

Agra Europe (2007) *CAP Monitor*. Agra Informa Ltd.

AHEWG (2009) Towards a strategy on climate change, ecosystem services and biodiversity. A discussion paper prepared by the EU Ad Hoc Expert Working Group on Biodiversity and Climate Change. European Commission, Brussels.

Alcamo, J., Leemans, R., and E. Kreileman (eds.) (1998) Global change scenarios of the 21st century. Results from the IMAGE 2.1 model. Elsevier Science, London.

Alcamo, J., Moreno, J.M., Nováky, B., Bindi, M., Corobov, R., Devoy, R.J.N., Giannakopoulos, C., Martin, E., Olesen, J.E., Shvidenko, A. (2007) Europe, in Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds.) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, pp541-580, Cambridge University Press, Cambridge, UK.

Alkemade, R, Bakkenes, M, Bobbink, R, Miles, L, Nellemann, C, Simons, H and Tekelenburg, T. (2006) GLOBIO 3: Framework for the assessment of global terrestrial biodiversity. In: MNP, *I*ntegrated modeling of global environmental change. An overview of IMAGE 2.4. Netherlands Environmental Assessment Agency (MNP), Bilthoven, The Netherlands, page 171-186.

Alkemade, R, van Oorschot, M, Miles, L, Nellemann, C, Bakkenes, M and ten Brink, B. (2009) GLOBIO3: A framework to investigate options for reducing global terrestrial biodiversity loss. *Ecosystems,* 12, pp374-390.

Alliance Environnement (2007) Evaluation of the application of cross compliance as foreseen under regulation 1782/2003: http://ec.europa.eu/agriculture/eval/reports/cross_compliance/index_en.htm

Alliance Environnement (2007) Evaluation of the application of cross compliance as foreseen under Regulation 1782/2003, Report for DG Agriculture.

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D.I., Nieuwenhuizen, W., van Eupen, M., Hennekens, S. and Zervas, G. (2003) Developing a High Nature Value Indicator. Report for the European Environment Agency, Copenhagen, accessed through http://eea.eionet.europa.eu/Public/irc/envirowindows/hnv/library.

Anderson, A.B. and Jenkins, C.N. (2006) Applying nature’s design: corridors as a strategy for biodiversity conservation. Columbia University Press. New York.

Anderson, B.J., Armsworth, P.R., Eigenbrod, F., Thomas, C.D., Gillings, S., Heinemeyer, A., Roy, D.B., and Gaston, K.J. (2009) Spatial covariance between biodiversity and other ecosystem service priorities. *Journal of Applied Ecology*, 46, pp888-896.

Andrén, H. (1999) Habitat fragmentation, the random sample hypothesis and critical thresholds, *Oikos*, 84, pp306-308.

Anon. (2003) Agricultural practice and bats: a review of current research literature and management recommendations. Project No. BD2005. Report to Defra, London.

Anon. (2005) Land abandonment, biodiversity and the CAP, in Land abandonment and biodiversity, in relation to the 1st and 2nd pillars of the EU's Common Agricultural Policy; outcome of an international seminar in Sigulda, Latvia, 7-8 October, 2004. DLG Service for Land and Water Management, Utrecht.

Anon. (2006) Tools for Managing manure nutrients. www.organic.aber.ac.uk/library/tools%20managing%20manure%20nutrients.pdf

Arets, E., C. Verwer, R. Alkemade, M. Araújo, M. Bakkenes, R. Heikkinen, F. Skov and J.C. Svenning (in prep.) Potential effects of projected climate change on species diversity in Europe. Alterra, working paper.

Arets, E.J.M.M., Verwer, C., Alkemade, J.R.M., Araújo, M.B., Bakkenes, M., Heikkinen, R.K., Skov, F., and Svenning, J.C. (in prep.) Potential effects of projected climate change on species diversity in Europe.

Atkinson, P.W., Fuller, R.J., and Vickery, J. (2002) Large-scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales. *Ecography*, 25, pp466–480.

Atkinson, P.W., Fuller, R.J., Vickery, J.A., Conway, G.J., Tallowin, J.R., Smith, R.E.N., Haysom, K.A., Ings, T.C., Asteraki, E.J., Brown, V.K. (2005) Influence of agricultural management, sward structure and food resources on grassland field use by birds in lowland England, *Journal of Applied Ecology*, 42, pp932–942.

Ausden, M., Sutherland, W.J., James, R. (2001) The effects of flooding lowland wetland grassland on soil macroinvertebrate prey of breeding waders, *Journal of Applied Ecology*, 38, pp320–338.

Bak, A. and Reijnen, R. (1997) De verbindingszones binnen de EHS (Ecological corridors within the National Ecological Network), Landschap, 14 , 33–46.

Baldock, D., Beaufoy, G., Bennett, G., and Clark, J.A. (1993) Nature conservation and new directions in the Common Agricultural Policy, Institute for European Environmental Policy, London.

Baldock, D., Beaufoy, G., Brouwer, F. and Godeschalk, F. (1996) Farming at the margins: Abandonment or redeployment of agricultural land in Europe. Institute for European Environmental Policy (IEEP)/Agricultural Economics Research Institute (LEI-DLO), London/The Hague.

Baldock, D., Carveli, H., Dwyer, J., Einschütz, S., Petersent, J-E., Sumpsi-Vinas, J. and Varela-Ortega, C. (2000) Environmental impacts of irrigation in the European Union. The Institute for European Environmental Policy, London.

Balmford, A., Rodrigues, A., Walpole, M., ten Brink, P., Kettunen, M., Braat, L., and de Groot, R. (2008) Review on the economics of biodiversity loss: scoping the science. Cambridge, UK: European Commission (contract: ENV/070307/2007/486089/ETU/B2).

Banse M, Meijl Hv, Tabeau A, Woltjer G. 2008. Will EU Biofuel Policies affect Global Agricultural Markets? *European Review of Agricultural Economics*, 35, pp117-141.

Banse, M., Nowicky, P., Van Meijl, H. (2008) Waarom zijn de huidige wereldvoedselprijzen zo hoog? Rapport 2008 043, LEI Wageningen UR, 33 pp.

Bartholomé, E. and Belward, A.S. (2005) GLC2000: a new approach to global land cover mapping from Earth observation data. *International Journal of Remote Sensing*, 26 (9), pp1959-1977.

Baruth, B., Genovese, G. and Montanarella, L. (eds.) (2006) SINFO, New soil information for CGMS (Crop Growth Monitoring System), new and extended version of the soil data from the Soil Geographical Data Base of Europe (SGDBE) version 3.1, developed for use in the MARS Crop Yield Forecast Sing System", European Community- DG Joint Research Centre, July 2007.

Baur, B., Cremene, C., Groza, G., Rakosy, L., Schileynko, A., Baur, A., Stoll, P., Erhard, A. (2006) Effects of abandonment of subalpine hay meadows on plant and invertebrate diversity in Transylvania, Romania, *Biological Conservation*, 132, pp261–273.

Beaufoy, G., Baldock, D. and Clark, J. (1994) The Nature of Farming: Low Intensity Farming Systems in Nine European Countries. IEEP, London.

Beaufoy G. (1998) The EUNIS Habitats Directive in Spain: can it contribute effectively to the conservation of extensive agro-ecosystems? *Journal of Applied Ecology* 35, pp974–978.

Beaufoy, G. (2007) HNV farming – explaining the concept and interpreting EU and national policy commitments. European Forum on Nature Conservation and Pastoralism. www.efncp.org

Beaufoy, G. and Cooper, T. (2008) Guidance Document - The Application of the High Nature Value Impact Indicator. Report for The European Evaluation Network for Rural Development.

Beier, P. and Noss, R.F. (1998) Do habitat corridors provide connectivity? *Conservation Biology*, 12 , pp1241–1252.

Bender, D.J. and Fahrig, L. (2005) Matrix structure obscures the relationship between interpatch movement and patch size and isolation, *Ecology*, 86, pp1023-1033.

Bengtsson, J., Ahnström, J. and Weibull, A.C. (2005) The effects of organic agriculture on biodiversity and abundance: a meta-analysis, *Journal of Applied Ecology*, 42, pp261–269.

Bennett, A.F. (2003) Linkages in the landscape: The role of corridors and connectivity in wildlife conservation. Gland, Switzerland: World Conservation Union (IUCN).

Bennett, A.F. (2009) Interaction between policy concerning spatial planning and ecological networks in Europe: Overview Report. ECNC, Tilburg, the Netherlands.

Bennett, G. and Mulongoy, K.J. (2006) Review of experience with ecological networks, corridors and buffer zones. CBD Technical Series no. 23, Montreal: Secretariat of the Convention on Biological Diversity.

Bennett, G. and Wit, P. (2001) The development and application of ecological networks: a review of proposals, plans and programmes. IUCN and AID Environment. Amsterdam.

Berry, P.M., Paterson, J., Cabeza, M., Dubuis, A., Guisan, A., Jäättelä, L., Kühn, I., Midgley, G., Musche, M., E., W., and Piper, J. (2008) Meta-analysis of adaptation and mitigation measures across the EU25 and their impacts and recommendations how negative impacts can be avoided. Minimisation of and Adaptation to Climate change Impacts on biodiverSity (MACIS).

Beyer, C., Altfelder, S., Duijnisveld, W.H.M., Streck, Th. (2009) Modelling spatial variability and uncertainty of cadmium leaching to groundwater in an urban region. *Journal of Hydrology*, 369, pp274–283.

Bignal, E.M. and McCracken, D.I. (1996) Low-intensity farming systems in the conservation of the countryside, *Journal of Applied Ecology*, 33, pp413 - 424.

Bignal, E.M. and McCracken, D.I. (2000) The Nature Conservation Value of European Traditional Farming Systems. *Environmental Reviews*, 8, pp149-171.

Billeter, R., Liira, J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R., Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekotter, T., Dietz, H., Dirksen, J., Dormann, C., Durka, W., Frenzel, M., Hamersky, R., Hendrickx, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D., Maelfait, J. P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O., Smulders, M. J. M., Speelmans, M., Simova, P., Verboom, J., van Wingerden, W. K. R. E., and Zobel, M. (2007) Indicators for biodiversity in agricultural landscapes: a pan-European study. *Journal of Applied Ecology*, 45, pp141-150.

BirdLife International (2004) Birds in the European Union: a status assessment. BirdLife International, Wageningen, The Netherlands.

BirdLife International (2009) Food security, climate change and biodiversity, the role of European agriculture in a changing world, Birdlife International: Brussels.

BirdLife, EEB, EFNCP, IFOAM, WWF (2009), Proposal for a new EU Common Agricultural Policy, December 2009.

Bloemmen, M. and van der Sluis, T. (eds) (2005) European corridors - example studies for the Pan-European Ecological Network; 102 pp. Alterra report 1087.

Boccaccio, L., Brunner, A., and Powell, A. (2009) Could do better. How is EU Rural Development policy delivering for biodiversity? BirdLife International, Sandy, UK.

Bolck, C., Van Diepen, C., Koning, N., Loffler, H. and Sanders, J. (2008) Hoeveel biomassa voor voedsel en non-food kan de wereld technisch gezien produceren? Position paper. Wageningen UR.

Bonnin, M., Bruszik, A., Delbaere, B., Lethier, H., Richard, D., Rientjes, S., van Uden, G. and Terry, A. (2007) The Pan-European ecological network: taking stock. Nature and Environment No. 146. Council of Europe Publishing, Strasbourg.

Bossard, M., Feranec, J. and Otahel, J. (2000) CORINE land cover technical giude – Addendum 2000. Technical report 40. European Environment Agency, Copenhagen. http://terrestrial.eionet.eea.int

Bouma, J., (2009) Soils are back on the global agenda: Now what? *Geoderma*, 150, pp224-225.

Braat L and P ten Brink (eds.) (2008) The cost of policy inaction. The case of not halting biodiversity loss. Report to the European Commission. Alterra report 1718. Wageningen.

Braat, L. C. (1979) Functions of the natural environment. Institute for Environmental Studies, Free University, Amsterdam.

Briggs, B., Hill, D.A. and Gillespie, R. (2009) Habitat Banking – how it could work in the UK, *Journal of Nature Conservation*, 17, pp114-124.

Broekmeyer, M. and Steingröver, E., eds (2001) Handboek Robuuste Verbindingen (Handbook for ecological corridors), Alterra, Wageningen.

Brouwer, F. and Hellegers, P. (1996) The Nitrate Directive And Farming Practice In The European Union. European Environment Volume 6 Issue 6.

Brouwer, F.; Baldock, D.; Godeschalk, F., Beaufoy, G. (1997) – Marginalisation of Agricultural Land in Europe – LSIRD NAPLIO Conference Papers

Brown, A., Hall, R., and Townshend, D., (eds.) (2001) State of Nature. The upland challenge. English Nature, Peterborough.

Bruinenberg M.H., Valk H., Korevaar H. and Struik P.C. (2002) Factors affecting digestibility of temperate forages from seminatural grasslands: a review. *Grass and Forage Science*, 57, pp292-301.

Bunce, R.G.H., Groom, G.B., Jongman R.H.G. and Padoa Schioppa, E. (eds) (2005) Handbook for Surveillance and Monitoring of European Habitats. Alterra Report 1219, EU FP project EVK CT-2002-20018, pp107.

Bunce, R.H.G., Metzger, M.J., Jongman, R.H.G., Brandt, J., de Blust, G., Elena Rossello, R., Groom, G. B., Halada, L., Hofer, G., Howard, D.C., Kovář, P., Mücher, C. A., Padoa-Schioppa, E., Paelinx, D., Palo, A., Perez-Soba, M., Ramos, I. L., Roche, P., Skånes, H. and Wrbka, T. (2008) A standardized procedure for surveillance and monitoring European habitats and provision of spatial data. *Landscape Ecology*, 23, pp11-25.

Bunn, A.G., Urban, D.L. and Keitt, T.H. (2000) Landscape connectivity: a conservation application using of graph theory. *Journal of Environmental Management*, 59, pp265-278.

Bureau, J.C. and Mahé, L.P. (2008) CAP Reform Beyond 2013: An Idea for a Longer View, Notre Europe, Paris

Burghardt, W., Banko, G., Hoeke, S., Hursthouse, A., de L'Escaille, Th., Ledin, St., Marsan, F.A., Sauer, D., Stahr, K., Amann, E., Quast, J., Nerger, M., Schneider, J. and Kuehn, K. (2004) Sealing soils, soils in urban areas, land use and land use planning. Report of Task Group 5, Vol. VI. Research, sealing and cross-cutting issues, in Van-Camp. L., Bujarrabal, B., Gentile, A-R., Jones, R.J.A., Montanarella, L., Olazabal, C. and Selvaradjou, S-K. (eds.) *Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection*. EUR 21319 EN/6, pp872. Office for Official Publications of the European Communities, Luxembourg.

Busch, G. (2006) Future European agricultural landscapes—What can we learn from existing quantitative land use scenario studies? *Agriculture Ecosystems and Environment*, 114, pp121-140.

Butler, S.J., Vickery, J.A., & Norris, K. (2007) Farmland biodiversity and the footprint of agricultural change. *Science*, 315, pp381-384.

Büttner, G. and Maucha, G. (2006) The thematic accuracy of Corine Land Cover 2000. Assessment using LUCAS (land use/cover frame statistical survey) EEA Report 7. Copenhagen, European Environment Agency. ISSN 1725-2237.

Büttner, G., Feranec, J., Jaffrain, G., Mari, L., Maucha, G. and Soukup, T. (2004) The CORINE Land Cover 2000 Project. in R. Reuter, (ed.) EARSeL eProceedings, 3(3). pp. 331-346. EARSeL, Paris.

Büttner, G., Soukup, T. and Sousa, A. (2007) CLC2006 technical guidelines. EEA report 17. 2007. Copenhagen, European Environment Agency. ISSN 1725-2237.

Calladine, J., Baines, D. and Warren, P. (2002) Effects of reduced grazing on population density and breeding success of black grouse in northern England, *Journal of Applied Ecology*, 39, pp772–780.

Carroll, C. (2006) Linking connectivity to viability, in R. K. Crooks and M. Sanjayan, (eds.) *Connectivity conservation*, pp369-389. Cambridge University Press, Cambridge.

Catchpole, R. (2006) Planning for biodiversity. English Nature, Peterborough.

CBD AHTEG (2009) Draft findings of the Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Convention on Biological Diversity, Montreal.

CEC (2008) Food Prices in Europe*,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2008) 821, 9.12.2008.

Chambers and Ball (2007) Biodiversity requires adaptation in northwest Europe under a changing climate – BRANCH. *APaNGO Newsletter*. 3 March 2007.

Christensen, J.H. and Christensen, O.B. (2007) A summary of PRUDENCE model projections of changes in European climate by the end of this century, *Climatic Change*, 81, pp7-30.

Ciscar, J.C., Iglesias, A., Feyen, L., Goodess, C.M., Szabó, L., Christensen, O.B., Nicholls, R., Amelung, B., Watkiss, P., Bosello, F., Dankers, R., Garrote, L., Hunt, A., Horrocks, L., Moneo, M., Moreno, A., Pye, S., Quiroga, S., van Regemorter, D., Richards, J., Roson, R. and Soria, A. (2009) Climate change impacts in Europe. Final report of the PESETA research project. http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2879

Collin, M.L. and Melloul, A.J. (2003) Assessing groundwater vulnerability to pollution to promote sustainable urban and rural development, *Journal of Clean Products*, 11(7), pp727–36.

COM (2005) Note to the Scientific Working Group: Conclusions of workshop 'Ecological networks and coherence according to article 10 of the Habitats Directive', Vilm, Germany, May 2005.

COM(2002)179 final. Towards a Thematic Strategy for Soil Protection – Communication of the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions (16-04-2002). EEA, 1999

Conservation International (2000) Designing sustainable landscapes: the Brazilian Atlantic Forest. Washington, D.C.: Center for Applied Biodiversity Science, Conservation International.

Cooper, T. and Arblaster, K. (2007) Climate change and the rural environment in a European context: implications for land use and land use policy. A background paper for the LUPG and BfN conference “Future Policies for Rural Europe 2013 and Beyond – Delivering Sustainable Rural Land Management in a Changing Europe” Held on the 19th – 20th September 2007 in Brussels.

Cooper, T., Hart, K. and Baldock, D. (2010) The Provision of Public Goods Through Agriculture in the European Union, Report Prepared for DG Agriculture and Rural Development, Contract No 30-CE-0233091/00-28, Institute for European Environmental Policy: London.

Council of Europe (2000) General guidelines for the development of the Pan-European Ecological Network. Nature and Environment, No. 107, Council of Europe Publishing.

Crooks, R.K., and Sanjayan, M. (2006) Connectivity conservation: maintaining connections for nature. in Crooks, R.K., and Sanjayan, M. (eds.) *Connectivity conservation*, pp 1-19, Cambridge University Press, Cambridge.

Davies, Z.G. and Pullin, A.S. (2007) Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. *Landscape Ecology*, 22, pp333-351.

Dawson, D. (1994) Are habitat corridors conduits for animals and plants in a fragmented landscape? A review of the scientific evidence. English Nature, Peterborough.

Dawson, J.J.C. and Smith, P. (2007) Carbon losses from soil and its consequences for land-use management, *Science of the Total Environment*, 382, pp165-190.

De Chazal, J. and Rousevell, M.D.A. (2009) Land-use and climate change within assessments of biodiversity change: a review. *Global Environmental Change* 19: 306-315.

de Groot, R. (1992) Functions of nature: evaluation of nature in environmental planning, management and decision making. Wolters-Noordhof BV, Groningen, The Netherlands.

De Roo, A.J.P., Barredo, J., Lavalle, C., Bodis, K. and Bonk, R. (2007) Potential Flood Hazard and Risk Mapping at Pan-European Scale, in Peckham, R.J. and Jordan, G. (eds) *D*igital Terrain Modelling Development and Applications in a Policy Support Environment, pp183-202.

DG Agriculture (2008) Rural development in the European Union - statistical and economic information report 2008

DG Agriculture (2009) Prospects for agricultural markets and income in the European Union 2008-2015, March 2009.

Di Gregorio, A. (2005) Land Cover Classification System (LCCS): classification concepts and user manual. FAO, Rome.

Dilly, O. and Hüttl, R.F. 2009. Top-down and Europe-wide versus bottom-up and intra-regional identification of key issues for sustainability impact assessment. Env. Science and Policy 12 (2009): 116801176.

Donald, P. F. (1998) Changes in the abundance of invertebrates and plants on British farmland. *British Wildlife,* 9, pp279-289.

Donald, P. F. (2005) Climate change and habitat connectivity; assessing the need for landscape-scale adaptation for birds in the UK. RSPB, Sandy.

Donald, P. F. and A. D. Evans. (2006) Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. *Journal of Applied Ecology*, 43, pp209-218.

Donald, P. F., Green, R.E., and Heath, M.F. (2001) Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London Series B, 268, pp25-29.

Donald, P. F., Sanderson, F. J., Burfield, I. J., S. M. B., Gregory, R. D. and Waliczky, Z. (2007) International conservation policy delivers benefits for birds in Europe, *Science*, 317: pp810-813.

Dunnet, N., and Clayden, A. 2007. Rain gardens: managing water sustainably in the garden and designed landscape. Timber Press, 188 pp, Lecture Notes in Geoinformation and Cartography, Springer Berlin Heidelberg.

Dutch Soil Platform (2008) De bodem als partner in duurzame ontwikkeling: een onderzoeksagenda voor de toekomst. Ministeries van LNV, VandW, VROM/Wageningen UR/RIVM/Deltares, 33 pp.

Duverge, P.L., Jones, G. (2003) Use of farmland habitats by greater horseshoe bats, in Tattersall, F. and Manley, W. (eds.), Conservation and Conflict. Mammals and Farming in Britain. Linnean Society Occasional Publications 4. Westbury Publishing, Otley, UK, pp. 64–81.

ECA (2003) Special Report No 4/2003 Concerning Rural Development: Support For Less-Favoured Areas. European Court of Auditors. Luxembourg.

EEA (1995) Europe's Environment: The Dobris Assessment. Stanners D. and Bourdeau. P. (Eds.) European Environment Agency, Copenhagen.

EEA (2001) Proceedings of the Technical Workshop on Indicators for Soil Sealing. Copenhagen, 26-27 March 2001.

EEA (2004a) High Nature Value farmland. Characteristics, trends and policy challenges. European Environment Agency, Copenhagen, Denmark.

EEA (2004b) Impacts of Europe's changing climate. European Environment Agency, Copenhagen, Denmark.

EEA. (2005a) Agriculture and environment in EU-15 - the IRENA indicator report. European Environment Agency, Copenhagen, Denmark.

EEA (2005b) 3.1. Environmental accounting. Methodological guidebook. Data processing of land cover flows. 23 pp.

EEA (2005c) IRENA indicator fact sheet. IRENA 13 – Cropping/Livestock Patterns. European Environment Agency, Copenhagen.

EEA (2005d) Vulnerability and adaptation to climate change in Europe. European Environment Agency, Copenhagen, Denmark.

EEA (2006) Integration of environment into EU agriculture policy - the IRENA indicator-based assessment report. EEA Report No 2/2006, ISBN 92-9167-775-2, ISSN 1725-9177, Office for Official Publications of the European Communities. Luxembourg.

EEA (2006) Urban Sprawl in Europe. The Ignored Challenge, EEA Report No. 10/2006, København, EU.

EEA (2007) Europe's environment—The fourth assessment. European Environment Agency, Copenhagen, Denmark.

EEA (2009) Ensuring quality of life in Europe's cities and towns Tackling the environmental challenges driven by European and global change. EEA Report No 5/2009. European Environment Agency, 108pp.

EFMA (2009) Forecast of food, farming and fertilizer use in the EU 2008-18. European Fertilizer Manufacturers Association

Eftec and IEEP (2009) The use of market-based instruments for biodiversity protection – the case of habitat banking. Report submitted to the European Commission, Directorate-General Environment.

EEA, DG JRC (2002) Towards an urban atlas: assessment of spatial data on 25 European cities and urban areas. Environmental Issue Report No. 30. European Environment Agency and European Commission and DG Joint Research Centre. Office for Official Publications of the European Communities, Luxembourg. ISBN 92-9167-470-2. 131 pp.

Eickhout B, van Meijl, H, Tabeau, A, van Rheenen, T. (2007) Economic and ecological consequences of four European land use scenarios. *Land Use Policy*, 24, pp562-575.

Eickhout, B. and A. G. Prins (2008) Eururalis 2.0. Technical background and indicator documentation. Bilthoven. The Netherlands, Wageningen University and Research and Netherlands Environmental Assessment Agency (MNP).

Emanuelsson U. (2008) Semi-natural grasslands in Europe today. *Grassland Science in Europe*, 13, pp3-8.

Emmerling C. and Udelhoven T. (2002) Discriminating factors of spatial variability of soil quality parameters at landscape scale, Journal of Plant Nutrition and Soil Science, 165(6), pp706–22.

Etienne, M., Le Page, C. and Cohen, M. (2003) A Step-by-step Approach to Building Land Management Scenarios Based on Multiple Viewpoints on Multi-agent System Simulations *Ecology and Society*, 6, http://jasss.soc.surrey.ac.uk/6/2/2.html

EU Ruralis (2008) The future of rural Europe. Project documentation and results. Alterra, 2008.

Europa Press Releases Rapid (http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/609andformat=HTMLandaged=0andlanguage=ENandguiLanguage=en, accessed 2 June 2009).

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

European Commission (2006a) Communication from the Commission to the Council, the European parliament, the European Economic and Social Committee and the Committee of the Regions. Thematic Strategy for Soil Protection COM(2006)231 final.

European Commission (2006b) Halting the Loss of Biodiversity by 2010 – and Beyond: Sustaining ecosystem services for human well–being (COM (2006) 216 final) http://eur-lex.europa.eu/LexUriServ/site/en/com/2006/com2006_0216en01.pdf

European Commission (2006c) SCENAR 2020 Scenario study on agriculture and the rural world. http://ec.europa.eu/agriculture/publi/reports/scenar2020/index_en.htm

European Commission (2007) Fact sheet. Climate Change: the challenges for agriculture. http://ec.europa.eu/agriculture/publi/fact/climate_change/2008_en.pdf

European Commission (2009) Composite report on the conservation status of habitat types and species as required under Article 17 of the Habitats Directive. COM(2009) 358 final. Commission of the European Communities, Brussels.

European Council (2006) Community Strategic Guideline for Rural Development (programming period 2007 to 2013), Council Decision of 20 February 2006 (2006/144/EC)

Ewers, R.M. and Didham, R.K. (2006) Confounding factors in the detection of species responses to habitat fragmentation, *Biological Reviews,* 81, pp117-142.

Ewert, F., Rounsevell, M.D.A., Reginster, I., Metzger, M.J., and Leemans, R. (2005) Future scenarios of European agricultural land use I. Estimating changes in crop productivity. *Agr. Ecosyst. Environ.,* 107, 101-116.

Fahrig, L. (2003) Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution and Systematics*, 34, pp487-515.

Fahrig, L. and Rytwinski, T. (2009) Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and Society,* 14(1), 21.

Falcucci, A., Maiorano, L. and Boitani, L. (2007) Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation, *Landscape Ecology*, 22, pp617-631.

Falcy, M.R. and Estades, C.F. (2007) Effectiveness of corridors relative to enlargement of habitat patches. Conservation Biology, 21, pp1341–1346.

FAO (2006) World agriculture: towards 2030/2050. Global Perspective Studies Unit Food and Agriculture Organization of the United Nations, Rome, June 2006. 78 pp.

Farina, A. (1998) Principles and methods in landscape ecology. Chapman and Hall, London.

Farmer, M., Cooper, T., Baldock, D., Tucker, G., Eaton, R., Hart, K., Bartley, J., Rayment, M., Arblaster, K., Beaufoy, G., Pointereau, P., Coulon, F., Herodes, M., Kristensen, L., Andersen, E., Landgrebe, R., Naumann, S., Povellato, A., Trisorio, A., Jongman, R., and Bunce, B. (2008) Final Report - Reflecting environmental land use needs into EU policy: preserving and enhancing the environmental benefits of unfarmed features on EU Farmland. Contract No. ENV.B.1/ETU/2007/0033, report for DG Environment. Institute for European Environmental Policy.

Farmer, M., Cooper, T., Swales, V. and Silcock, P. (2008) Funding for Farmland Biodiversity in the EU: Gaining Evidence for the EU Budget Review A Report for the RSPB, IEEP, London.

FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US gov't). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. Adopted by the USDA Natural Resources Conservation Service as National Engineering Handbook Part 653, Stream Corridor Restoration: Principles, Processes, and Practices (NEH-653).

Feranec, J., Hazeu, G.W., Cebecauer, T. and Jaffrain, G. (2007a) Cartographic aspects of land cover change detection (over- and underestimation in the Iand CORINE Land Cover 2000 Project) *The Cartographic Journal*, Vol.44, No.1, pp44-54.

Feranec, J., Hazeu, G.W., Christensen, S. and Jaffrain G. (2007b) CORINE Land Cover change detection in Europe (Case studies of the Netherlands and Slovakia) *Land Use Policy*, 24, pp234-247.

Feranec J., Jaffrain G., Soukup, T., Hazeu, G. (2009) Changes of the European landscape in 1990-2000 identified by the CORINE land cover data. *Applied Geography*, DOI 10.1016/j.apgeog.2009.07.003.

Ferrer, M., Newton, I., and Bildstein, K. (2008) Climatic change and the conservation of migratory birds in Europe: identifying effects and conservation priorities. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee 28th meeting, Strasbourg, 24-27 November 2008. Council of Europe, Strasbourg.

Fischer, G. (2008) Agricultural Food Production and the Natural Resource Base. Presentation in the Conference Pressures on Prime Agricultural Land, Brussels, 19 November 2008. The Dutch Ministry of Agriculture, Nature and Food Quality and Wageningen UR.

Fischer, G., Shah, M.M., van Velthuizen, H.T., and Nachtergaele, F.O. (2001) Global Agro-ecological Assessment for Agriculture in the 21st Century. IIASA, Laxenburg, Austria.

Freibauer, A., Rounsevell, M.D.A., Smith, P., and Verhagen, J. (2004) Carbon sequestration in European agricultural soils. *Geoderma*, 122, pp 1-23.

Gaskell, P., Ingram, J., Mills, J., Kirwan, J., Short, C., Dwyer, J., Groom, G., Boatman, N., Turley, D. (2007) Environmental Impacts of CAP Reform – Assessment of Implications of Farm Level Change for Environmental Outcomes. Final Report for the Defra Agricultural Change and Environment Observatory programme. Countryside and Community Research Institute and Central Science Laboratory. https://statistics.defra.gov.uk/esg/ace/research/pdf/ccri_implic07.pdf.

Gerard, F., Thompson, A., Manchester, S., Smith, G., Wadsworth, R., Swetnam, S., Petit, S., Gregor, M., Luque, S., Huitu, H., Köhler, R., Olschofsky, K., Hazeu, G., Mücher, C.A., Halada, L., Bugár, G. and Pino, J. (2006) Land Cover Change in Europe from the 1950'ies to 2000. Aerial photo interpretation and derived statistics from 59 samples distributed across Europe. Köhler, R., Olschofsky, K. and Gerard, F. (eds.) University of Hamburg, World Forestry Institute, Germany. ISBN 80- 89088-46-5, 364 pp.

Gergel, S.E. and Turner, M.G. (eds) (2002) Learning landscape ecology: a practical guide to concepts and techniques. Springer-Verlag, New York.

Gill, S., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007) Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33(1), pp115–133.

Gobin, A, Daroussin, J. and Jones, R.J.A. (2003) Input Data. PESERA, European Commission funded fifth framework project - contract QLK5-CT- 1999-01323, Technical Report Deliverable 17, 34pp.

Gregory, R.D., van Strien, A.J., Vorisek, P., Gmelig Meyling, A.W., Noble, D.G., Foppen, R.P.B. and Gibbons,D.W. (2005) *Philosophical Transactions of the Royal Society*, B., 360, pp269-288.

Groot Bruinderink, G., van der Sluis, T., Lammertsma, D., Opdam, P. and Pouwels, R. (2003) Designing a coherent ecological network for large mammals in northwestern Europe. *Conservation Biology,* 17, pp549-557.

Gunreben, M. (2003) Dealing with soil threats in Lower Saxony, Germany , Lower Saxony State Agency for Ecology, Sub-Department for Soil Protection and Old Sites, Hildesheim, Germany. - http://www.forsten.sachsen.de/umwelt/en/14150.htm

Gyulai, I. (2006) The Biomass Dilemma. MTvSz-National Society of Conservationists, Budapest, Hungary.

H2O (2009) Rotterdam is klaar voor extra water. H twee O : tijdschrift voor watervoorziening en afvalwaterbehandeling, 42(8), pp6-7.

Haasse, D. (2009) Effects of urbanisation on the water balance – A long-term trajectory, *Environmental Impact Assessment Review* 29, pp211–219.

Haines-Young, R. and Weber, J.-L. (2006) Land accounts for Europe 1990-2000. Towards integrated land and ecosystem accounting. EEA Report 11. Copenhagen, European Environment Agency. ISSN 1725-9177 or http://www.eea.europa.eu/publications/eea_report_2006_11

Halpin, P.N. (1997) Global climate change and natural-area protection: management responses and research directions. *Ecological Applications*, 7(3), pp828-843.

Hamell, M. (2008) An environmental perspective on pressures on prime agricultural land. Presentation in the conference Pressures on Prime Agricultural Land, organized by the Dutch Ministry of Agriculture, Nature and Food Quality, Alterra and the Agricultural Economics Institute (Wageningen UR), November 19th, Brussels.

Hargreaves, K.J., Milne, R., & Cannell, M.G.R. (2003) Carbon balance of afforested peatland in Scotland. *Forestry*, 76, pp299-317.

Hart, K. and Eaton, R. (2008) Options for using national envelopes in the UK as part of Common Agricultural Policy reform, report to the Land Use Policy Group Institute for European Environmental Policy, London.

Hazeu. G., Mücher, S., Kienast, F. and Zimmerman, N. (2008a) Land cover maps for environmental modelling at multiple spatial scales. ECOCHANGE - Challenges in assessing and forecasting biodiversity and ecosystem. Integrated Project, EU Funded Project FP6 2006 GOCE 036866. Deliverable D01.02.01. 57 pp.

Hazeu, G.W., Mücher, C.A., Kramer, H. and Kienast, F. (2008b) Compilation and assessment of Pan-European land cover changes. 28th EARSeL Symposium "Remote sensing for a changing Europe", 2-5 June 2008, Istanbul, Turkey. Conference proceedings. p. 220-225.

Hector A., Schmid B., Beierkuhnlein C., Caldeira, M. C., *et al* (1999) Plant diversity and productivity experiments in European grasslands. *Science*, 286, pp1123-1127.

Hejazi, M. and Markus, M. (2009) Impacts of Urbanization and Climate Variability on Floods in Northeastern Illinois, *Journal of Hydrologic Engineering*, Vol. 14, No. 6, pp606-616.

Hellmann, F. and Verburg P.H. (2009) Spatially explicit modelling of biofuel crops in Europe. *Biomass and Bioenergy*. doi:10.1016/j.biombioe.2008.09.003.

Hermans, T. and Verhagen, J. (2008) Spatial impacts of climate and market changes on agriculture in Europe. Alterra report 1697/PRI report 188. Wageningen UR, 75 pp.

Hertel, T.W. (ed.) (1997) *Global Trade Analysis: Modelling and Applications*. Cambridge University Press, Cambridge

Heymann, Y., Steenmans, Ch., Croissille, G. and Bossard, M. (1994) CORINE land cover. Technical guide. Luxembourg, Office for Official Publications European Communities.

Hillier, J., Hawes, C., Squire, G., Hilton, A., Wale, S., & Smith, P. (2009) The carbon footprints of food crop production. *International Journal of Agricultural Sustainability*, 7, pp107-118.

Hilty, J. A., Lidicker, W. Z. and Merenlender, A. M. (2006) *Corridor ecology: the science and practice of linking landscapes*. Island Press, New York.

Hobbs, R. J. (1992) The role of corridors in conservation - solution or bandwagon. *Trends in Ecology and Evolution*, 7, pp389-392.

Hobbs, R. J. and Hopkins, A.J.M. (1991) The role of conservation corridors in a changing climate, in Saunders, D. A. and Hobbs, R.J. (eds.) *Nature conservation 2: The role of corridors*. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

Hodgson, J.A., Thomas, C.D. Wintle, B.A. and Moilanen, A. (2009) Climate change, connectivity and conservation decision making: back to basics, Journal of Applied Ecology, 46, pp949-969.

Hofmann, N. (2001) Urban Consumption Of Agricultural Land. Rural and Small Town Canada Analysis Bulletin Catalogue no. 21-006-XIE Vol. 3, No.2.

Holden, N.M. and Brereton, A.J. (2002) An assessment of the potential impact of climate change on grass yield in Ireland over the next 100 years. *Irish Journal of Agricultural and Food Research*, 41, pp213-226.

Holden, J., Shotbolt, L., Bonn, A., Burt, T.P., Chapman, P.J., Dougill, A.J., Fraser, E.D.G., Hubacek, K., Irvine, B., Kirkby, M.J., Reed, M.S., Prell, C., Stagl, S., Stringer, L.C., Turner, A., & Worrall, F. (2007) Environmental change in moorland landscapes. *Earth-Science Reviews*, 82, pp75-100.

Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D. (2005) Does organic farming benefit biodiversity? *Biological Conservation*, 122, pp113–130.

Hopkins, A. (2004) Productivity and nutrient composition of multi-species swards, in Hopkins, A. (ed.) (2004) Organic farming: science and practice for profitable livestock and cropping. BGS Occassional Symposium No 37, pp117-120. The British Grassland Society, University of Reading.

Hopkins A. and Del Prado A. (2007) Implications of climate change for grassland in Europe: impacts, adaptations and mitigation options: a review, *Grass and Forage Science*, 62, pp118-126.

Hopkins, A. (2009) Relevance and functionality of semi-natural grassland in Europe – status quo and future prospective. International Workshop of the SALVERE-Project 2009

Hopkins A. and Lobley M. (2009) A scientific review of the impact of ruminant livestock of UK greenhouse gas emissions. University of Exeter Centre for Rural Policy Research, Research Report 27, 74pp. http://centres.exeter.ac.uk/crpr/publications/working_papers.htm.

House of Commons Environment Food and Rural Affairs (Efra) Committee (2009) Securing food supplies up to 2050: The challenges faced by the UK: Fourth Report of Session 2008-2009, HMSO, London.

Huber, S., Prokop, G., Arrouays, D., Banko, G., Bispo, A., Jones, R.J.A., Kibblewhite, M.G., Lexer, W., Möller, A., Rickson, R.J., Shishkov, T., Stephens, M., Toth, G. Van den Akker, J.J.H., Varallyay, G., Verheijen, F.G.A., Jones, A.R. (eds) (2008) Environmental Assessment of Soil for Monitoring: Volume I Indicators and Criteria. EUR 23490 EN/1, Office for the Official Publications of the European Communities, Luxembourg, 339pp.

Hudec, B., Kaufmann, C., Landgrebe-Trinkunaite, R. and Naumann, S. (2007) Evaluation of soil protection aspects, in Certain Programmes Of Measures Adopted By Member States. Final report. European Commission, Environment Directorate-General, 538 pp.

Humphrey, J., Watts, K., McCracken, D., Shepherd, N., Sing, L., Poulsom, L. and Ray, D. (2005) A review of approaches to developing Lowland Habitat Networks in Scotland. Scottish Natural Heritage Commissioned Report No. 104 (ROAME No. F02AA102/2).

Huntley, B. (2007) Climatic change and the conservation of European biodiversity: Towards the development of adaptation strategies. Convention on the Conservation of European Wildlife and Natural Habitats, Standing Committee 27th meeting, Strasbourg, 26-29 November 2007. Council of Europe, Strasbourg.

Huntley, B., Collingham, Y.C., Green, R.E., Hilton, G.M., Rahbek, C., & Willis, S.G. (2006) Potential impacts of climatic change upon geographical distributions of birds. *Ibis*, 148, pp8-28.

IAASTD (2008) Agriculture at a Cross Roads. International Assessment of Agricultural Knowledge, Science and Technology for Development, Synthesis Report - A Synthesis of the Global and Sub-Global IAASTD Reports. 106 pp.

IEEP, (2007) HNV Indicators for Evaluation. Report for DG Agriculture, Contract Notice 2006 – G4-04. Institute for European Environmental Policy, London.

IEEP, Alterra, Ecologic, PBL and UNEP-WCMC. (2009) Scenarios and models for exploring future trends of biodiversity and ecosystem services changes. Final report to the European Commission, DG Environment on Contract ENV.G.1/ETU/2008/0090r. Institute for European Environmental Policy, Alterra Wageningen UR, Ecologic, Netherlands Environmental Assessment Agency, United Nations Environment Programme World Conservation Monitoring Centre.

Imhoff, M.L., Bounoua, L, DeFries, R., Lawrence, W.T., Stutzer, D., Tucker, C.J. Ricketts, T. (2004) The consequences of urban land transformation on net primary productivity in the United States. *Remote Sensing of Environment*, 89, pp434-443.

International Union for the Conservation of Nature and Natural Resources (IUCN) (1980) World Conservation Strategy . IUCN, Gland.

IPCC (2001a) Climate change 2001: synthesis report. Intergovermental Panel on Climate Change, Geneva.

IPCC (2001b) Climate Change 2001: Working Group II: Impacts, adaptation and vulnerability. IPCC, Geneva.

IPCC (2007) Climate Change 2007: Impacts, adaptation and vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Summary for policymakers. Intergovermental Panel on Climate Change, Geneva.

ITE (1994) The role of corridors, stepping stones and islands for species conservation in a changing climate. English Nature, Peterborough.

IUSS Working Group (2006) World Reference Base for soil resources. World Soil Resources Reports 103. FAO, Rome.

Jones, P.D., Lister, D.H., Jaggard, K.W. and Pidgeon, J.D. (2003) Future climate impact on the productivity of sugar beet (*Beta vulgaris* L.) in Europe. *Climatic Change*, 58, pp93-108.

Jones G (2008) Small farms – major embarrassment or key to policy delivery? La Cañada – Number 22. European Forum for Nature Conservation and Pastoralism

Jones-Walters, L., Snethlage, M., Civic, K., Çil, A., and Smit, I. (2009) Making the connection! Guidelines for involving stakeholders in the implementation of ecological networks. ECNC, Tilburg, the Netherlands.

Jongeneel, R Bezlepkina, I., and Farmer, M. (eds.) (2008) Final Report: Compliance and costs of compliance with standards and their impact on the EUs external competitiveness. CROSS-COMPLIANCE project, EU 6th Framework Programme, Priority 8.1 (European Commission, DG RTD, contract no. SSPE-CT-2005-006489), 97 p.

Jongman, R. and Kristiansen, L. (2001) National and regional approaches for ecological networks in Europe. Council of Europe, Strasbourg.

Jongman, R. H. G. and Kristiansen, I. (2001) *National and regional approaches for ecological networks in Europe.* Council of Europe Publishing, Strasbourg.

Jongman, R. and Pungetti, G. (2004) Ecological networks and Greenways. Concept, Design, Implementation, in Wiens, J., Hobbs, R., Dennis, P., Milne, B., Fahrig, L., Joan, N., Fortin, M.J. and Opdam, P.(eds.) *Cambridge Studies in Landscape Ecology*. Cambridge University Press, Cambridge.

Jongman, R.H.G., Külvik, M. and Kristianen, I. (2005) European ecological networks and greenways, Landscape and Urban Planning 68, pp305–319.

Jongman, R. H. G., Bouwma, I. M. and Doorn, A. M. (2006) Indicative map of the Pan-European Ecological Network in Western Europe. Alterra report 1429, pp103.

Joop, P. (2009) Blauwestad -particulier natuurbeheer in de EHS. Vakblad natuur bos landschap / Stichting Vakblad Natuur Bos Landschap, 53, p.6-9

JRC (2003) European Summer School on Soil Survey, 21-25 July 2003. Presentation on MOLAND (Monitoring Land Use/Land Cover Dynamics) http://moland.jrc.ec.europa.eu/

Kabourakis E. (1999) Code of practices for ecological olive production systems in Crete. *Olivae*, **77**, pp46 - 55. International Olive Oil Council, Madrid.

Kahmen, S., Poschlod, P. (2008) Effects of grassland management on plant functional trait composition, *Agriculture, Ecosystems and Environment*, 128, pp137–145.

Karaczun, Z. (2005) Preparing for EU environmental policy in Poland: the case of the nitrates directive, *Land Use Policy*, 22, pp245–253.

Kavaliauskas, P. (1996) Lithuania: the nature frame, in Nowicki, Bennett, Middleton and Rientjes (eds.) *Perspectives on ecological networks*. European Centre for Nature Conservation, Man and Nature Series, Vol 1, pp93-100.

Keenleyside, C. and Oppermann, R. (2009) A farmer-centred approach to maintaining High Nature Value grasslands in Europe, in Veen, P., Jefferson, R., de Smidt, J. and van der Straaten, J. (eds.) *Grasslands in Europe of High Nature Value*, KNNV, the Netherlands.

Kettunen, M, Terry, A., Tucker, G. and Jones A. (2007) Guidance on the maintenance of landscape features of major importance for wild flora and fauna - Guidance on the implementation of Article 3 of the Birds Directive (79/409/EEC) and Article 10 of the Habitats Directive (92/43/EEC) Institute for European Environmental Policy (IEEP), Brussels, 114 pp. and Annexes.

Kettunen, M., Adelle, C., Baldock, D., Cooper, T., Farmer, M. Hart, K., Torkler, P. (2009) Biodiversity and the EU Budget – an IEEP briefing paper. Institute for European Environmental Policy, London / Brussels. 27 pp. (to be published).

Keulartz, J. (2007) Using metaphors in restoring nature. Nature and Culture 2, pp27–48.

Killer, K, van de Ven, G. and van Ittersum, M. (2007) Competing Claims on Natural Resources. In: Haverkort, Bindraban and Bos (eds) Food, Fuel or Forest. Proceedings of the seminar held at Wageningen, The Netherlands March 2.

Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., Van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., Van Lynden, G.J. and Huting, J. (2004) Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73) European Soil Bureau Research Report No.16, EUR 21176, 18pp. and 1 map in ISO B1 format. Office for Official Publications of the European Communities, Luxembourg.

Kleijn, D., Berendse, F., Smit, R. and Gilissen, N. (2001) Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes, *Nature*, 413, pp723–725.

Kleijn, D. and Sutherland, W.J. (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, 40, pp947–969.

Klijn, J.A., Vullings, L.A.E., van den Berg, M., van Meijl, H., van Lammeren, R., van Rheenen, T., Veldkamp, A., Verburg, P.H., Westhoek, H., Eickhout, B. (2005) The EURURALIS study: Technical document. Wageningen, Alterra, Alterra-rapport 1196, 215pp. http://www.eururalis.nl/background.htm.

Kok, K., Farrow, A., Veldkamp, A. and Verburg, P. H. (2001) A method and application of multi-scale validation in spatial land use models Agriculture, *Ecosystems and Environment,* 85, pp223-238.

Koning, N.B.J.; Ittersum, M.K. van; Becx, G. A.; Boekel, M.A.J.S. van; Brandenburg, W.A.; Broek, J.A. van den; Goudriaan, J.; Hofwegen, G. van; Jongeneel, R.A.; Schiere, J.B.; Smies, M. (2008) Long-term global availability of food: continued abundance or new scarcity? NJAS Wageningen *Journal of Life Sciences*, 553, pp229 – 292.

Kramer, H. and Mücher, S. (2006) Land use from the days before the satellites. In: Proceedings of the second workshop of the EARSeL SIG on remote sensing of land use and land cover; application and development, Bonn (Germany), September 28-30, 2006. Bonn (Germany): EARSeL, pp316- 22.

Kramer, H. and C.A. Mücher (2008) HISLU60: A historical land use database for Europe from around 1960. In: Proceedings Historical GIS 2008, 21-22 Augustus 2008, University of Essex, UK, 36pp.

Kristensen, L. and Primdahl, J. (2004) Potential for Environmental Cross-compliance to Advance Agri-environment Objectives, Project report under EU Concerted Action 'Cross Compliance' QLK5-CT-2002-02640 (Denmark: Danish Centre for Forest, Landscape and Planning, The Royal Veterinary and Agricultural University, 2004).

Kuik, O. (2006) Ex ante and ex post costs of implementing the Nitrates Directive. Case study in the framework of the project 'Ex post estimates of costs to business of EU environmental policies' Framework Contract No ENV.G.1/FRA/2004/0081.

Kuussaari, M., Heliola, J., Luoto, M., Poyry, J. (2007) Determinants of local species richness of diurnal Lepidoptera in boreal agricultural landscapes, *Agriculture, Ecosystems and Environment*, 122, pp366-376.

Lal, R. (2008) Soils and world food security. *Soil and Tillage Research*, Volume 102, Issue 1, January 2009, Pages 1-4.

Lambeck, R. J. (1997) Focal species: A multi-species umbrella for nature conservation. *Conservation Biology*, 11, pp849-856.

Latimer, W. and Hill, D.A. (2007) Mitigation Banking: Securing no net loss to biodiversity. A UK perspective, *Planning Practice and Research*, 22, 155-175.

Law, N., Cappiella, K. and Novotney, M.E. (2009) The need for improved pervious land cover characterization in urban watersheds. *Journal of Hydrologic Engineering*, 14(4), pp305-308.

Lazar, C. and Genovese, G. (eds.) (2004) Methodology Of The Mars Crop Yield Forecasting System - Vol 2 Agrometeorological Modelling, Processing And Analysis. JRC, 100 pp.

Lehmann B. and Hedeger W. (2004) The contribution of grassland to social benefits of agriculture- an economic analysis, *Grassland Science in Europ*e, 9, pp105-116.

Lesschen, J.P., Schils, R., Kuikman, P.J., Smith, P. and Oudendag, D. (2008) PICCMAT: Policy Incentives for Climate Change Mitigation Agricultural Techniques: European quantification results. PICCMAT Deliverable D7.

Lindborg, R. and Eriksson, O. (2004) Historical landscape connectivity affects present plant species diversity, *Ecology*, 85, pp1840–1845.

LNV/WUR (2008) Pressures on Prime Agricultural Land in Europe. Conference report, COPA-COGECA, Brussels, November 2008.

Lorenz, K. and Lal, R. 2009. Biogeochemical C and N cycles in urban soils. Environment International 35 (2009) 1–8.

LUPG and BfN (Bundesamt für Naturschutz) (2007) Reflections on conference proceedings, Conference Paper, 'Future Policies for Rural Europe: 2013 and beyond – delivering sustainable rural land management in a changing Europe' Brussels, Belgium.

MacArthur, R.J. and Wilson, E.O. (1967) The Theory of Island Biogeography, Princeton: Princeton University Press.

Magyar, A. (2005) Case study, soil sealing – highways in Slovenia. Department of Landscape architecture, Slovenia.

Manhoudt, A.G.E., de Snoo, G.R. (2003) A quantitative survey of semi-natural habitats on Dutch arable farms. Agriculture Ecosystems and Environment 97, 235–240.

Markandya, A., Nunes, P.A.L.D., Brauer, I., ten Brink, P., Kuik, O., and Rayment, M. (2008) Review on the economics of biodiversity loss - phase 1 (scoping) economic analysis and synthesis. Fondazione Eni Enrico Mattei, Venice.

McCracken, D.I. and Tallowin, J.R. (2004) Swards and structure: the interactions between farming practices and bird food resources in lowland grasslands, *Ibis*, 146, pp108–114.

Melman, T.C.P., Schotman, A.G.M., Hunink, S. and de Snoo, G.R. (2008) Evaluation of meadow bird management, especially Black-tailed Godwit (Limosa limosa L.), in the Netherlands, *Journal of Nature Conservation*, 16, pp88–95.

Metzger, M.J., Schröter, D. (2006) Towards a spatially explicit and quantitative vulnerability assessment of environmental change in Europe, *Regional Environmental Change*, 6, pp201–216.

Metzger, M.J., Schröter, D. Leemans, R. and Cramer, W. (2008) A spatially explicit and quantitative vulnerability assessment of ecosystem service change in Europe, Environmental *Change*, 8, pp91–107.

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute, Washington, D.C.

Mottet, A., Ladet, S., Coque, N. and Gibon, A. (2006) Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees, *Agriculture, Ecosystems and Environment*, 114, pp296-310.

Mücher, C.A., J.L. Champeaux, K.T. Steinnocher, S. Griguolo, K. Wester, C. Heunks, W. Winiwater, F.P. Kressler, J.P. Goutorbe, B. ten Brink, V.F. van Katwijk, O. Furberg, V. Perdigao and Nieuwenhuis, G.J.A. (2001) Development of a consistent methodology to derive land cover information on a European scale from Remote Sensing for environmental monitoring. The PELCOM report. 160 pp. Alterra-report 178, ISSN 1566-7197.

Mücher, C.A , Vos, Renetzeder, C.C., C., Wrbka, T., Kiers, M., van Eupen, M. and Bugter R. (2007) The application of satellite imagery to identify landscape structure. In: Proceedings of the IALE 2007 World Congress July 8th – 12th , Wageningen, the Netherlands, pp590 – 591.

Mücher, S., Vos, C., Kiers, M., Renetzeder, C., Wrbka T. and van Eupen, M. (2008) The use of satellite imagery to identify landscape permeability through observed landscape structure and land cover. In: International Conference “Impact Assessment of Land Use Changes”, IALUC 2008, April 6th – 9th , 2008, Humboldt University Unter den Linden, Berlin, Germany. pp. 57.

Mücher, C. A., van Eupen, M., Vos, C. C., Kiers, M. A., Rentzeder, C. and Wrbka, T. (2009a) Spatial Cohesion – An indicator for regional assessment of biodiversity in SENSOR. *SENSOR Report Series 2009/1*, www.sensor-ip.eu, ZALF, Germany (eds. K. Helming and H. Wiggering), pp206.

Mücher, C. A., Hennekens, S. M., Bunce, R. G. H., Schaminee, J. H. J. and Schaepman, M. E. (2009b) Modelling the spatial distribution of Natura 2000 habitats across Europe. *Landscape and Urban Planning*, 92, pp148-159.

Nachabe, M., Maseka, C. and Obeysekerab, J. (2004) Observations and modeling of profile soil water storage above a shallow water table, *Soil Science Society of America Journal*, 68, pp719-724.

Nagy, G. (1998) Ecological conditions, yield potential and grassland management in Hungary, in Nagy, G. and Pet, K. (eds.), Ecological Aspects of Grassland Management, Grassland Science in Europe, vol. 3. European Grassland Federation, Zurich, pp. 1–13.

Natural England (2009a) Mapping values: the vital nature of our uplands. An atlas linking environment and people. Natural England, Peterborough.

Natural England (2009b) Vital Uplands. A 2060 vision for England’s upland environment. Natural England, Peterborough.

Newton, I. (2004) The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis,* 146, pp579-600.

Nilsson S. (2008) The three Fs: food, fiber, and fuel. bioenergy in the Nordic countries: Lessons and future framework conditions workshop 4 March 2008, Nordic Centre for Spatial Development, Stockholm, Sweden. Accessed at www.nordicenergy.net

Nizeyimana, E.L., Petersen, G.W., Imhoff, M.L., Sinclair, H.R., Waltman, S.W., Reed-Margetan, D.S., Levince, E.R. and Russo, J.M. (2001) Assessing the impact of land conversion to urban use on soils wit different productivity levels in the USA, *Soil Science Society of America Journal,* 65, pp391-402.

Noss, R.F. (2001) Beyond Kyoto: Forest management in a time of rapid climate change. *Conservation Biology*, 15, pp 578-590.

Noss, R. F., and Daly, K. M. (2006) Incorporating connectivity into broad-scale conservation planning, in Sanjayan, M. (ed.) Connectivity conservation, pp587-619. Cambridge University Press, Cambridge.

O'Brien, M., Green, R.E., Wilson, J. (2006) Partial recovery of the population of corncrakes *Crex crex* in Britain, 1993–2004, *Bird Study*, 53, pp213–224.

Ockinger, E., Hammarstedt, O., Nilsson, S.G. and Smith, H.G. (2006) The relationship between local extinctions of grassland butterflies and increased soil nitrogen levels, *Biological Conservation*, 128, pp564–573.

O'Connor, R. J., and Shrubb, M. (1986) *Farming and birds*. Cambridge University Press, Cambridge.

Odum, E.P. (1971) Fundamentals of Ecology. Saunders, Philadelphia.

OECD, (2008) OECD Environmental Outlook to 2030. Paris, OECD.

OECD (2009) Agricultural policies in OECD Countries 2009 monitoring and evaluation.

OECD-FAO (2009) OECD-FAO Agricultural Outlook 2009-2018 – Highlights. http://www.agri-outlook.org/pages/0,3417,en_36774715_36775671_1_1_1_1_1,00.html

Oenema, O, (2004) Governmental policies and measures regulating nitrogen and phosphorus from animal manure in European agriculture, *Journal of Animal Science*, 82, pp196-206.

Olesen, J. E. and Bindi, M. (2002) Consequences of climate change for European agricultural productivity, land use and policy. *European Journal of Agronomy*, 16, pp239-262.

Olofsson, J., Hickler, T., Sykes, M.T., Araújo, M.B., Baletto, E., Berry, P.M., Bonelli, S., Cabeza, M., Dubuis, A., Guisan, A., Kühn, I., Kujala, H., Piper, J., Rounsevell, M., Settele, J. and Thuiller, W. (2008) Climate change impacts on European biodiversity – observations and future projections. Minimisation of and Adaptation to Climate change Impacts on biodiverSity (MACIS).

Opdam, P. and Wiens. J. A. (2002) Fragmentation, habitat loss and landscape management, in Conserving bird biodiversity: general principles and their application, in K. Norris, and Pain, D. J. (eds.), pp202-223. Cambridge University Press, Cambridge.

Opdam, P. and Wascher, D. (2004) Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation*, 117, pp285 - 297.

Opdam, P., Steingröver, E., Vos, C. and Prins, D. (2002) Effective protection of the Annex IV species of the EU-Habitats Directive: the landscape approach. Alterra, Wageningen.

Opdam, P., Steingröver, E. and van Rooij, S. (2006) Ecological networks: a spatial concept for multi-actor planning of sustainable landscapes, Landscape and Urban Planning, 75, pp322–332.

Overmars K.P., Verburg, P.H. and Veldkamp, T. (2007) Comparison of a deductive and an inductive approach to specify land suitability in a spatially explicit land use model. *Land Use Policy*, 24, pp584-599.

Pain, D. J., and Pienkowski, M. W. (eds.) (1997) Farming and birds in Europe. The Common Agricultural Policy and its implications for bird conservation. Academic Press, London.

Paracchini, M.L., J.M. Terres, J.E. Petersen and Y. Hooogeveen (2007) High nature value farmland and traditional agricultural landscapes, in Pedroli, B., van Doorn, A., de Blust, G., Paracchini, M.L., Wascher, D. and Bunce, F. (eds.) Europe's Living Landscapes. Essays on Exploring Our Identity in the Countryside, pp22-34. Landscape Europe/Knnv, Wageningen.

Parry, M. (ed.) (2000) Assessment of Potential Effects and Adaptations for Climate Change in Europe: The Europe ACACIA Project. Jackson Environment Institute, University of East Anglia, Norwich, United Kingdom, 320 pp.

Patzel, N., Sticher, H., and Karlen,D.L. (2000) Soil fertility: phenomenon and context. *Journal of Plant Nutrition and Soil Science*, Volume 163, Issue 2, pp129-142.

Pauleit S, Ennos R. and Golding Y. (2005) Modeling the environmental impacts of urban land use and land cover change – a study in Merseyside, UK, *Landscape and Urban Planning*, 71, pp295–310.

PBL and Stockholm Resilience Centre (2009) Getting into the Right Lane for 2050. Netherlands Environmental Assessment Agency, Stockholm Resilience Centre and Stockholm University. PBL, Bilthoven, 104 pp.

Pedroli, B., van Doorn, A., de Blust, G., Paracchini, M.L., Wascher, D. and Bunce F. (eds.) (2007) Europe's living landscapes. essays on exploring our identity in the countryside. Landscape Europe / KNNV, Wageningen.

Peeters A. and Janssens F. (1998) Species-rich grasslands: diagnostic, restoration and use in intensive livestock production systems, *Grassland Science in Europe*, 3, pp375-393.

Phillips, A (2003) Turning ideas on their heads – the new paradigm for protected areas. The George Wright Forum, 20 (2), pp8-32.

Pinto-Correia, T. and Sørensen, E.M. (1995) Marginalisation and marginal land: processes of change in the countryside. Skriftserie, 152.

Pointereau, P and Coulon, F (2008) Case Study Report: France. Prepared for the report: Reflecting environmental land use needs into EU policy: preserving and enhancing the environmental benefits of unfarmed features on EU farmland. Contract No. ENV.B.1/ETU/2007/0033, report for DG Environment, IEEP, London.

Pontius, R., Boersma, W., Castella, J.C., Clarke, K., de Nijs, T., Dietzel, C., Duan, Z., Fotsing, E., Goldstein, N., Kok, K., Koomen, E., Lippitt, C., McConnell, W., Mohd Sood, A., Pijanowski, B., Pithadia, S., Sweeney, S., Trung, T., Veldkamp, A. and Verburg, P. (2008) Comparing the input, output, and validation maps for several models of land change, *The Annals of Regional Science,* http://dx.doi.org/10.1007/s00168-007-0138-2

Post, W.M. and Kwon, K.C. (2000) Soil carbon sequestration and land-use change: processes and potential. *Global Change Biology*, 6, pp317-327.

Pötsch, E. and Krautzer, B. (2009) Semi-natural grassland as a source of biodiversity. 15th Meeting of the FAO-CIHEAM Mountain Pastures Network Integrated research for the sustainability of mountain pastures

Pouyat, R., Groffman, P., Yesilonis, I. and Hernandez, L. (2002) Soil carbon pools and fluxes in urban ecosystems, *Environmental Pollution*, 116, pp107-118.

Poyatos, R., Latron, J., and Llorens, P. (2003) Land Use and Land Cover Change after agricultural abandonment. *Mountain Research and Development,* 23, pp362-368.

Poyry, J., Lindgren, S., Salminen, J. and Kuussaari, M. (2004) Restoration of butterfly and moth communities in semi-natural grasslands by cattle grazing. *Ecological Applications*, 14, pp1656–1670.

Pykala, J. (2003) Effects of restoration with cattle grazing on plant species composition and richness of semi-natural grasslands. *Biodiversity and Conservation*, 12, pp2211–2226.

Pykala , J., Luoto, M., Heikkinen, R.K., Kontula, T. (2005) Plant species richness and persistence of rare plants in abandoned semi-natural grasslands in northern Europe, *Basic and Applied Ecology*, 6, pp25–33.

Qian, Y. and Follett, R. (2002) Assessing soil carbon sequestration in turfgrass systems using long-term soil testing data, *Agronomy Journal*, 94, pp930-935.

Raatikainen, K.M., Heikkinen, R.K. and Pykala, J. (2007) Impacts of local and regional factors on vegetation of boreal semi-natural grasslands, *Plant Ecology*, 189, pp155–173.

Rabbinge, R. (2007) Food, Feed, Forest of Fuel? Summing up of consensus and debate, in: Haverkort, A., Bindraban, P. and Bos, H. (eds) Food, Fuel or Forest. Proceedings of the seminar held at Wageningen, The Netherlands March 2, 2007.

Reger, B., Otte, A. and Waldhardt, R. (2007) Identifying patterns of land-cover change and their physical attributes in a marginal European landscape, *Landscape and Urban Planning,* 81, pp104-113.

Reid, H. (2006) Climate change and biodiversity in Europe. *Conservation and Society*, 4, pp84-101.

Reidsma, P., Tekelenburg, T., van den Berg, M., & Alkemade, R. (2006) Impacts of land-use change on biodiversity: an assessment of agricultural biodiversity in the European region. *Agriculture Ecosystems Environment*, 114, pp86-102.

Renetzeder, C., Schindler, S., Peterseil, J., Prinz, M.A., Mücher, C.A. and Wrbka, T. (2010) Can we measure ecological sustainability? Landscape pattern as an indicator for naturalness and land use intensity at regional, national and European level., *Ecological Indicators*, 10, pp39-48.

Ricketts T.H. (2001) The matrix matters: effective isolation in fragmented landscapes, *American Naturalist*, 158, pp87–99.

Rijk, P. (2008) Landbouwgronden in Europa. Analyse van en visie op gewasopbrengsten, bevolking en milieu. Rapport 2008-004. LEI, Den Haag.

RIVM (2002) MINAS and Environment, Balance and Exploration. RIVM, Bilthoven, The Netherlands (in Dutch).

Robinson, R.A., Wilson, J.D. and Crick, H.Q.P. (2001) The importance of arable habitat for farmland birds in grassland landscapes, *Journal of Applied Ecology*, 38, pp1059-1069.

Robinson, R. A., and Sutherland, W. J. (2002) Post-war changes in arable farming and biodiversity in Great Britain, *Journal of Applied Ecology,* 39, pp157-176.

Sabo, P., Koren Sr., M., Steffek, J., Ruzickova, J., Koren jr., M, Kramarik, J., Maglocky, S., Straka, P., and others (1996) The Slovak approach to ecological networks, in Nowicki, P., Bennett, G., Middleton, D., Rientjes, S. and Wolters, R. (eds.) *Perspectives on ecological networks*. European Centre for Nature Conservation, Man and Nature Series, Vol. 1.

Scalenghe, R. and Marsan, F.A. (2009) The anthropogenic sealing of soils in urban areas, *Landscape and Urban Planning,* 90, pp 1–10.

Schmidt, J. and Michael, A. (2004) Rainfall infiltration under urban soil surface conditions. ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004. 6 pp.

Schmitt, T., Rakosy, L. (2007) Changes of traditional agrarian landscapes and their conservation implications: a case study of butterflies in Romania, *Diversity and distributions*, 13, pp855–862.

Schroter, D., Cramer, W., Leemans, R., Prentice, I.C., Araujo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Gracia, C.A., de la Vega-Leinert, A.C., Erhard, M., Ewert, F., Glendining, M., House, J.I., Kankaanpaa, S., Klein, R.J.T., Lavorel, S., Lindner, M., Metzger, M.J., Meyer, J., Mitchell, T.D., Reginster, I., Rounsevell, M., Sabate, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S., & Zierl, B. (2005) Ecosystem service supply and vulnerability to global change in Europe. *Science*, 310, pp1333-1337.

Schulp, C.J.E., Nabuurs, G.J. and Verburg, P.H. (2008) Future carbon sequestration in Europe - Effects of land use change, *Agriculture, Ecosystems and Environment*, 127, pp251-264.

Science for Environment Policy, DG Environment News Alert Service, 4 June 2009, issue 154. Accessed 5 June 2009.

SDC (Sustainable Development Commission) (2009) Food security and sustainability: The perfect fit, [Online], Available at: http://www.sdcommission.org.uk/publications/downloads/SDCFoodSecurityPositionPaper.pdf

Settele, J., Kudrna, O., Harpke, A., Kühn, I., van Swaay, C., Verovnik, R., Warren, M., Wiemers, M., Hanspach, J., Hickler, T., Kühn, E., van Halder, I., Veling, K., Vliegenthart, A., Wynhoff, I.. and Schweiger, O. (2008) Climatic risk atlas of European butterflies. *Biodiversity and Ecosystem Risk Assessment*, 1 (special issue).

Simberloff, D. and Cox, J. (1987) Consequences and costs of conservation corridors. Conservation Biology, 1, pp63–71.

Simberloff, D., Farr, J.A., Cox, J. and Mehlman, D.W. (1992) Movement corridors, conservation bargains or poor investments? Conservation Biology, 6, pp493–504.

Six, J., Elliot, E.T., Paustian, K., and Doran, J.W. (1998) Aggregation and soil organic matter accumulation in cultivated and native grassland soils, *Soil Science Society of America*, 65, pp1367-1377.

Smith, P. (2004) Soils as carbon sinks – the global context. *Soil Use and Management*, 20, pp212-218.

Smith, P. (2008) Land use change and soil organic carbon dynamics, *Nutrient Cycling in Agroecosystems*, 81, PP169-178.

Soderstrom, B., Svensson, B., Vessby, K., Glimskar, A. (2001) Plants, insects and birds in semi-natural pastures in relation to local habitat and landscape factors, *Biodiversity and Conservation*, 10, pp1839–1863.

Sojka, R. E., Upchurch, D.R. and Borlaug, N. E. (2003) Quality soil management or soil quality management: performance versus semantics. *Advances in Agronomy*, 79, pp1-68.

Soule, M. E. and Gilpin, M. E. (1991) The theory of wildlife corridor capability, in Saunders, D.A and Hobbs, R.J. (eds.) *Nature conservation 2: the role of corridors*, Beatty and Sons, Surrey UK. pp3-8.

SOWAP, 2007. Soil and surface water protection using conservation tillage in northern and central Europe. EU/LIFE03/ENV/UK000617, 44 pp.

Spehn, E., Hector, A., Joshi, J., Scherer-Lorenzen, M., Schmid, B., Bazeley-White, E., Beierkuhnlein, C., Caldeira, M. C., Diemer,M., Dimitrakopoulos, P. G., Finn, J. A., Koricheva, J., Leadley, P., Loreau, M., Minns, A., Mulder, C. P. H., O'Donovan, G., Otway, S., Palmborg, C., Pereira, J. S., Pfisterer, A. B., Prinz, A., Read, D. J., Schulze, E. D., Siamantziouras, A.-S. D., Terry, A. C., Troumbis, A. Y., Woodward, F. I., Yachi, S. and Lawton, J. H. (2005) Ecosystem effects of biodiversity manipulations in European grasslands, *Ecological Monographs*, 75(1), pp37–63.

Spellerberg, I. F. and Gaywood. M.J. (1993) Linear features: linear habitats and wildlife corridors. English Nature, Peterborough.

Squillace, P. and Moran, M. (2007) Factors Associated with Sources, Transport, and Fate of Volatile Organic Compounds and Their Mixtures in Aquifers of the United States, *Environmental Science and Technology*, 41(7), pp 2123–2130.

Stalnacke, P., Vandsemb, S.M., Vassiljev, A., Grimvall, A., Jolankai, G., (2004) Changes in nutrient levels in some East European rivers in response to large scale changes in agriculture. *Water Science and Technology,* 49, pp29–36.

Stevens, C.J., Dise, N.B., Owen Mountford, J. and Gowing, D.J. (2004a) Impact of nitrogen deposition on the species richness of grasslands, *Science*, 303, pp1876–1879.

Stevens, V.M., Polus, E., Wesselingh, R.A., Schtickzelle, N., Baguette, M. (2004b) Quantifying functional connectivity: experimental evidence for patch-specific resistance in the Natterjack Toad (*Bufo calamita*) *Landscape Ecology,* 19, pp829–842.

Stevens, V.M., Leboulengé, E., Wesselingh, R.A. and Baguette, M. (2006) Quantifying functional connectivity: experimental assessment of boundary permeability for the Natterjack Toad (*Bufo calamita*) *Oecologia*, 150, pp161–171.

Stoate, C. A. Baldi, P. Beja, N.D. Boatman, I. Herzon, A. van Doorn, G.R. de Snoo, L. Rakosy and C. Ramwell (2009) Ecological impacts of early 21stcentury agricultural change in Europe- a review. Journal of Environmental management 91 (2009) 22-46.

Strijker, D. (2005) Marginal lands in Europe - causes of decline. *Basic and Applied Ecology*, 6, pp99-106.

Sutcliffe, O.L., Bakkestuen, V., Fry, G. and Stabbetorp, O.E. (2003) Modelling the benefits of farmland restoration: methodology and application to butterfly movement. *Landscape and Urban Planning*, 63, pp15–31.

Tallowin J.R.B. and Jefferson R.G. (1999) Hay production from lowland semi-natural grasslands: a review of implications for ruminant livestock systems. *Grass and Forage Science*, 54(2), pp99-115.

Tasser, E., Walde, J., Tappeiner, U., Teutsch, A. and Noggler, W. (2007) Land-use changes and natural reforestation in the Eastern Central Alps, *Agriculture, Ecosystems and Environment*, 118, pp115-129.

TCB (2009a) Advies gevolgen afdekken van bodem. Technische Commissie Bodem. TCB A048.

TCB (2009b) Advies Doiepinfiltratie van afvloeiend hemelwater. TCB A047(2009).

TEEB (2008) The economics of ecosystems and biodiversity. European Commission, Brussels.

TEEB (2009) The economics of ecosystems and biodiversity for national and international policy makers – summary: responding to the value of nature. European Commission, Brussels.

TEN-STAC (2004) Scenarios, Traffic forecasts and analysis of corridors on the trans-european network. *TEN-STAC project report available from http://ec.europa.eu/ten/transport/documentation/index_en.htm*.

Thielen, J., Bartholmes, J., Ramos, M.H. and De Roo, A. (2009) The European Flood Alert System – Part 1: Concept and development. *Hydrological and Earth System Science*, 13, pp125–140.

Thomson, A.G., Manchester, S.J., Swetnam, R.D., Smith, G.M., Wadsworth, R.A., Petit, S., Gerard, F.F. (2007) The use of digital aerial photography and CORINE-derived methodology for monitoring recent and historic changes in land cover near UK Natura 2000 sites for the BIOPRESS project, *International Journal of Remote Sensing*, 28 (23), pp5397-5426.

Thuiller, W., Lavorel, S., Araújo, M.B., Sykes, M.T., & Prentice, I.C. (2005) Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Science of the United States of America*, 102, pp8245-8250.

Tillman J.R.B. (1999) Diversity and production in European grasslands, *Science*, 286, pp1099-1100.

Tinch, R. (2009) Case Study on the ecosystem services provided by a sustainable catchment management programme (in the UK uplands) Output of the EC project: Financing Natura 2000: Cost estimate and benefits of Natura 2000.

Torkler, P., Arroyo, A., Kettunen,. M. (2008) Linking management and financing of Natura 2000. Final report. WWF, Brussels.

Tóth, G. (2008a) Soil quality in the European Union, in: Tóth, G., Montanarella, L. and Russo, E. (eds.) Threats to soil quality in Europe. JRC Scientific and Technical Reports, EUR 23438 EN – 2008, 11-21.

Tóth, G., Montanarella, L., Stolbovoy, V., Máté, F., Bódis, K., Jones, A., Panagos, P. and Marc van Liedekerke, M. (2008b) Soils of the European Union JRC Scientific and Technical Reports, EUR 23439 EN – 2008, 100 pp.

Trnka, M., M. Dubrovski and Zalud, Z. (2004) Climate change impacts and adaptation strategies in spring barley production in the Czech Republic, *Climatic Change*, 64, pp227-255.

Trombulak, S.C. and Frissell, C.A. (2000) Review of ecological effects of roads on terrestrial and aquatic communities, *Conservation Biology,* 14, pp18-30.

Trumper, K., Bertzky, M., Dickson, B., van der Heijden, G., Jenkins, M., and Manning, P. (2009) The Natural Fix? The role of ecosystems in climate mitigation. UNEP World Conservation Monitoring Centre, Cambridge.

Tubelis, D.P., Lindenmayer, D. B. and Cowling, A. (2004) Novel patch-matrix interactions: patch width influences matrix use by birds. *Oikos,* 107, pp634-644.

Tucker, G. M., and M. Evans (1997) Habitats for birds in Europe: a conservation strategy for the wider environment. BirdLife International, Cambridge.

Tucker, G. M. (1997) Priorities for bird conservation in Europe: the importance of the farmed landscape in D. J. Pain, and Pienkowski, M.W. (eds.) Farming and birds in Europe. The Common Agricultural Policy and its implications for bird conservation. Academic Press, London.

Tucker, G.M. and de Soye, Y. (2009) Biodiversity and climate change in relation to the Natura network. Tasks 2b and 3b - Impacts of climate change on EU biodiversity policy, and recommendations for policies and measures to maintain and restore biodiversity in the EU in the face of climate change. IUCN / IEEP, Brussels / London.

Tucker, G., Hart, K., Baldock, D., Farmer, M. and Hegarty, J. (in press) Recent and possible EU agricultural policy developments and their potential implications for farmland birds. BOUPROC Supp.

Turnpenny, J.R., Parsons, D.J., Armstrong, A.C., Clark, J.A., Cooper, K. and Matthews, A.M. (2001) Integrated models of livestock systems for climate change studies. 2. Intensive systems. *Global Change Biology*., **7**, pp163-170.

Uphoff, N., Ball, A.S., Fernandes, E., Herren, H., Husson, O., Laing, M., Palm, C., Pretty, J., & Sanchez, P., eds. (2006) Biological approaches to sustainable soil systems. CRC Press.

Van der Knijff, J. and De Roo, A. (2008) LISFLOOD - Distributed Water Balance and Flood Simulation Model. JRC Scientific and Technical Reports. EUR 22166 EN/2 – 2008, 126 pp.

Van Der Windt, H.J. and Swart, J.A.A. (2007) Ecological corridors, connecting science and politics: the case of the Green River in the Netherlands, Journal of Applied Ecology, 45, pp124-132.

van Dooren, N. And Kunst, K. (2009) Regenwater in de tuin? Mooi wel!. De betekenis van de particuliere kavel voor het stedelijke watersysteem. Stichting RIONED, 64 pp.

van Langevelde, F. and Jaarsma, C. F. (2004) Using traffic flow theory to model traffic mortality in mammals. *Landscape Ecology,* 19, pp895-907.

Van Meijl, H., T. van Rheenen, A. Tabeau and Eickhout, B. (2006) The impact of different policy environments on land use in Europe. Agriculture, Ecosystems and Environment, 114, pp21-38.

van Ravesteyn, M. (2008) Meebouwen met water. Debate 'Water 2040 en Later', September 2008. Nederlands Instituut voor Ruimtelijke Ordening en Volkshuisvesting. Accessed at www.nirov.nl

Van Strien, A.J. Pannekoek, J. and Gibbons, D.W. (2001) Indexing European bird population trends using results of national monitoring schemes: a trial of a new method, *Bird Study*, 48: pp200-213.

Van Swaay, C.A.M. and Van Strien, A.J. (2008) The European Butterfly Indicator for Grassland species 1990-2007. Report VS2008.022, De Vlinderstichting, Wageningen.

Van-Camp. L., Bujarrabal, B., Gentile, A-R., Jones, R.J.A., Montanarella, L., Olazabal, C. and Selvaradjou, S-K. (2004) Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection. EUR 21319 EN/6, 872 pp. Office for Official Publications of the European Communities, Luxembourg.

Vellinga, T.V., van den Pol-van Dasselaar, A., and Kuikman, P.J. (2004) The impact of grassland ploughing on CO2 and N2O emissions in the Netherlands. *Nutrient cycling in agroecosystems*, 70, pp33-45.

Velthof, G.L., Oudendag, D., Witzke, H.P., Asman, W.A.H., Klimont, Z. and Oenema, O. (2009) Integrated assessment of nitrogen emissions from agriculture in EU-27 using MITERRA-Europe. *Journal of Environmental Quality*, 38, pp402-417.

Verboom, J., and R. Pouwels (2004) Ecological functioning of ecological networks: a species perspective, in R. Jongman, and Pungetti, G. (eds.) *Ecological networks and greenways: concept, design and implementation*. Cambridge University Press, Cambridge.

Verburg, P. H., Soepboer, W., Limpiada, R., Espaldon, M.V.O., Sharifa, M. and Veldkamp, A. (2002) Land use change modelling at the regional scale: the CLUE-S model, *Environmental Management*, 30, pp391-405.

Verburg, P.H., de Nijs, T.C.M., van Eck, J.R., Visser, H., de Jong, K. (2004) A method to analyse neighbourhood characteristics of land use patterns. *Computers, Environment and Urban Systems,* 28, pp667-690.

Verburg, P. and Westhoek, H. (2006) Sealing: hoeveel bodem verdwijnt er onder de stad? Bodem.

Verburg, P.H., Schulp, C.J.E., Witte, N., Veldkamp, A. (2006) Downscaling of land use change scenarios to assess the dynamics of European landscapes. *Agriculture, Ecosystems and Environment*, 114, pp39-56.

Verburg, P.H., Eickhout, B., van Meijl, H. (2008) A multi-scale, multi-model approach for analyzing the future dynamics of European land use. *Annals of Regional Science*, 42(1), pp57-77.

Verburg, P. and Overmars K. (2009) Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. *Landscape Ecology*, 24(9), pp1167-1181.

Verhulst, J., Ba' ldi, A., Kleijn, D. (2004) The relation between land-use intensity and species-richness and abundance of birds in Hungary, *Agriculture, Ecosystems and Environment*, 104, pp465–473.

Vickery, J.A., Tallowin, J.R., Feber, R.E., Asteraki, E.J., Atkinson, P.J., Fuller, R.J. and Brown, V.K. (2001) The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources, *Journal of Applied Ecology*, 38, pp647–664.

Vos C.C., Verboom, J., Opdam, P.F.M. and Ter Braak, C. J. F. (2001) Toward ecologically scaled landscape indices. *The American Naturalist,* 183, pp24–41.

Vos, C.C. and Smulders, M.J.M. (2004) Monitoring Ecologische Effectiviteit Van Verbindingszones (Monitoring ecological effectivity corridors) Alterra/WUR, Wageningen.

Vrščaj, B., Poggio, L. and Ajmone Marsan, F. (2008) A method for soil environmental quality evaluation for management and planning in urban areas. *Landscape and Urban Planning*, 88, pp81-94.

Walker, R. and Craighead, L. (1997) Analyzing wildlife movement corridors in Montana using GIS. *ESRI user conference proceedings*. http://proceedings.esri.com/library/userconf/proc97/proc97/abstract/a116.htm, California.

Walker, S., Brower, A.L., Stephens, R.T.T. and Lee, W.G. (2009) Why bartering biodiversity fails, Conservation Letters, (in press).

Walmsely, C.A., Smithers, R.J., Berry, P.M., Harley, M., Stevenson, M.J. and Catchpole, R. (eds.) (2007) MONARCH - Modelling Natural Resource Responses to Climate Change – a synthesis for biodiversity conservation, UKCIP, Oxford.

Wassenaar, T., P. Gerber, P. H. Verburg, M. Rosales, Ibrahim M. and Steinfeld. H. (2007) Projecting land use changes in the Neotropics: The geography of pasture forest expansion, *Global Environmental Change*, 17, pp86-104.

Watts, K., Griffiths, M., Quine, C., Ray , D. and Humphrey, J. (2005) Towards a woodland habitat network for Wales. Countryside Council for Wales, Bangor, Wales.

Weber, J.L. (2007) Implementation of land and ecosystem accounts at the European Environment Agency. *Ecological Economics,* 61, pp695-707.

Wenzel, M., Schmitt, T., Weitzel, M., Seitz, A. (2006) The severe decline of butterflies on western German calcareous grasslands during the last 30 years: a conservation problem, *Biological Conservation*, 128, pp542–552.

Wessolek, G., Duijnisveld, W.H.M. and Trinks, S. (2008) Hydro-pedotransfer functions (HPTFs) for predicting annual percolation rate on a regional scale. *Journal of Hydrology,* 356, pp17– 27.

West, C.C. and Gawith, M.J. (eds.) (2005a) Measuring progress: Preparing for climate change through the UK Climate Impacts Programme. UK Climate Change Impacts Programme Technical Report.

West, C. C. and M.J. Gawith, (eds.) (2005b) The UKCIP Integration Report. UK Climate Change Impacts Programme, 110 pp.

Westhoek, H.J., Vna den Berg, M. and Bakkes, J.A. (2006) Scenario development to explore the future of Europe's rural areas. *Agriculture, Ecosystems and Environment*, 114, pp7–20.

Whalley, W.R., Clark, L.J, Gowing, D.J.G., Cope, R.E., Lodge, R.J. and Leeds-Harrison, P.B., (2006) Does soil strength play a role in wheat yield losses caused by soil drying? *Plant and Soil*, **280**, pp279-290.

Wilson, J.D., Evans, A.D., and Grice, P.V. (2009) Bird conservation and agriculture. Cambridge University Press, Cambridge.

Worrall, F., Evans, M.G., Bonn, A., Reed, M.S., Chapman, D., & Holden, J. (2009) Can carbon offsetting pay for upland ecological restoration? *Science of the Total Environment*, 408, pp26-36.

WUR/MNP (2008) EU Ruralis project datasets. The Netherlands, Wageningen University and Research and Netherlands Environmental Assessment Agency (MNP).

WWF (2009) Good and innovative examples of financing Natura 2000 in the EU. Output of the EC project: Financing Natura 2000: Cost estimate and benefits of Natura 2000. (Final draft) WWF, Brussels.

Wynhoff, I. (2001) At home on foreign meadows: the reintroduction of two/Maculinea/ butterfly species. PhD thesis, Wageningen Agricultural University, Wageningen, 236 pp.

Xiao, Q., McPherson, E.G., Simpson, J.R. and Ustin, S.L. (2007) Hydrologic processes at the urban residential scale, *Hydrological Processes,* 21, pp2174–2188.

Zaehle, S., Bondeau, A., Carter, T., Cramer, W., Erhard, M., Prentice, I., Reginster, I., Rounsevell, M., Sitch, S., Smith, B., Smith, P. and Sykes, M. (2007) Projected changes in terrestrial carbon storage in Europe under climate and land-use change, 1990–2100. *Ecosystems*, 10, pp380-401.